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Shoulder injury prevention in overhead sports:

Independent learning material for musculoskeletal physiotherapy studies

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Abstract

An overhead throwing motion is the fastest motion in sports, creating high rotational and compressive forces in the shoulder. Due to the high loads, repetitive movement and athlete-specific factors, overhead sports have a high prevalence of shoulder injuries. Injury prevention through conditioning helps alleviate the health and career effects and the cost of injury to both the individual and the sport. For successful preventive intervention, a physiotherapist needs to understand the sport-specific biomechanics and have knowledge on the injury risks and their detection.

The aim of the thesis was to increase the knowledge base of physiotherapy students on typical shoulder injuries, injury risks, and to present tools for injury prevention in overhead sports. Following the practice-based methodology, the findings of the current literature were used to develop an independent electronic study material for musculoskeletal physiotherapy studies in Satakunta University of Applied Sciences. The study material presented the current research on biomechanics, functional requirements, and injury risks of the shoulder in unilateral overhead sports. It also provided evidence-based guidelines for physiotherapeutic assessment and conditioning tools specifically aimed for the shoulder injury prevention in high-performing overhead athletes. The piloting of the study material was conducted via a workshop for physiotherapy students.

Injury prevention in overhead sports lacks good quality, long-term research on large participant groups. This places limitations to the reliability of the thesis. Acknowledging these limitations in several factors of injury risk factors, the study material created in this thesis is based on the most agreed-on proposals in the current literature.

The thesis aimed to provide usable information for the future working life in sports physiotherapy. The focus of the study material was on high-level athletes in unilateral overhead sports, but the knowledge can be adapted for other overhead sports with sport-specific considerations. Also, the underlying principles of the thesis can be useful in the physiotherapy of growing athletes and other clients with repeated overhead work or activities.

Key words: Shoulders, Sports injuries, Pre-emption, Athletes, Physiotherapy, Ball sports, Biomechanics

CONTENTS

1 INTRODUCTION

"In sports, injuries happen… Sometimes they are difficult, even impossible to explain. But frequently there are patterns. And when there are patterns, there are also opportunities for reducing the risk of injury." (Engebretsen & Bahr 2011.)

The multiple health benefits of sports and exercise are well documented. However, sports also have an inherent risk for musculoskeletal injuries, increasing with repetition and exercise load. Injuries can be defined as any events occurring during sports activity causing either the need for medical treatment, or time loss from the sport activity. (Engebretsen & Bahr 2011; Gabbett 2016; Fuller et al. 2006.) In Scandinavia, every sixth adult and every third child treated by physicians have sustained their injuries in a sports activity (Bahr, van Mechelen & Kannus 2002, 299–314).

Injury prevention is a growing field of research, as it has been shown to increase the health of the athlete, enable longer active career, and reduce costs to the individual, the sport, the health care system and the society. Injury prevention programmes can also improve the athlete's performance and ensure an unbroken competitive season. Not all injury risk factors can be modifiable (for example gender), but the modifiable factors can be minimized through sport- and individual specific conditioning and changes of sports environment. (Meeuwisse & Bahr 2011.)

Overhead sports refer to any sport which includes moving the upper arm in an arc over the head to propel a ball or other object towards a target. Typical examples of overhead sports are baseball, volleyball, tennis, javelin, and basketball, but also swimming is often counted as an overhead sport. (DeFroda, S., Goyal, D., Patel, N., Gupta, N., Mulcahey, M. 2018; Website of Segen's Medical Dictionary 2020.) These sports are also very popular, presenting 7 out of 20 most popular sports in the world according to sports journalists (Website of Total Sportek 2020).

The overhead throwing motion is the fastest movement in all sports and unsurprisingly shoulder injuries are very prominent among athletes in overhead sports (Dugas & Mathis 2016; Lesniak et al. 2013) Shoulder and elbow injuries represent 50-67% of all injuries in professional baseball pitchers, 8-20% in volleyball players and 4-17% in tennis players and the risk of shoulder injuries increases with the level of the player. Due to the high prevalence, there is a definite need for mapping the risks of these injuries and development of prevention methods. (Abrams, Renstrom & Safran 2012; Briner & Kacmar 1997; Lin, Wong & Kazam 2018; Posner, Cameron, Wolf, Belmont & Owens 2011.)

This thesis focuses on shoulder injury prevention in unilateral overhead sports, where one arm is the dominant throwing arm. The main example are baseball pitchers, due to the highest shoulder injury prevalence. In professional baseball pitchers the incidence of shoulder injuries has been reported to be 58 per 100 games played, but the increase in injury prevalence has been reported already on the little league level (Lesniak et al. 2013). A baseball pitch is also an archetype of what happens in the body during any throwing motion. (Abrams, Renstrom & Safran 2012; Briner & Kacmar 1997; Lin, Wong & Kazam 2018; Posner, Cameron, Wolf, Belmont & Owens 2011.)

The independent study package was developed to present the functioning of a healthy shoulder girdle, and the anatomy required to enable the movement and throwing motion of this complex structure. The biomechanics and functional requirements of the overhead sports are discussed to form the basis for assessing the shoulder injury risk of individual athletes. Assessment methods are presented as proposed by the current literature, followed by the principles of choosing suitable conditioning approaches to fit the needs risen from the assessment and prevent injuries in an overhead athlete’s shoulder. The study material provides an outlook on some sport-specific considerations in assessment and conditioning of athlete clients, keeping in mind the level of functional requirements of their shoulders and the general physical performance level.

2 AIM AND OBJECTIVES

The aim of the thesis is to increase the knowledge base of physiotherapy students on typical shoulder injuries, injury risks, and tools for injury prevention in overhead sports for physiotherapy students based on the current literature.

The objective of the thesis is to build an independent electronic learning material package to be included as a part of the musculoskeletal studies in the physiotherapy curriculum of Satakunta University of Applied Sciences (SAMK). The study package presents the current research on biomechanics, functional requirements, and injury risks of the shoulder in unilateral overhead sports. The study package will be built to provide evidence-based physiotherapeutic assessment and conditioning tools specifically aimed for the shoulder injury prevention in this category of athletes.

3 STRUCTURE AND FUNCTION OF THE SHOULDER

The shoulder joint is the most mobile joint in human body, which makes it also the least stable one. The mobility is caused by the nature of the joint (ball and socket), with shallow glenoid cavity and large humeral head, and the laxity of the joint capsule. The joint is stabilized by a set of muscles called the rotator cuff, ligaments, biceps tendon and a fibrocartilaginous ridge (glenoid labrum) surrounding the glenoid cavity. (Agur & Dalley 2013, 481-610; Website of Physiopedia 2020.) To make the structure more complex, the shoulder function and stability is also affected by the muscles controlling movements of the upper extremity and scapula. Imbalances in these structures impose a risk for acute and overuse sports injuries. (Faigenbaum & Myer 2010; Niederbracht, Shim, Sloniger, Paternostro-Bayles & Short 2008.)

The range of motion in a normal shoulder varies from person to person. Normal shoulder should actively flex 160°-180°, extend 50°-60°, externally rotate 80°-90°, internally rotate 60°-100° and adduct 50°-75°. Normal abduction (170°-180°) consists of the 120° abduction of the humerus and the 60° of movement coming from the external rotation and elevation of the scapula. The scapular movement activates after the initial 30° of abduction and the humerus rotates 90° externally during the last 90° of the movement. The combination and activation order of movements of humerus, scapula and clavicle are called scapulohumeral rhythm which can, if altered, be a sign of muscle weaknesses or control disturbance in the stabilizers of the scapula or humerus. (Magee 2014, 271-275.)

3.1 Joints and bony structures of the shoulder girdle

The shoulder region consists of three bones: scapula, clavicle and humerus. The four joints between these bones form the joints allowing the movement of the shoulder and the upper arm (see Figure 1). (Agur & Dalley 2013, 481-610.)

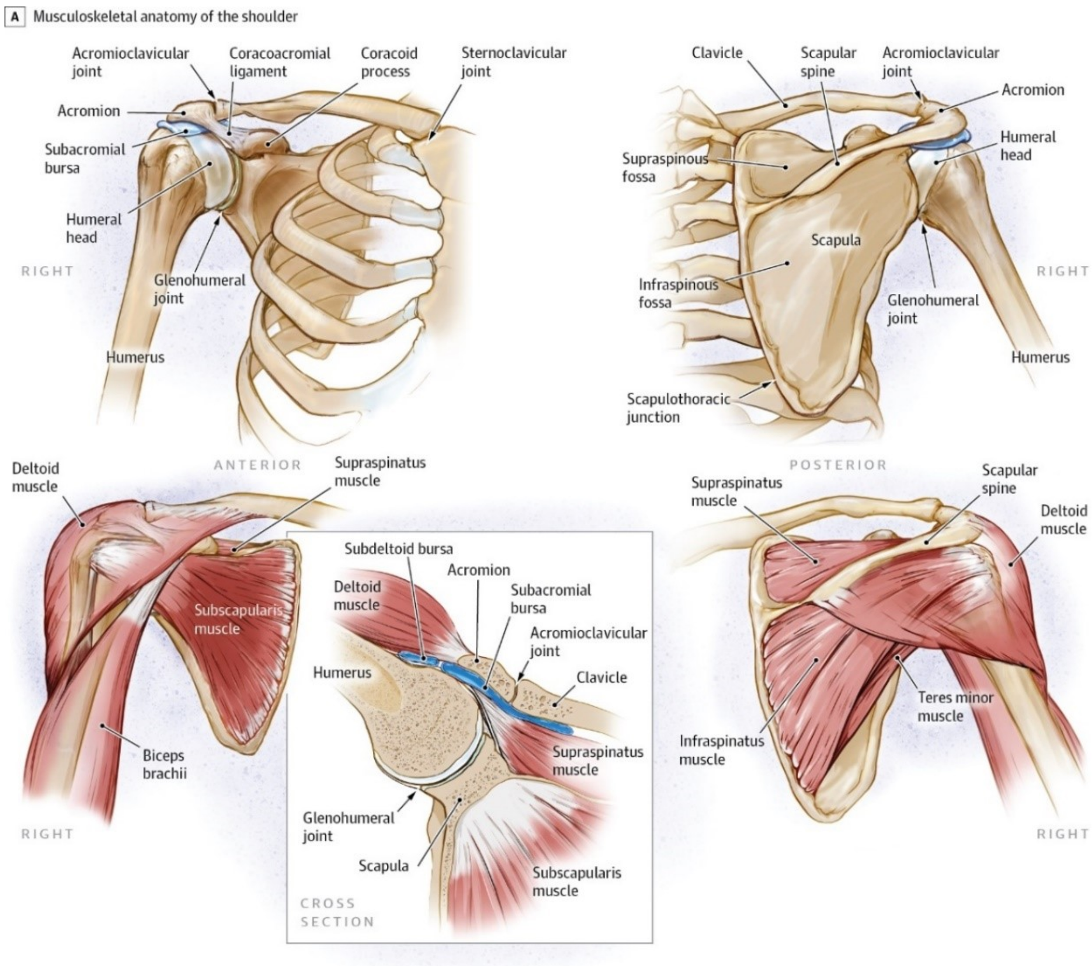

Figure 1. Bones and joint of the shoulder (Hermans, et al. 2003).

Glenohumeral (GH) joint is a ball and socket joint with three degrees of freedom (flexion – extension, abduction – adduction and lateral rotation – medial rotation). The ball of the humeral head rests in the socket formed by the glenoid cavity and the ligamental glenoid labrum. (Magee 2014, 252.)

Because the glenoid cavity is shallow, only part of the head of humerus is in contact with the glenoid at a time and thus can move very freely allowing the wide movement of the shoulder joint (Magee 2014, 252). This also requires the stability of the joint to come from the surrounding tissues. The joint is passively stabilized by a joint capsule and surrounding superior-, middle- and inferior glenohumeral ligaments addition to the glenoid labrum (Gibbons 2019, 32; Magee 2014, 252). Dynamic stabilization is provided by the four muscles forming the rotator cuff, discussed in chapter 3.5, and the long head of biceps brachii (Gibbons 2019, 32).

Sternoclavicular (SC) joint is the only “bone-to-bone” -joint attaching the upper extremity to the torso. It is a synovial saddle joint located between the manubrium of the sternum and the proximal end of the clavicle. A fibrocartilaginous disc and three ligaments (sternoclavicular, costoclavicular and interclavicular) provide the joint stability and absorb the forces coming from the upper limb. (Gibbons 2019, 35.)

Acromioclavicular (AC) joint is also a synovial joint between the acromion of the scapula and the distal end of the clavicle. The primary functions of the joint are to allow the motion of the scapula on thorax as the arm is raised above the head and to allow the scapula to adjust its position with the arm movements. (Website of Physiopedia 2020.) The joint is held stable by a meniscoid and three ligaments: acromioclavicular, trapezoid and conoid (Gibbons 2019, 36).

The scapulothoracic (ST) joint is not anatomically a true joint due to having no joint characteristics or ligamentous support. Instead, the scapula is supported by muscles and other joints. The joint consists of the connection between thorax and scapula and is a part of the functional chain created by the AC and SC joints and the thorax. The movement of the scapulothoracic joint is then always connected to the movements of AC and SC joints. (Website of Physiopedia 2020.) The main function of the scapulothoracic joint is to suspend the humerus in space in an optimal position needed for each shoulder movement (Gibbons 2019, 37).

3.2 Bursae

Bursae are defined as sacs of liquids situated between tissues. Their main function is to provide cushion and reduce the friction between moving tissues, such as between a bone and a tendon (see Figure 2). (Conduah, Baker III & Baker Jr. 2010.)

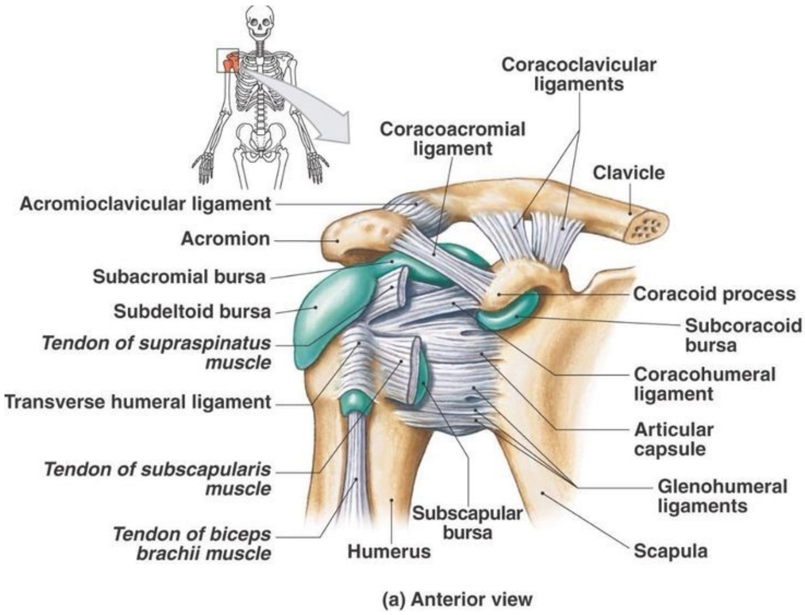

Figure 2. The bursae of the shoulder area (Website of Coding Info 2016).

The shoulder area has 4 main bursae and 2 minor bursae. The main bursae include the subscapular bursa between the subscapularis muscle tendon and the scapulohumeral joint capsule, and the subcoracoid bursa between the coracoid process and scapulohumeral joint capsule. The subacromial deltoid bursa, which consists of subdeltoid bursa between the deltoid muscle and scapulohumeral joint, and subacromial bursa between acromion and the greater tubercle of the humerus is often considered as one larger structure. (Hitzrot 1933, 273.)

The two minor bursae are the infraspinatus bursa between infraspinatus tendon and scapulohumeral joint capsule, and the thin subcutaneous acromial bursa between the acromion and the skin (Hitzrot 1933, 273).

The bursae are innervated by nerves, and their irritation or swelling can cause shoulder pain. There are multiple causes for bursitis, including injury, overuse of the shoulder, or impingement caused by repetitive overhead activity. (Walker-Bone, Palmer, Reading, Coggon & Cooper 2004.)

3.3 Muscles of the shoulder girdle

Muscles provide the mobility, stability, and postural control of the shoulder girdle. They also provide proprioceptive information to the central nervous system to enable muscle function coordination. (Comerford & Mottram 2012, 23, 29.)

Many muscles participate in the movements of the shoulder and scapula area. Main muscles affecting the movements of the shoulder joint can be divided into extrinsic primary and secondary movers, and intrinsic muscles, also known as the rotator cuff. (Website of Physiopedia 2020.) For a full list of participating muscles by function, see Appendix 1.

3.3.1 Extrinsic movers of the shoulder joint and scapula support

The controlled movements of the shoulder joint require agonistic, antagonistic and synergistic activities of multiple muscles. The muscles moving the shoulder area are depicted in Figures 3 and 4 below. The main flexors of the shoulder are the anterior part of the deltoideus and biceps brachii with weak support from coracobrachialis. Extension is enabled by the posterior part of deltoideus, latissimus dorsii and triceps brachii muscles. Pectoralis major also participates in the returning of the humerus from extension and flexion. (Gibbons 2019, 43-71; Sandström & Ahonen 2011, 261.)

External rotation of the shoulder is enabled primarily by two of the rotator cuff muscles, infraspinatus and teres minor, but the posterior part of deltoideus can assist and even compensate in case of rotator cuff weakness. Pectoralis major, latissimus dorsi, teres major, anterior part of the deltoideus and subscapularis as a part of the rotator cuff are the internal rotators of the humerus. (Gibbons 2019, 43-71; Agur & Dalley 2013, 481-610; Sandström & Ahonen 2011, 261.)

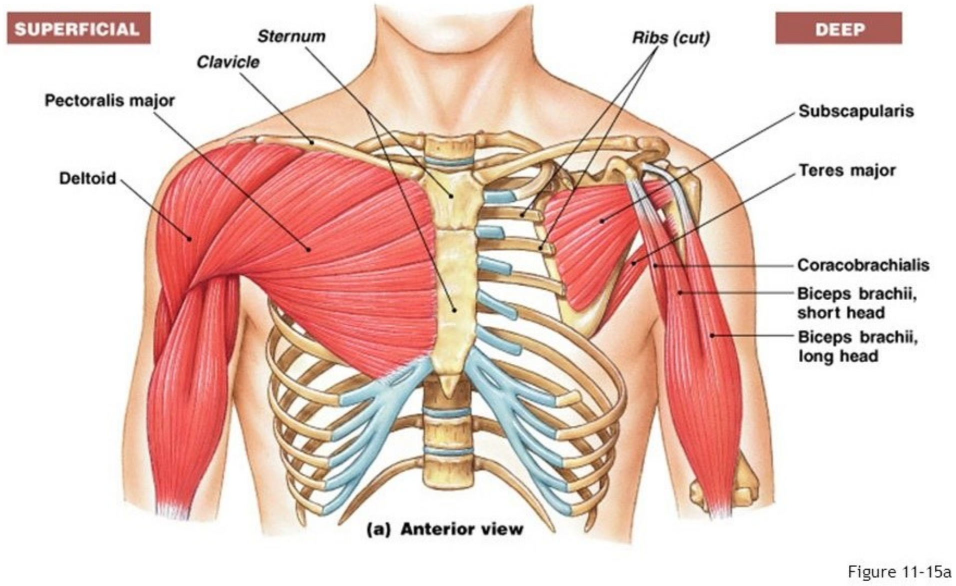

Figure 3. Muscles of the shoulder area, anterior view (Website of How to relief 2020).

The medial part of deltoideus abducts the shoulder together with a rotator cuff muscle supraspinatus. Adduction is a cooperation of pectoralis major, latissimus dorsi and teres major. (Sandström & Ahonen 2011, 261.)

The scapula is primarily supported by trapezius, serratus anterior, both rhomboideus major and minor, levator scapulae and in the front pectoralis minor. Secondary supporting muscles are pectoralis major and latissimus dorsi, which also participate in the movements of the shoulder joint. (Sandström & Ahonen 2011, 257-259.)

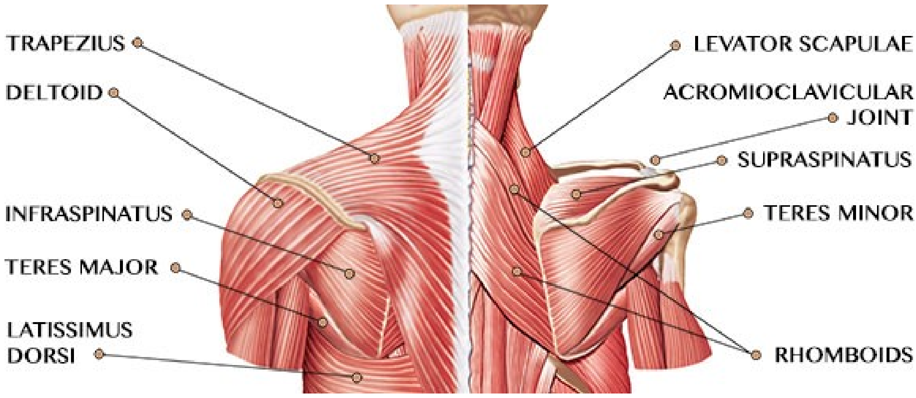

Figure 4. Muscles of the shoulder area, posterior view (Website of AMG Sport 2020).

3.3.2 Functioning of the rotator cuff

The rotator cuff consists of four muscles: supraspinatus, infraspinatus, teres minor and subscapularis (SITS-muscles, see Figure 5 below). These muscles provide fine-tuning of the movements of the glenohumeral joint and are an integral part of the neuromuscular control in all movements of the upper limb. (Gibbons 2019, 43-44; Website of Physiopedia 2020.)

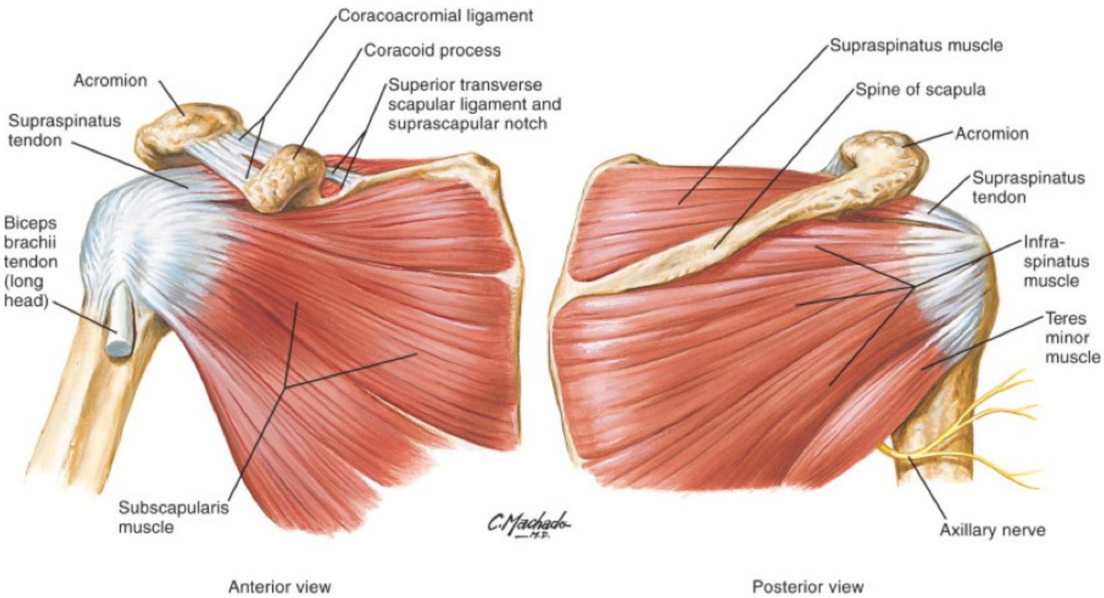

Figure 5. Muscles of the rotator cuff (Website of Canadiem 2020).

The rotator cuff muscles control the motion of the bones (osteokinematic) and joint surfaces (arthrokinematics) in relation to each other in the glenohumeral joint. When the shoulder is relaxed, the humerus ideally sits in the center of the glenoid cavity stabilized and depressed by the rotator cuff muscles. When activated, the muscles can slightly shift the position forwards, backwards, up, down or in a combination of movements, making space for and initiating the movement of the joint. (Gibbons 2019, 43; Magee 2014, 252.)

The action of the rotator cuff muscles can be best understood when looking at frontal plane abduction movement. Activation of supraspinatus initiates the first 10-15° of abduction and allows the humeral head to slide caudally and start rotating externally, which gives it space to move without hitting the acromion. At 60-90° range the supraspinatus and teres minor start to work in sync to further externally rotate the humerus and move the greater tubercle of the humerus posteriorly, and inferiorly, again away from the acromion. In overhead movements the infraspinatus acts as a stabilizer of the humeral head together with teres minor to depress the humeral head against the upward pull of the deltoid muscle. (Gibbons 2019, 43-50.)

Subscapularis is the antagonist muscle for the infra- and supraspinatus and teres minor muscles, as it internally rotates the humerus. However, in overhead movement, subscapularis participates in depression and stabilization of the humeral head against deltoid. While the other rotator cuff muscles push the humeral head anteriorly due to external rotation, subscapularis pulls it posteriorly, leading it to stay stabilized in the glenoid fossa. Problems with the activation of any of the rotator cuff muscles can thus cause impingement or other symptoms due to altered position of the humeral head and greater trochanter. (Gibbons 2019, 43-50.) The role of the rotator cuff in shoulder movements is depicted in Figure 6 below.

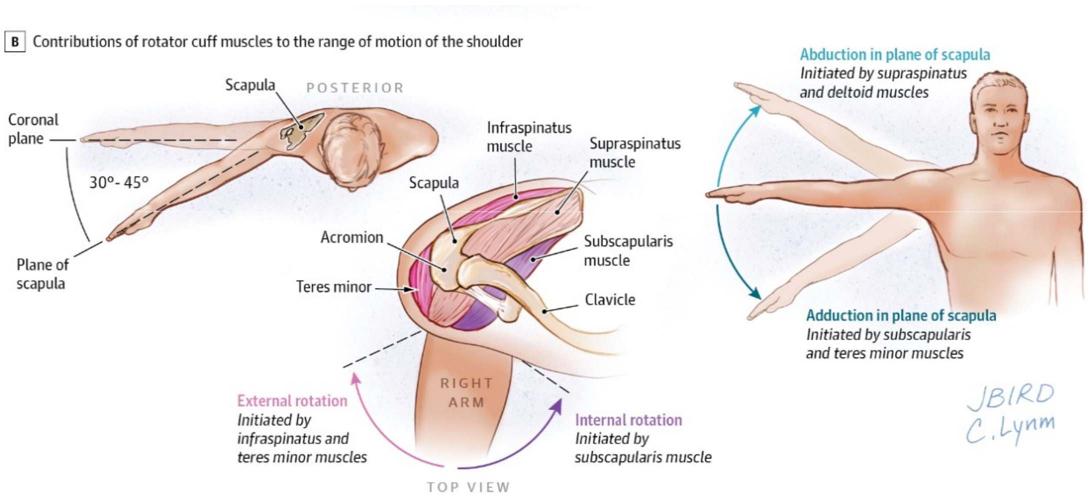

Figure 6. Role of the rotator cuff muscles in shoulder movement (Hermans et al. 2013).

3.4 Nerves and blood supply

The shoulder area blood supply originates from the subclavian artery branching from the aorta via brachiocephalic trunk. The subclavian artery dives under the clavicle and turns into axillary artery on the level of the first rib. Around the glenohumeral joint the the thoraco-acromial artery branches laterally from the axillary artery, which continues down the side of humerus and branches into subscapular artery traveling down the lateral side of the scapula. The lateral side of the scapula is also supplied by a descending branch of the cervicodorsal trunk (suprascapular artery). On the medial side, the cervicodorsal trunk branches into a descending dorsal scapular artery. The medial and lateral arteries connect around the upper and lower borders of the scapula, forming a circular network. The arteries branch into smaller arteries, arterioles and capillaries supplying blood to the surrounding muscles and tissues. (Agur & Dalley 2013, 481-610.)

In order to the muscles to produce shoulder movement, they need to be controlled by nerve impulses. Shoulder area muscles are innervated by nerves originating from the mid cervical and upper thoracic spine (C3-T1-levels). Anteriorly, the shoulder area is innervated by branches of the medial and lateral cords of brachial plexus, median and ulnar nerves, and the branches of the musculocutaneous nerve. Dorsally, the levator scapulae and rhomboid muscles are innervated from the branches of the cervical spine nerves. The rest of the posterior shoulder area is innervated by the branches of the posterior cord of brachial plexus, suprascapular, axillary and radial nerves. (Agur & Dalley 2013, 481-610.)

4 BIOMECHANICS OF OVERHEAD SPORTS

Majority of the literature on shoulder biomechanics in overhead sports consists of studies on baseball. Therefore, the biomechanical forces in a baseball pitch will be taken into closer view in this thesis to represent the loading of a throwing shoulder in overhead sports. However, many of the other overhead sports share similar phase when the arm is returned from a maximal external rotation to 0° with a swift movement for the hand or the racket to meet the ball. Due to this, the same biomechanical factors are applicable to other overhead sports with sport-specific loads taken into consideration. (Abrams, Harris, Andriacchi & Safran 2014; Lin, Wong & Kazam 2018; Seminati, Marzari, Vacondio & Minetti 2015.)

A baseball fastball-type pitch has been divided into 6 phases in the 1990's (Fleisig et al. 1996) and presented in the Figure 7 below.

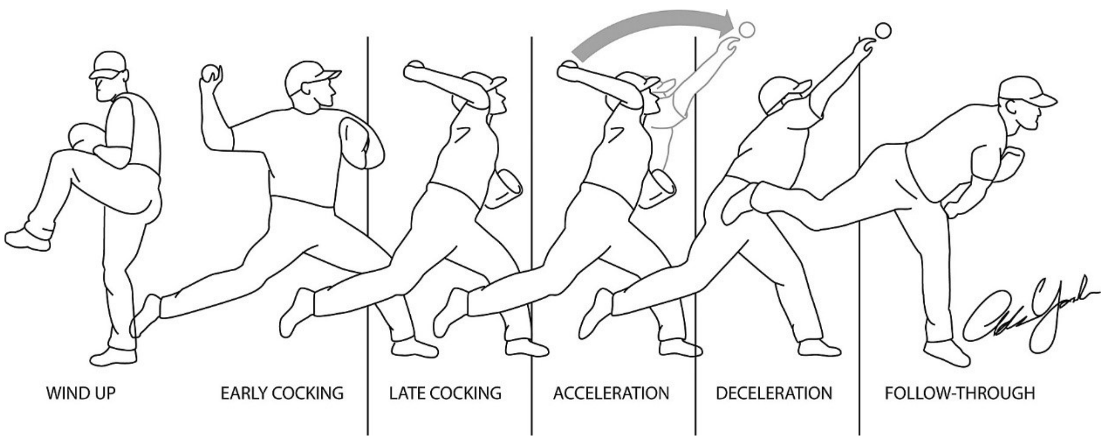

Figure 7. The phases of the baseball pitch (Website of Sean Cochran Sports Performance 2020).

In the early cocking phase, the shoulder is abducted into 90°, preparing for the extreme rotation in the late cocking phase of up to 170° in elite athletes (see Figure 8 below), which places a heavy stress on the anterior capsule of the shoulder as the humeral head translates forward in the glenoid fossa (Braun, Kokmeyer & Millet, 2009; Fleisig et al. 1996).

Figure 8. Late cocking external rotation on a professional baseball pitcher (Website of Lehman's Baseball 2016).

In the acceleration phase the external rotation returns to 0° with the peak rotational velocity reaching close to 7000°/s (Fleisig, Andrews, Dillman & Escamilla 1995). The deceleration phase, or what the spectator sees as the actual throwing stage, involves eccentric muscle work from the rotator cuff to slow down the arm motion and places a high stress on the posterior capsule. At the ball release the distracting force affecting the shoulder can reach up to 950N. (Fleisig et al. 1996; Jobe, Coen, & Screnar 2000, 293; Kibler 1998.)

The pitches are regularly very fast, the record for highest velocity being 169,14km/h from 2010 held by Aroldis Chapman (Website of Guinness World Record, 2020). The measurements on joint loads in fastball pitch are rather old, but research from the turn of the century have shown that decelerating the arm can cause joint loads of posterior shear of 400N, inferior shear of 300N and compressive internal forces of close to

1000N (Jobe, Coen, & Screnar 2000, 293.). Also, a paper from 2008 by Dun, Loftice, Fleisig, Kingsley & Andrews concluded that fastball-type pitch, described above, causes the highest joint loads compared to other types.

5 SHOULDER INJURIES IN OVERHEAD SPORTS

Injuries of the rotator cuff are common in all age groups and are usually caused by overuse in overhead activities, poor biomechanics or degenerative changes due to aging. Most common problems of the shoulder area are pain and dysfunction of the rotator cuff soft tissues due to tears, inflammation or irritation, degeneration, or impingement caused by biomechanical issues. (Website of Physiopedia 2020.)

5.1 Typical shoulder injuries

Typical injuries in overhead sports (see Table 1 below), especially connected to throwers, include tears of the glenoid labrum or tendons, such as SLAP tears, Blankart lesions, Bennet lesions and humeral avulsions of the inferior glenohumeral ligament (HAGL) (DeFroda, Goyal, Patel, Gupta & Mulcahey 2018). Other typical injuries are disorders of the long head of biceps tendon (Wolf & Altchek 2004), acromioclavicular joint (Jones & Schickendantz 2004, 209-221) or scapulothoracic joint (Kibler & McMullen 2004, 222-235). Neurological or vascular lesions occur usually in connection with other injuries and their symptoms can overlap or hide under the symptoms of other pathologies (Stanwood, Bigliani & Levine 2004).

Instability of the shoulder joint can be caused by a single trauma to the joint, or atraumatic factors such as microtrauma caused by repetitive movements, combined with congenital factors. Multidirectional instability (MDI) is most common in volleyball players and swimmers, but instability is prevalent in all overhead sports. (DeFroda, Goyal, Patel, Gupta & Mulcahey 2018; Magee 2014, 123.)

Dislocation of the glenohumeral joint is common due to the instability of the joint structure and wide ranges of movement. Dislocations can occur in any direction, but most commonly anteriorly (humeral head slides downwards and anteriorly from the glenoid fossa). A traumatic dislocation is often caused by a direct or indirect injure due to excessive extension and lateral rotation and is typical especially on young adult athletes. (Magee 2014, 123; Website of Physiopedia 2020) Fractures in the shoulder region are quite uncommon (Jones & Schickendantz 2004, 209-221) but can occur in case of hard hits or falls (Krishnan, Nowinski & Burkhead 2004, 236-266).

Table 1. Typical injuries of the shoulder in different overhead sports (DeFroda, Goyal, Patel, Gupta & Mulcahey 2018).

Sport	Common Injuries
Baseball	SLAP tear, Bennett lesion, GIRD, HAGL, Batter's shoulder (Posterior subluxation)
Tennis	GIRD, SLAP tear
Volleyball	MDI, HAGL
Swimming	MDI, rotator cuff tendinopathy
Javelin	GIRD
American Football	Posterior instability (linemen), GIRD in throwers

5.2 Risks of injury

The underlying condition affecting to the risk of injuries is often muscle imbalance caused by faulty technique or overtraining. The cycle of imbalance and dysfunction is described in the Figure 9 below. Another significant risk factor is a loss of muscle control and the correct firing order due to tiring of the muscles, repetitive microtrauma or other factors affecting to muscle dysfunction. (Comerford & Mottram 2012, 29-49; Gibbons 2019, 80-82.)

The joint stabilizing (tonic) muscles can contract for a long time, thus being susceptible to shortening. This in turn can cause inhibition and weakening in the joint mobilizing (phasic) muscles. The imbalance between these muscle groups causes the structures to compensate, which in turn can cause irritation and dysfunction in the structures. (Gibbons 2019, 80-82.)

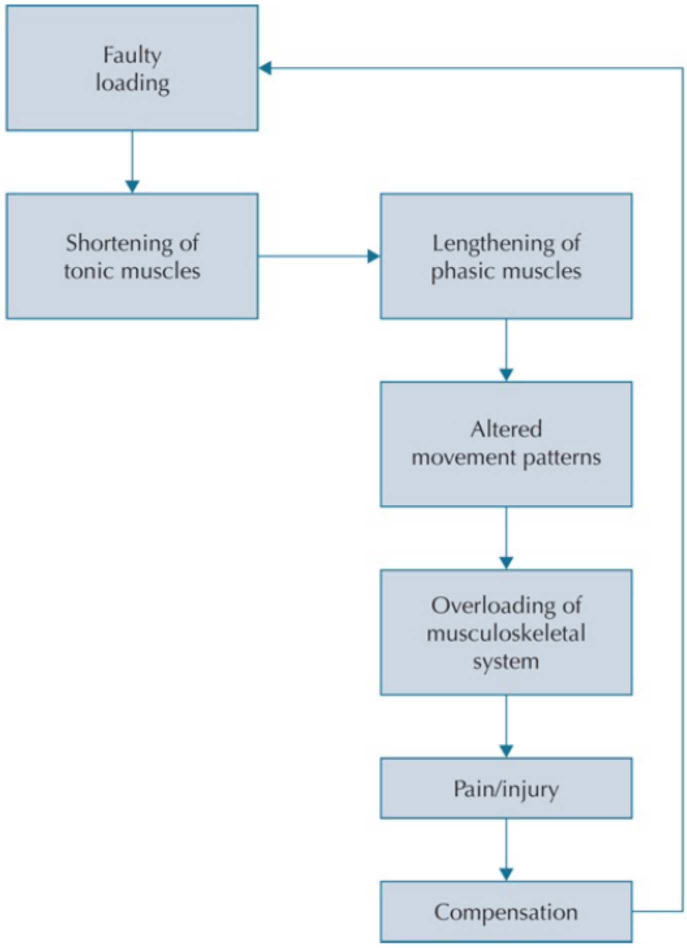

Figure 9. The cycle of muscle imbalance and injury (Gibbons 2019, 82).

In case of muscle dysfunction, the joint stabilizing muscles tend to decrease in tension and alter their recruitment timing and order, leading to loss of control of the joint position and movement for example due to tiredness. Joint mobilizing muscles then tend to lose their extensibility, leading to reduced motion, overactive recruitment, and compensatory mechanisms elsewhere in the body. While compensation of a restricted movement is normal to some extent, it can also lead to the loss of active control of the movement. Uncontrolled movement can in turn lead to pathologies and pain due to cumulation of microtraumas in the joint mobilizing tissues. (Comerford & Mottram 2012, 29-49.)

5.2.1 Shoulder and arm function

In overhead sports the internal rotation of the shoulder is often limited and the external rotation is increased due to the nature of the sport, but excessive glenohumeral joint internal rotation deficit (GIRD) has been mentioned in multiple research articles as a measure for the risk of certain shoulder injuries (Burkhart, Morgan & Kibler 2003). Because the external rotation of an overhead athlete is expected to be increased comparing to non-overhead athletes, a lack of increased ROM is a sign of external rotation deficit, ERD, in the overhead population (Wilk et al. 2015).

Alterations in IR and ER may vary between athletes and the stage of the training season. Thus, a more significant predictor for risk of shoulder injury is the loss of total range of motion (TROM) and especially the ratio between internal and external rotations (Marcondes, Jesus, Bryk, Vasconcelos & Fukuda 2013; Shitara et al. 2017.) Also, reduced shoulder flexion and horizontal adduction have been shown to increase risks of injuries in both shoulder and elbow of overhead athletes (Hellem, Shirley, Schilaty & Dahm 2019; Wilk et al. 2011; Wilk et al 2015).

Injuries and functional limitations elsewhere in the arm affect the shoulder function through kinetic chain and compensation mechanisms (Ellenbecker & Aoki 2020). For example, according to two classic studies (n = 84 and n = 2633), 21% of male and 23% of female tennis players had simultaneous elbow and shoulder injuries, and the players with a history of elbow injuries had 63% greater incidence in shoulder injuries (Priest, Braden & Gerberich 1980; Priest & Nagel 1976.)

Considering muscle function, rotator cuff muscular imbalances especially between internal and external rotators have been shown to increase the risk of injury (Marcondes, Jesus, Bryk, Vasconcelos & Fukuda 2013). Strength deficiencies of lower trapezius and serratus anterior are especially linked to shoulder injuries (Cools, Johansson, Borms & Maenhout 2015; Kibler 1998). Weakness of the serratus anterior can be observed as winging of the scapula especially when arm is returning from the overhead position of abduction or flexion (Gibbons 2019, 54).

Studies have also introduced the concept of total arm strength (TAS) (Ellenbecker & Davies 2001), which refers to the strength ratio of several muscles of the upper limb between the dominant and non-dominant arms of the overhead athlete. For an uninjured tennis player, the dominant arm has significantly higher TAS relative to body weight than the non-dominant arm. However, players with lateral epicondylitis have little to no strength difference or even negative strength ratio between the dominant and non-dominant arm strengths. (Alizadehkhaiyat, Fisher, Kemp, Vishwanathan & Frostick 2007; Lucado, Kolber, Cheng & Echternach 2012; Day, Bush, Nitz & Uhl 2015.) Due to the significant relationship with elbow and shoulder injuries, the total arm muscle function and injuries in other joints of the arm should be considered a risk factor for shoulder injuries (Ellenbecker & Aoki 2020).

5.2.2 Scapular control

When considered from a wider perspective than glenohumeral joint dysfunction, a poor dynamic balance and stability of the upper extremities and the shoulder girdle (upper quadrant or upper quarter) has been shown to be an important risk factor for shoulder injury (Hazar, Ulug & Yuksel 2014). Abnormal scapular retraction or protraction during movement is connected to a loss of normal neuromuscular control of the scapula. This loss can cause abnormal scapular rhythm (scapular dyskinesis) with the movement of the upper extremity or winging of the scapula off the thoracic wall. (Rabin, Chechik, Dolkart, Goldstein & Maman 2018; Kibler et al. 2013; Maor, Ronin & Kalichman 2017.)

Because of the importance of scapular rhythm to the proper movement of the humerus, disturbances in the scapular stability or scapular dyskinesis can be a risk factor for injuries and is often associated with shoulder pain (Hickey, Slolvig, Cavalheri, Harrold & Mckenna 2018; Matzkin, Suslavich, & Wes 2016). Scapular dyskinesis can be caused e.g. by poor posture due to kyphotic thorax or shortened pectoralis minor, dysfunction of the trapezius muscle due to the muscle itself or effects of dysfunction in the muscles attached to it via myofascial slings, or altered neuromuscular function (Gibbons 2019; Schory, Bidinger, Wolf & Murray 2016; Yeşilyaprak, Yüksel & Kalkan 2016).

However, there are also studies showing no statistically significant difference in injury rates between overhead athletes with scapular dysfunction and normal scapular function, and scapular dyskinesis has been found in non-injured throwers (Saka, Yamauchi, Yoshioka, Hamada & Gamada 2015; Shitara et al. 2017). A systematic review noted, that even though overhead athletes have greater prevalence in scapular dyskinesis than other athletes, there is no high-level research on the subject. Also, the existing research does not correlate the prevalence of scapular dyskinesis with important aspects of overhead sports, such as hand dominance and laterality. (Burn, McCulloch, Lintner, Liberman & Harris 2016.)

5.2.3 The role of the core and lower body

The shoulder does not function in force and movement production on its own, but by the kinetic chain principle affects and is affected by the movement of both proximal and distal functional segments (Ellebecker & Aoki 2020). The force transfer in the body travels through four outer *myofascial slings* (posterior longitudinal, lateral, anterior oblique and posterior oblique slings) depicted in Figure 10 below. An example of a myofascial sling effect on the shoulder is latissimus dorsi, which connects the inferior angle of the scapula to the contralateral gluteus maximus via posterior oblique sling. In a case of a weak gluteus maximus, the latissimus dorsi can overwork, affecting the position and movement of the scapula and thus the shoulder movement. (Gibbons 2019, 59-60, 87-90.)

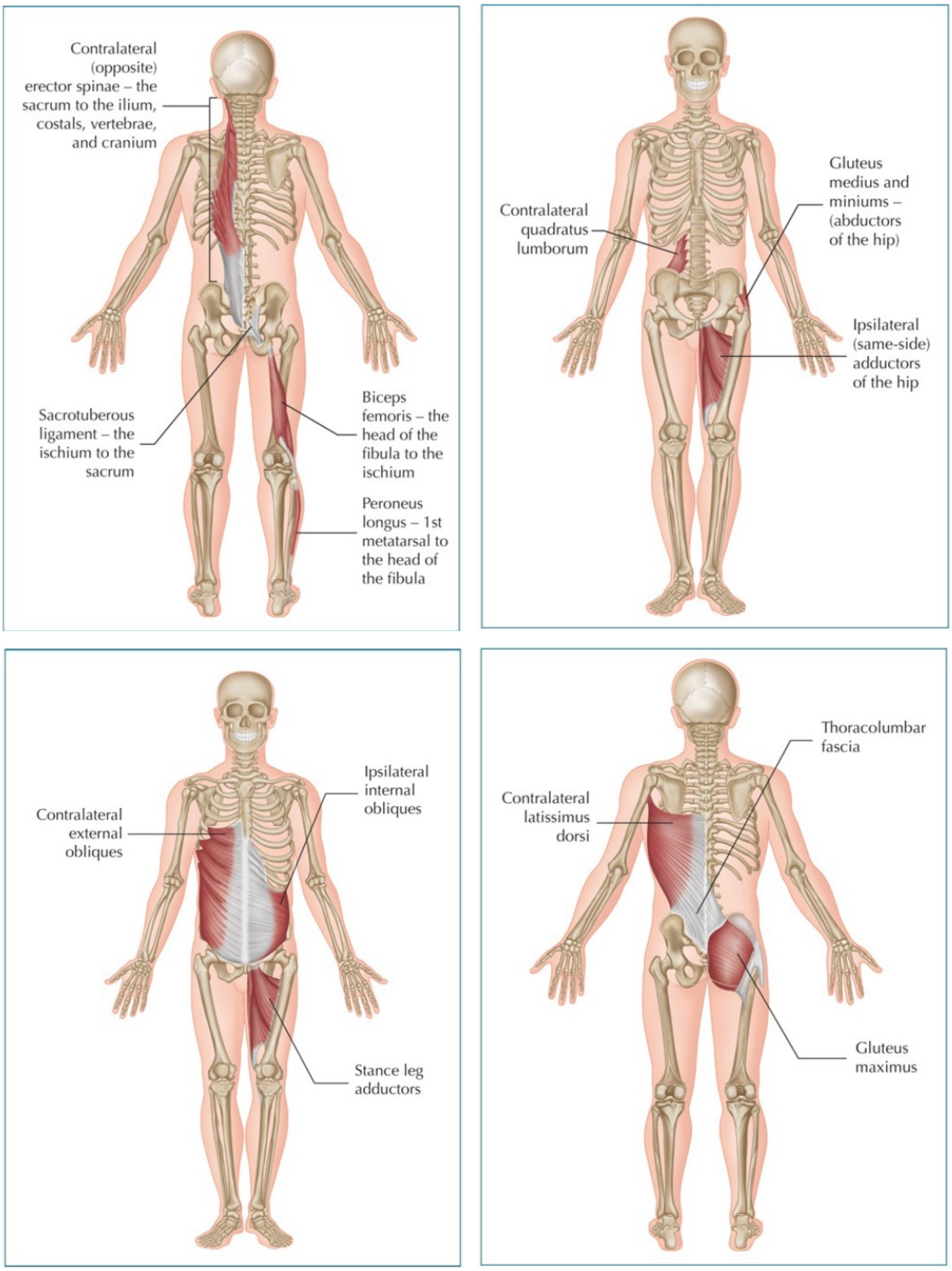

Figure 10. Outer myofascial slings (Gibbons 2019, 87-90).

Instability and poor neuromuscular control of the core muscles have been shown to be linked to shoulder pain in overhead athletes (Silfies, Ebaugh, Pontillo & Butowicz 2015; Pogetti, Nagakawa, Conteçote & Camargo 2018). As the core muscles can create over half of the kinetic energy of the throwing motion, they affect greatly to the overall performance of the overhead athlete (Kibler et al. 2013). The local *inner core* of postural stability and force transfer includes four deep muscle groups (transversus abdominis, multifidus, diaphragm, and the muscles of the pelvic floor) shown in Figure 11 (Gibbons 2019, 85).

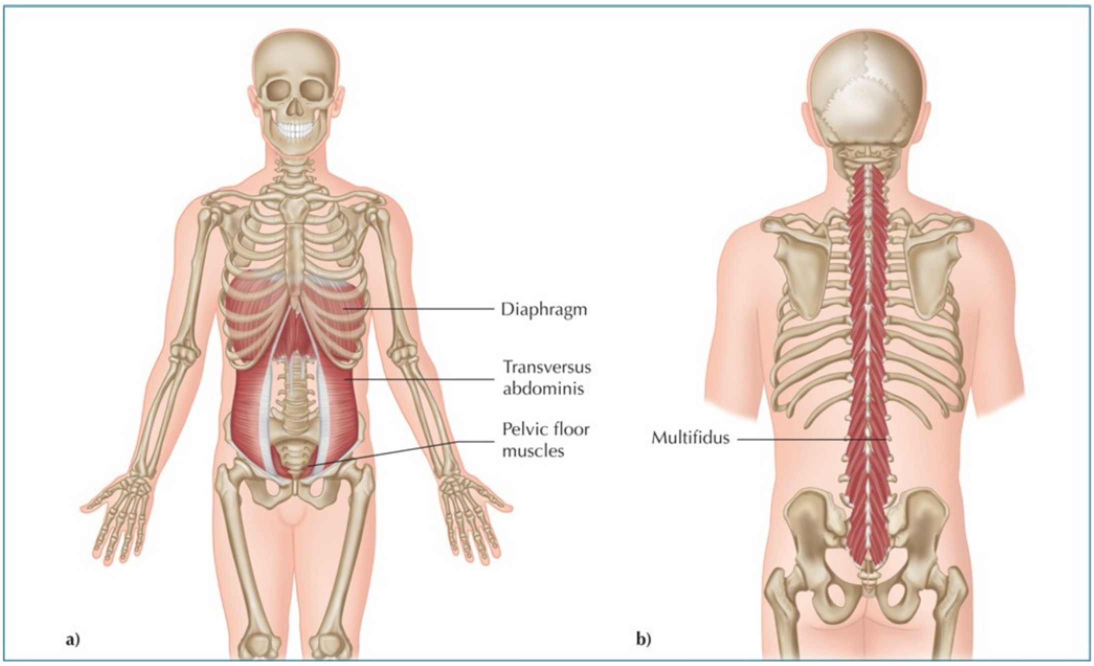

Figure 11. The inner core (Gibbons 2019, 85).

According to the proximal-to-distal sequencing concept described by Bunn (1972), the throwing motion should be initiated in the proximal parts, such as core, and initiate the motion of the distal part when the proximal segment has reached its maximum speed. Studies on tennis and throwing sports has however shown a modification to this basic concept, including the use of humerus internal rotation and pronation of the forearm to increase the speed in the release of the ball or impact of the ball and the racket. This modification further emphasizes the importance of the functional kinetic chain, as the non-optimal use of the force of the legs, lower body and the core increases the use of the humerus internal rotation modification as a power source, increasing the load on the shoulder and potential injury risk. (Ellebecker & Aoki 2020; Kovacs & Ellenbecker 2011; Marshall & Elliot 2000.)

For the proper throwing motion to take place, the hip joints also need to have enough range of motion to enable the pelvis to turn into the position required in the early cocking phase of the throw. This requires the throwing side leg (stance leg) to have adequate internal rotation, while the opposite leg (leading leg) needs to have adequate external rotation to square towards the throwing target. (Wilk et al. 2011.)

In conclusion, in the throwing shoulder, the kinetic chain links the ability to produce optimal shoulder movement to scapular function, core strength, hip strength, and ROM and all the way to knee and ankle mobility. Improper use, injury, weakness, or tightness in these parts, although seemingly far from the shoulder, can lead to increased injury in the shoulder. Also, poor balance has been shown to affect the function of the kinetic chain. (Kibler et al. 2013; Sciascia, Thigpen, Namdari & Baldwin 2012; Silfies, Ebaugh, Pontillo & Butowicz 2015.)

6 INJURY PREVENTION

Injury prevention is typically divided in three phases based on the classification of Haddon (1980). Primary prevention in sports injuries would refer to introducing methods focusing on preventing future injuries in healthy athletes. Secondary prevention refers to focusing on early detection and diagnosis of injury, as early start of treatment can improve the recovery and prevent future re-injury. Tertiary prevention focuses on rehabilitation of a chronic injury, preventing future complications and connected injuries, and enabling the functioning of the athlete within the boundaries of the injury. (Pasanen & Leppänen 2020.)

The focus on preventing sports injuries in throwing sports should consist of knowing the demands of the sport and the sports-typical mechanisms of injury. Recognizing the risk factors and regular assessment of the athletes will help to pinpoint possible risks and help with creating the needed preventive conditioning programs. (Pasanen & Leppänen 2020.)

6.1 An optimized thrower – normal anatomical modifications in overhead athletes

Due to the repetitive throwing or arching motion, it has been shown that the shoulders of an overhead athlete have adapted on a functional, but also on an anatomical level to withstand the requirements of the sport. These changes can especially be noticed in the dominant throwing arm. (Burkhart, Morgan & Kibler 2003; Hellem, Shirley, Schilaty & Dahm 2019.)

Typical overhead athlete's dominant arm shows an increased external rotation (ER) and decreased internal rotation (IR). Part of the phenomenon is thought to be due to the protective adaptation of the bone and can be expected already on very young athletes. The bony structures in the shoulder adapt towards humeral retrotorsion (HRT = humerus is rotated outwards in comparison to humeral head) and glenoid retroversion (GRV = glenoid cavity is tilted posteriorly), giving the shoulder more space for external rotation (see Figure 12 below). Due to these bony adaptations, the increased ER and decreased IR in a thrower's shoulder should be considered normal. (Hellem, Shirley, Schilaty & Dahm 2019.)

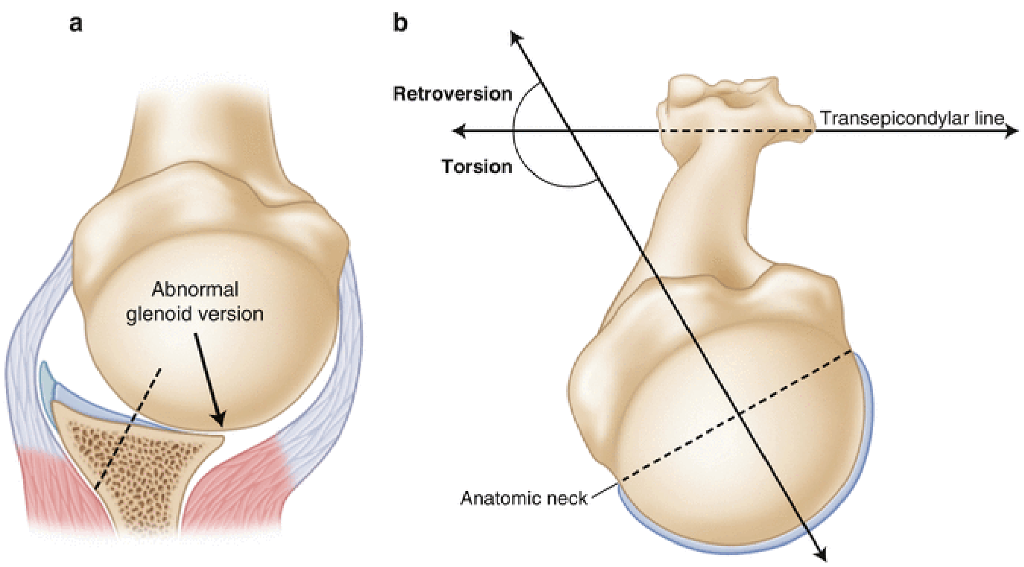

Figure 12. Retrotorsion of the humerus and retroversion of the glenoid cavity (Website of Musculoskeletal Key 2020).

The IR and ER of a thrower are also affected by the thickening of the posterior capsule of the glenohumeral joint and the thickening of the rotator cuff muscles due to repetitive motion. Thickening of the posterior capsule is a common finding in the overhead athlete and may be caused by repetitive microtrauma and scar tissue. (Burkhart, Morgan & Kibler 2003.) Studies have shown that the ROM of the shoulder rotation changes also according to the amount of throwing and over the course of the game season, which suggests that part of the loss of ROM in the throwing shoulder is caused by the stiffness of the rotator cuff muscles (Kibler et al. 2013; Tokish 2014). The increased ER of a thrower can be seen in the Figure 13 below.

Figure 13. The increased active ER of an overhead athlete (Website of Peak Form Health Center 2020).

Scapular dyskinesis has been found to be almost twice as common in overhear athletes compared to other athletes (61% vs. 33%) (Burn, McCulloch, Lintner, Liberman & Harris 2016). Soft tissue alterations can be expected in the dominant arm of an overhead athlete, causing changes in the scapular positioning. As scapular alterations have not been completely agreed by the science to cause a risk of injury, minor changes in scapular position and orientation can be considered normal and should not be considered as a pathology or a primary cause of the shoulder problems. In rest such minor alterations can show as anterior tilt and internal rotation of the scapula. In elevation the scapula may show increased upward rotation, internal rotation, and retraction. (Hellem, Shirley, Schilaty & Dahm 2019.)

6.2 Assessment for injury prevention

In overhead athletes, typical alterations of posture are slightly protruded position of the head and lower positioning of the dominant arm on the shoulder level. Muscle thickening or atrophy anywhere in the body can be observed in the posture assessment, as well as kyphosis, which may affect the movement pattern of the scapula. Differences in the rotator cuff and scapular muscles are enhanced for view when the client stands in a hands-on-hips-position, thumbs pointing posteriorly. (Gibbons 2019, 73, 82-83; Manske & Ellenbecker 2013.)

For the assessment of motor control, strength, imbalances or endurance of the scapular muscles, the upper limbs are repetitively raised overhead in flexion, abduction and scaption of 30°, depending on the test used. Example of proposed scapular dyskinesis tests (see Figure 14 below) are the 4-type test (Kibler et al. 2002), the Yes/No classification (Uhl, Kibler, Gecewich & Tripp 2009) and the Scapular Dyskinesis Test (McClure, Tate, Kareha, Irwin & Zlupko 2009). (Rossi, Pedroni, Martins, & de Oliveira 2017.) Adding weight resistance to the movement is proposed to add the reliability of the test (Sciascia, Thigpen, Namdari & Baldwin 2012).

Original operational definitions of the classification methods of scapular dyskinesis.

4-type [10]	**Type 1**	Prominent inferior medial scapular border at rest and during arm motion
	Type 2	Prominent entire medial scapular border at rest and during arm motion
	Type 3	Elevation of the superior border and anterior displacement of the scapula at rest and shoulder shrug without the occurrence of significant winging of the scapula at the beginning of the movement
	Type 4	Both scapulae are positioned symmetrically (the scapula of the dominant member may be a bit lower) at rest and turn symmetrically upwards with the medial border attached to the thorax during movement.
Yes/No [11]	**Yes**	Types 1, 2, and 3: Patterns of scapular asymmetry
	No	Type 4: Symmetric scapular motion
SDT [12]	**Obvious**	Apparent prominence of any portion of the medial border or inferior angle or dysrhythmia, or excessive or premature movement of the scapula during elevation or lowering of the arm
	Subtle	Questionable evidence of abnormality, inconsistently present
	Normal	Absence of projection of the scapula, and upper and lower rotations are smooth and continuous during elevation and lowering of the arm, respectively.

Abbreviation: SDT, scapular dyskinesis test.

Figure 14. Scapular dyskinesis test classifications (Rossi, Pedroni, Martins, & de Oliveira 2017).

6.2.1 Adequate AROM and PROM of the shoulder

Based on a recent literature review, a set of upper limb tests have been suggested for screening the risk for injury. These tests include passive ROM measurements of internal and external rotation to define glenohumeral joint internal rotation deficit (GIRD) and TROM of the shoulder, added with shoulder flexion and horizontal adduction. (Hellem, Shirley, Schilaty & Dahm 2019.)

The total range of motion (TRM or TROM) is defined by adding together the internal and external passive rotations of the shoulder in 90° abduction. The TROM can vary from 160° to 210° depending on the study, and when the IR or ER are measured individually, there might be a 10-15° difference between sides. However, compared to the other shoulder, the difference of TROM should not exceed 5°. (Camp et al. 2017; Wilk et al. 2011; Wilk, Macrina & Arrigo 2012.)

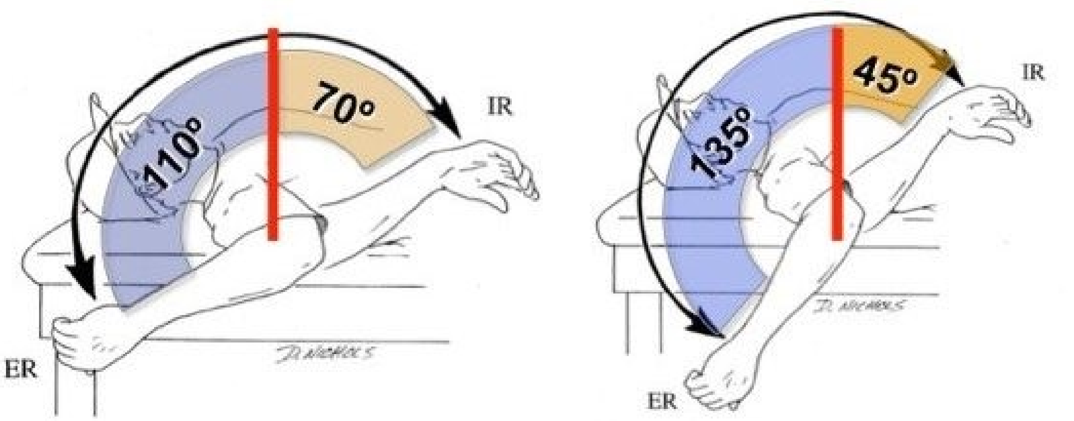

Figure 15. Two versions of normal TROM of the shoulder (Website of Whole Body Health Physiotherapy 2020).

GIRD has been mentioned in multiple research articles as a measure for the risk of certain shoulder injuries. GIRD occurs when the internal rotation of the throwing shoulder is decreased 20° or more compared to the other shoulder (see Figure 16). (Burkhart, Morgan & Kibler 2003.)

Figure 16. GIRD of the right shoulder (Website of Orthobullets 2020).

Normal values given for flexion vary from 165° to over 180°, while the horizontal adduction ranges from 3° to 50° (Camp et al. 2017; Hellem, Shirley, Schilaty & Dahm 2019; Wilk, Macrina & Arrigo 2012). The great variation is due to individuals covering a large variation of ages, but as shown in studies mentioned before, the overhead athlete's physical adaptations start at a young age and are similar across individuals. Thus, the ranges provide a general guideline for clinical examination for injury risk identification. (Hellem, Shirley, Schilaty & Dahm 2019.) According to Wilks et al. (2011 & 2015), the dominant arm deficit in passive flexion and adduction as parts of the TROM of the arm of greater than 5° compared to the non-dominant side should be considered as a risk for elbow and shoulder injury.

There is also evidence that due to the adaptations in an overhead athlete's shoulder and the demands of the throwing action, the external rotation difference between the dominant and non-dominant shoulder should be more than 5°. Less than 5° would be considered external rotation deficiency, ERD, which is shown to correlate with shoulder injury risk. (Wilk et al. 2015.)

6.2.2 Adequate strength and muscle balance of the shoulder and scapula.

Muscle imbalance has been mentioned above as a major risk for injuries. Manual muscle testing (MMT) has been proposed to be used, combined with palpation and position control as the method for defining the strength of individual muscles of the shoulder girdle. However, it has been suggested that a hand-held dynamometer is more sensitive and reliable for testing the isometric strength of the rotator cuff muscles. Multiple methods have been proposed to test the isokinetic, eccentric and isometric strength of the rotator cuff, but in general the studies conclude that in order to prevent injury, the dominant side strength should show 10% increase in all of these strength types compared to the non-dominant shoulder. (Byram et al. 2010; Cools, Johansson, Borms & Maenhout 2015; Ellenbecker& Roetert 2003; Manske & Ellenbecker 2013.)

Scapular strength can be measured with several protocols and with "make" (concentric) or "break" (eccentric) tests. A dynamometer can be used to test the strength and an increase of 10% in muscle strength should be seen in the dominant side when the sport is one-handed (baseball, tennis, volleyball etc.). In bilateral overhead sports such as swimming no difference should be noticed. (Cools, Johansson, Borms & Maenhout 2015; Kibler 1998.)

6.2.3 Dynamic stability and balance of the shoulder girdle (upper quadrant).

Screening for injury risk requires testing for active functioning of the shoulder girdle. For this purpose, physical performance tests such as Closed Chain Upper Extremity Stability Test (CKCUEST) and Seated Medicine Ball Throw (SMBT) has been developed. However, these tests are not fully recognizing the specificities of one-handed overhead sports. Upper Limb Rotation Test (ULRT) has been specifically developed for overhead athletes, but while the introductory research paper presented clinical reliability, the test still needs more testing. (Borms, Maenhout & Cools 2016; Decleve et al. 2020.) Upper Quadrant Y-balance test (UQYBT, see Figure 17 below) is shown to be reliable for defining the dynamic balance and neuromuscular control of the shoulder girdle in one-handed overhead sports, thus making it usable for testing overhead athletes (Gorman, Butler, Plisky & Kiesel 2012).

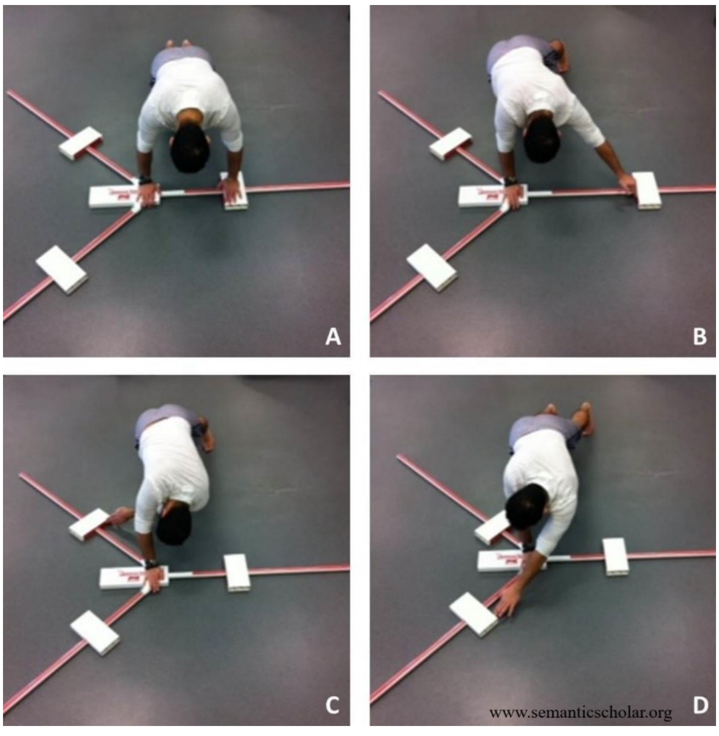

Figure 17. Upper Quadrant Y-Balance Test (UQYBT) (Myers, Poletti & Butler 2017).

A study aiming to create reference values for CKUEST, SMBT and UQYBT for overhead athletes has shown that in general, male athletes have significantly higher test scores than females, and that athletes under 25 have generally higher test scores than older age groups. As only UQYTB test can differentiate the side difference, multiple studies have shown that in general, the performance of non-dominant hand is significantly better than the dominant hand. Some reference values are presented in Table 2 below. However, the number of participants in these tests has been too small to be used as definitive standards and should be considered as an example of side difference and the effect of age. (Borms & Cools, 2018.)

Table 2. Reference values for UQYBT in cm with standard deviation (in parenthesis) (Borms & Cools, 2018).

Age	**Male**		**Female**	
	Dominant	Non-dominant	Dominant	Non-dominant
18-25	88,56 (7,11)	89,71 (6,63)	83,41 (10,36)	84,23 (9,43)
26-33	89,49 (6,31)	90,78 (7,28)	81,24 (14,08)	81,24 (14,08)
34-50	87,42 (8,66)	89,04 (8,22)	77,65 (10,09)	79,62 (9,86)

6.2.4 Optimal functioning of the core and lower limbs.

As mentioned, the poor function or neuromuscular control of the core and lower limbs increase the risk of shoulder injuries through the kinetic chain principle. For example, studies have shown that 45-55% of non-injured tennis players show weakness in 1 leg standing test for leg stability. (Ellenbecker, Windler, Dines & Renstrom 2015; Rice et al. 2018.) Balance and lower limb stability, core strength (flexion, extension and isometric) and hip rotational ROM should be included in the evaluation of an overhead athlete's injury risk. Balance tests such as 1 leg stance and Y-balance test can reveal deficits in neuromuscular control, balance, or muscle strength of the lower limbs. (Ellenbecker & Aoki 2020.) For hip ROM measurements, typical findings in baseball pitchers are increased external rotation in leading leg and increased internal rotation in the stance leg. (McCulloch, Patel, Ramkumar, Noble & Lintner 2014)

6.3 Conditioning for risk prevention

Current evidence shows that a correctly designed conditioning program could reduce the prevalence of injuries caused by hypermobility, muscle weakness or imbalance (Andersson, Bahr, Clarsen & Myklebust 2017; Faigenbaum & Myer 2010; Niederbracht, Shim, Sloniger, Paternostro-Bayles & Short 2008). For general shoulder injury prevention, the emphasis should be placed on glenohumeral and scapulothoracic muscle strength, shoulder mobility, neuromuscular control and dynamic stability of the shoulder (see Figure 18 below), and due to the kinetic chain also the core and lower body control (Andersson, Bahr, Clarsen & Myklebust 2017; Niederbracht, Shim, Sloniger, Paternostro-Bayles & Short 2008; Reinold, Gill, Wilk & Andrews 2010, 103).

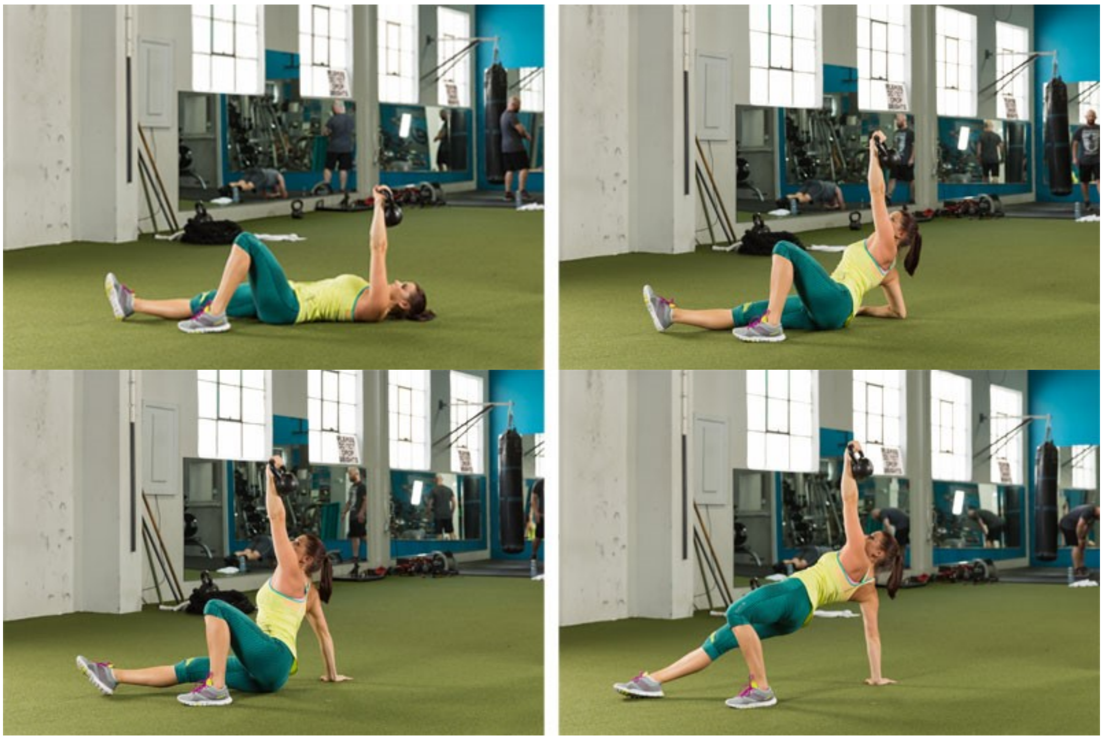

Figure 18. Open chain exercise for dynamic stability of the shoulder (Website of American Council on Exercise 2020).

Open chain exercise provides better isolation and control of the movements, and identifies the possible weaknesses in strength, power or ROM (Kisner & Colby 2012, 190). However, high-loading open chain exercise can also create an injury risk for unstable joints and worsen the problem (Escamilla et al. 1998). Also, pull-up type movements, especially reverse pull-up, or a wide-grip pull-up have been linked to shoulder injuries, particularly impingement and should be avoided (Caine & Nassar 2005; Rooks, Johnston, Ensor, Mclntosh & James 1995; Prinold & Bull 2016, 634).

Due to these findings, the currently proposed injury prevention training programmes focus on connecting the postural and motor control to improve neuromuscular activation, sensory patterns and to improve joint stability. Programmes often include mostly unilateral resistance training exercises performed on an uneven surface. The postural instability has been produced using balance boards, varying stances, planking, and laying on a balance ball. The resistance is provided with elastic bands, weights, or balls. (Behm & Anderson 2006; Saeterbakken & Fimland 2013.)

Another unstable element can be produced by using stochastic resistance (a partially water-filled pipe) especially in training internal and external rotation, as the unstable mass of the exercise resistance tool produces a higher neuromuscular activation with less need for increasing the resistance. This can be especially beneficial in cases where increasing resistance weight could cause problems in co-activation of the limb and scapula muscles, leading to compensation. (Baritello et al. 2020.)

Neuromuscular control can also be improved by e.g. closed kinetic chain exercises to facilitate joint proprioception and the cooperation of muscle couples, or plyometric exercises (see Figure 19 below) to increase the stretch reflex to increase muscle reflexes in quick movements. (Reinold, Escamilla & Wilk 2009; Reinold, Wilk, Dugas & Andrews 2009, 128-129.)

Figure 19. Plyometric catch-exercise (Kovacs, Roetert & Ellenbecker 2008).

In case of GIRD in a throwing shoulder, studies suggest stretching of the posterior soft tissues to increase the internal rotation of the affected shoulder. Stretches include variations of the sleeper stretch and horizontal adduction, which can be performed individually or with assistance. The goal of the stretching is to increase the internal rotation of the affected arm within 10°-12° of the non-affected side. However, the literature is inconsistent whether the posterior soft tissue stretching is necessary in other cases if GIRD is not present. (Wilk, Macrina & Arrigo 2012.)

In general, conditioning should include specific exercises that resemble the day-to-day sport activities and movements of the client and include the cooperation of the whole kinetic chain in the throwing motion (Gibbons 2019, 91). In addition, attention should be paid to the right technique and the psychosocial factors affecting the risk of injury, such as the client's attitudes towards injury prevention and conditioning (Shrier & Hallé 2011; Ivarsson et al. 2017).

The studies have shown a link between the exercise loading and injury risk, meaning that successful prevention includes regulating the amount of sports and conditioning load. The load-risk relation follows a curve where both too little and too much loading increases the risk of injury. Also, quick increases in training amount or change of type increase the risks. This should be kept in mind also when creating conditioning programs. (Gabbett 2016.)

7 INDEPENDENT STUDIES IN MODERN PHYSIOTHERAPY EDUCATION

The current higher-level education is moving towards ever greater amount of independent work from the students in effort to meet the modern need for life-long learning and independent searching for knowledge. Methods of e-learning, blended learning and hybrids of learning methods have arisen on the side of traditional face-to-face teaching. It is thought that through independent learning the students can improve general professional competences, creativity in knowledge seeking and problems solving, and self-development skills needed in the working life. (Nortvig, Petersen, & Balle 2018; Shurygin, & Krasnova 2016.) The increase of independent studies increases the student's responsibility on their own studies, but also causes an increase of differences in learning results in heterogenic student groups. The reduced face-to-face contacts are seen by students as reducing mostly the development of professional skills. (Nenonen 2020, 147, 157.)

The Finnish higher education reform has caused changes in the amount of face-to-face teaching both from the student and faculty point of view (Nenonen 2020, 30). This has been seen as a factor reducing the quality and loading of education, but also as an opportunity to develop teaching methods and bring flexibility into the studies (Nenonen 2020, 156-157).

Via independent learning tools the students are changed from passive consumers of knowledge and education to independent actors affecting their own professional growth. The best student satisfaction and subjective learning results are achieved through the combination of online material and the possibility to reflect with teachers and other students. (Nortvig, Petersen, & Balle 2018; Shurygin, & Krasnova 2016.) In Satakunta University of Applied Sciences (SAMK) the bachelor studies in physiotherapy include face-to-face-teaching, projects and learning tasks independently and in groups, independent learning and e-learning (Website of Satakunta University of Applied Sciences 2020).

It is nearly impossible to provide quality high-level education in the modern era without the use of electronic learning materials and the use of information technology. Distant education plays a crucial role in this respect, providing certain important aspects are met. The institution needs to be able to provide sufficient ICT solutions to support distance learning, the teachers need to have enough knowledge in the use of the solutions and there needs to be both allocation and favourable conditions for independent learning in the studies. Perhaps most importantly, there needs to be good quality educational material available to meet the needs for distance learning. (Shurygin, & Krasnova 2016.)

8 THE LEARNING MATERIAL FOR INJURY PREVENTION

The learning material based on this thesis was produced in the form of an independent study package as a part of the Musculoskeletal Physiotherapy 2 course in the curriculum. An open-source H5P editor was used to create and interactive electronic book in Moodle, which is used as the main platform to contain and deliver course material and for completing course tasks (Website of H5P 2020; Website of Satakunta University of Applied Sciences 2020). The interactive book platform enabled the study package to include sections of theory, including images and videos, followed by small quizzes on the content of each section (Website of H5P 2020).

8.1 Contents of the independent electronic study package

The interactive book consisted of a cover page including introduction to the subject and a short description on the contents of the study package. The material was divided into 7 subcategories. Part 1 consisted of a revision of the basic deep anatomy of the shoulder including bones, joints, ligaments, and bursae. Built on this basis, the part 2 described the muscle anatomy and movement of the shoulder girdle from a functional point of view. The anatomical and functional theory were chosen to be the first parts of the study package to firstly revise the students’ knowledge on this complicated structure and all the parts of it which need to work together, and secondly to revise the muscle cooperation and ROM of a normally functioning shoulder. Also, the anatomy part of the material was planned to provide a “reminder” of all the structures where injuries can occur in the shoulder.

Part 3 of the material presented the biomechanical requirements of overhead sports, especially to throwers. Baseball was taken as an example in the material, as was in this thesis in general. This part also included the typical injuries in overhead sports. Due to the nature of the sports and the measurable anatomical and functional adaptations of the athlete’s body in them, part 4 was added to describe what are the normal adaptations and what kind of differences should be expected when examining an overhead athlete versus other client groups. Part 4 was also meant to explain why certain measurements and reference values would differ from “normal” values, and to explain why certain measurements and evaluations (e.g. TROM) are more valuable in this client group than others (e.g. separate rotational ROM).

In part 5 the material describes the current knowledge of the risk factors of shoulder injuries in overhead athletes, again focusing mainly on throwers. In this part the aim was to emphasis the role of the whole body and the kinetic chain on the proper functioning of the shoulder and how changes in force production in the body affect the load on the shoulder. The risk factors were presented in groups, divided into the function of shoulder and arm, scapular control and the function of lower body and the core based on the same general grouping found in the studies on shoulder injuries and injury risks in the literature.

Part 6 focused on the functional requirements for a thrower’s body for optimal throwing and injury prevention. The material was divided by functions, such as adequate range of motion of the shoulder or dynamic balance and control of the shoulder girdle and upper quadrant. The division was made to answer to the questions “What functional aspects does the client need for minimizing injury risk?” and “What am I assessing as a physiotherapist?” instead of presenting a list of tests on its own. Tests for assessing if the athlete meets these requirements was provided as proposed by the literature, including overhead sports specific reference values if available. The presented tests were chosen if the literature mentioned them as valid and reliable for unilateral overhead sports, and/or if multiple studies agreed on the use of a certain measurement having significant correlation with injury risk.

Finally, part 7 focused on creating a sport-specific conditioning program presenting the currently proposed exercise types to be included and emphasized in the conditioning for overhead athletes. Each exercise type was described according to their aim (e.g. neuromuscular control) mentioned by literature and provided with examples. Another emphasis of the part was the importance and regulation of conditioning and training load to prevent increasing injury risk by well-intentioned conditioning overload. The motivational and psychological factors of the athlete were included in this part as well, as the athlete is the one doing the actual leg work of the conditioning program. The references to each part were presented in the last page of the book divided by the parts of the material. This way of presentation was chosen for easier access to the reference material if the student wanted information on a certain subject, as the reference list of this learning material was extensive.

Each part consisted of a short section of theory paired with visuals, such as images, image slideshows or videos. The videos were embedded as links from YouTube and straight links were added in the text in case the embedded videos would not work. The end of each section included a small quiz in the form of 1-2 true/false questions or a set of multiple-choice questions, where the student chooses the right statements from 4-6 options. The answers to the questions could be found in the text above and were planned to highlight the main aspects of the subject on hand. After a successful completion of the quiz the student could access the next subject.

The independent study package was planned in agreement with SAMK to take 0,5-1h of active study time. The interactive book was tested on three 4th year physiotherapy students, who all were able to complete the material within the expected time. The 3 students were asked for a short, written feedback on the interactive book format and the contents of the study material. The comments can be found in Appendix 2. In general, the testers considered the material clear and 2 of them mentioned the chosen pictures and videos to bring extra value to the study package.

After completion, the material was piloted as a workshop provided for physiotherapy students in SAMK. The workshop itself was implemented as part of other studies, so the planning and implementation process will not be further discussed in this thesis. However, as the material of the workshop was created as part of the thesis, the participants were asked to fill out a questionnaire for feedback on the theoretical and educational content of the workshop.

8.2 Feedback for the study material piloting

The study material was piloted in a workshop organized for SAMK physiotherapy students in the SAMK premises. The invitations were sent to all class groups of both Finnish and international study programmes. The 12 participants were 2nd to 4th year students.

The workshop theory slides consisted of the same information given in the study package to test if the amount of information was satisfactory for the students. Added slides consisted of extra images, which were not included in the study package due to clarity of the pages and their “nice to know, but not essential” nature. The order of the information points was slightly altered due to different medias and the flow of the presentation. In addition, the workshop included a practical part where the participants could try out testing methods and a few selected exercises presented in the conditioning example videos of the material.

The feedback of the workshop was collected in the form of a 5-point Likert scale questionnaire presented in Table 3 below. The feedback was given on a scale of 5 (totally agree) to 1 (totally disagree). A score of 3 was given the value “I don’t know”. 5-point Likert type scales are widely used in measuring the opinions of people and are considered adequately reliable and easy to use. The questions are proposed to be worded positively and to have a midpoint with neutral answer, such as “neutral” or “undecided”. Although there is a difference between these two neutral answers, the wording of the neutral point has been proposed to not be statistically significant for the reliability of the results. (Armstrong, R. 1987; Likert, R. 1932; Wakita, Ueshima & Noguchi 2012.)

Table 3. Results of the 5-point Likert scale questionnaire.

5=completely agree, 4=partially agree, 3=I don’t know, 2=partially disagree, 1=completely disagree								
		5	4	3	2	1	Mean	%
Q1	I found the information useful	11	1				4,92	98,33
Q2	I got enough information	9	3				4,75	95,00
Q3	The information was presented in an understandable manner	12					5,00	100,00
Q4	The questions were answered properly	11		1			4,58	96,67
Q5	I found the practical part useful	10	2				4,83	96,67
Q6	The practical part was demonstrated properly	11	1				4,92	98,33
Q7	I got new ideas/perspectives on injury prevention	10	1	1			4,50	95,00
Q8	I can use the information from today in my future work	11	1				4,92	98,33
Q9	I would recommend the workshop for other students	12					5,00	100,00
Q10	Would you like to give any other feedback? Feel free to write your comments below!							

The questionnaire had 9 scored questions and a free text field for optional feedback or comments. Questions Q1-2 and Q7-8 can be considered as measuring the quality of the material, although the verbal and visual presentation in a workshop will have its effect on the score. Question 3 can be considered measuring the material partially, with significant effect from the verbal and visual presentation. The rest of the questions were measuring the opinion on the practical implementation of the workshop.

There are limitations of the 5-point Likert-type scale, one being the attitude conviction, when a person may feel strongly about the subject already (Berger & Alwitt 1996). The attitude conviction may also affect the results of this workshop questionnaire, as all participants were volunteers, suggesting they were already interested in the subject. Also, due to the initial interest in the subject, a participant may have higher expectations on the amount and depth of the presented information, the amount of practical exercise time and the interest in using the information later in their working life.

The questionnaire results show that in general, the participants agreed on the claims in the questions at the level of 95% or higher. From the questions concerning the material (Q1-2 & Q7-8), the participants agreed on the usefulness of the information and usability of the information on the working life on the level of 98,33%, while the amount of information and the gained new ideas/perspectives had the agreement level of slightly lower, 95%. The understandability of the presentation of the information, including the theoretical material and personal presentation was agreed with by 100% of the participants.

8 participants also gave their comments to the free text field (Q10). All questionnaire responses are presented in the Appendix 3. In general, the written comments mostly wished for more time on the practical part of the workshop. The parts of the comments concerning material included “Very comprehensive and clear teaching!”, “Good overview…”, and “…relative, up to date info.”.

These results show that the collected material, the parts of the subject chosen for the educational package and the usability of the presented knowledge were seen successful by the piloting students.

9 THESIS PROCESS

The author’s thesis process started originally in the beginning of 2019 on similar subject of shoulder injury prevention, but in another type of sports and for another client. Unfortunately, before the completion of the original thesis, a thesis on the same subject was published from another university of applied sciences in Finland. In this situation, the original subject matter was kept to salvage as much of the ready material as possible, but the focus was changed into the shoulder injury prone overhead sports and especially unilateral throwing sports. The general process schedule is presented in the Figure 20 below.

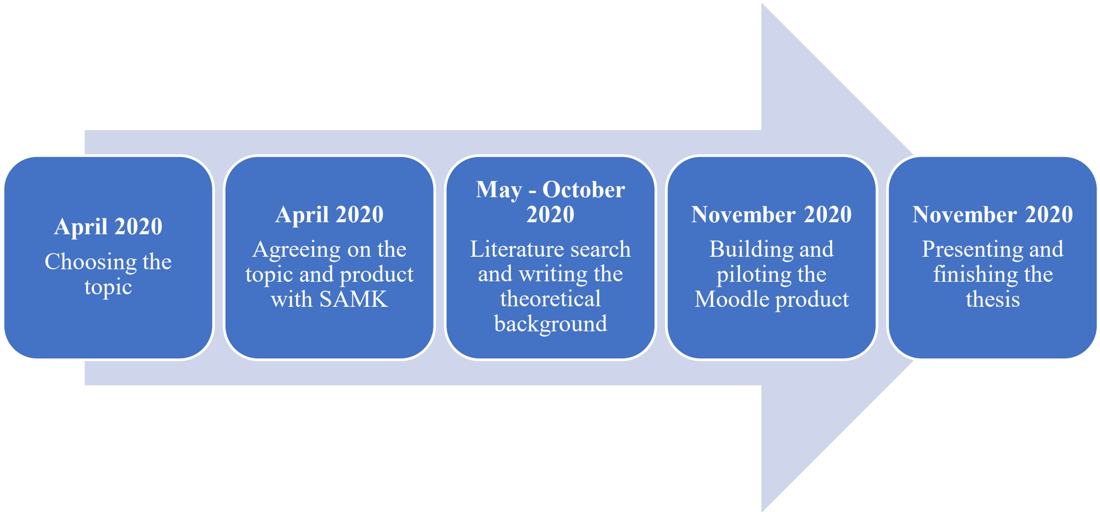

Figure 20. The thesis process.

After a discussion on the changed thesis situation, it was agreed that the new thesis would consist of an independent study material package to accompany an existing musculoskeletal course in the curriculum of physiotherapy studies in Satakunta University of Applied Sciences. The platform was decided to be Moodle, and in June 2020 the H5P interactive tools were decided to be used to produce the study package.

Although preliminary material was already collected and parts of the theory were written for the previous subject, a new literature search was performed as the search terms were not completely applicable. The theory on anatomy remained, but otherwise the theory of this thesis was written anew. PubMed, Finna, Science Direct and EBSCO host were used to search for initial material using combinations of search terms "shoulder", "injury/injuries", "injury prevention" and "overhead sport/s". Also, terms "baseball", "tennis" and "volleyball" were used to find more sports-specific material. After an initial material search, Google Scholar was used to track the references used in the found articles to widen the article base and find the original research results.

The amount of search engines and terms was caused by difficulty to find a reasonable number of articles to create an overall view on the subject. It was found out that although the subject has been studied somewhat, larger high-quality studies or reviews are few and far between. Most of the studies found were small and the prospective cohort studies found had low n values. A lot is also disagreed on among the researchers, which makes the subject rather complicated. Due to the widely differing results of the found studies, the theory of this thesis is based on the most agreed-on factors, consensus of the majority when available, and the findings of the found reviews. When possible, the theory section refers to two or more references to increase the reliability of the material provided in the study package.

This thesis is considered as a practice-based thesis. The basis of a practice-based thesis is a practical problem or need for which the thesis aims to provide an evidence-based solution by creating a usable product, such as an event, a physical product, or as in this thesis, study material (Hakala 2004, 23-27; Vilkka & Airaksinen 2004, 9-15; Website of student intranet Oiva 2020). In addition to the structural parts of a typical thesis, practice-based thesis includes an overview of the subject or environment for which the product is created, and the description of a product or an action (Website of Centria Kirjasto- ja tietopalvelu 2020).

10 DISCUSSION

Despite the planning and best intention, sometimes “life happens” during a long-term process, such as writing a thesis study. Choosing the topic to concern musculoskeletal physiotherapy and especially the shoulder girdle injury prevention were clear from the start due to the author’s personal interest in this complex musculoskeletal structure. However, the choice of overhead sports was rather coincidental due to external circumstances. With no personal connection to ball sports, delving into the world of overhead sports and especially ball sports has been interesting and educational, and useful for the future career due to the popularity of these activities. The process has not only required growing in academic skills, but also in being flexible, open minded and resilient. This thesis is a proof to the author that it is possible to use something already known, add a new angle to it, and learn something completely new in the process.

Due to unforeseen circumstances, the schedule of the thesis process had to be adjusted multiple times. In the end however, the product (independent learning package) was delivered as agreed, tested by 3 fellow students, and piloted by 12 students in the form of a workshop. The results of the workshop and the feedback of the people trialing the electronic learning material propose that the product development was successful in presenting understandable and usable information on the subject and providing guidelines for practical use in the future working life. As the workshop results show, the students would like to have more practical training on the subject, which is unfortunately impossible to provide in the form of an e-learning material. However, for this reason, the videos and example images in the learning material were chosen to show multiple possible practical implementations to answer to that need as well as possible using this medium.

The product and the theoretical background in this thesis are collected from shards of knowledge in a sea of studies on overhead shoulder injuries. Many studies can be found on the thesis subject, but the level of research papers varies greatly, and there are only a few high-quality reviews available. The longitudinal studies found had low numbers of participants or did not differentiate according to age or gender. Also reference values and measurement outcomes had rather wide variations. The variety of results, the general level of the studies in the field, and the disagreements on factors of injury risk correlation (for example in the case of scapular dyskinesis) cause limitations to the reliability of the information in this thesis. Due to these reasons, this thesis should not be considered as a definitive guide, but as a collection of the most agreed-on factors and proposals in the literature.

Given these circumstances, the challenge was to formulate the plethora of theoretical material into understandable and student-friendly form in the study package and the workshop. This required the author to evaluate critically what to include in the learning material. The material had to be specific enough to justify a separate study package and provide detailed enough information for the students who are interested in working with athletes. However, the knowledge had to be easy and practical enough to transfer to the working life. The author feels that this critical process was what grew her knowledge base and professional skills the most during the thesis process.

It should be noted that this thesis is merely a scratch on the surface of the science of shoulder functioning, overhead sports, shoulder injuries and injury prevention, as it is meant merely to give an overview on the subject and give some hints on how to approach injury prevention and what kind of tools are available. To continue the work, a future possibility would be to continue the topic of injury prevention to create a progressive conditioning program for a specific overhead sport. It would also be very interesting to map out what kind of injury prevention programs the active overhead athletes already use and how they vary between different age groups of athletes, what is the physiotherapist's role in creating them, and how personalized and load-adjusted they are. If given an ideal research situation, the author would also like to see if the chosen conditioning methods would have statistical differences in the long run with large participant groups, even though that kind of study would be very challenging to organize in reality.

Hopefully, this thesis and the study material created will be able to spark further interest in the function of the shoulder in the physiotherapy students and provide useable information for the future working life in sports physiotherapy. However, for the students not planning to work with high-level athletes, the underlying principles in the material can also be useful in the physiotherapy of e.g. young athletes, recreational players and other clients with repeated overhead work or activities.

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APPENDIX 1

Muscles participating in the movement and control of the shoulder girdle (Gibbons 2019, 38-40; Agur & Dalley 2013, 481-610)

Movement	**Participating muscles**
Shoulder flexion	Pectoralis major clavicular head deltoid anterior part biceps brachii short head coracobrachialis
Shoulder extension	Pectoralis major sternocostal head (extends shoulder from flexed position) latissimus dorsi deltoid posterior part
Shoulder adduction	Pectoralis major latissimus dorsi subscapularis teres major
Shoulder abduction	deltoid middle part supraspinatus (initiates abduction) biceps brachii long head (stabilizes joint during abduction) coracobrachialis triceps brachii long head (stabilizes humeral head when arm is abducted)
Shoulder lateral rotation	deltoid posterior part infraspinatus teres minor
Shoulder medial rotation	Pectoralis major latissimus dorsi deltoid anterior part subscapularis teres major
Glenohumeral stability (rotator cuff)	supraspinatus infraspinatus teres minor subscapularis
Scapular stability	pectoralis major (draws anteriorly and inferiorly) pectoralis minor (draws anteriorly and inferiorly) levator scapulae rhomboid major and minor
Sternoclavicular joint stability	subclavius (anchors and depresses)
Scapula protraction	serratus anterior
Scapula retraction	trapezius transverse part rhomboid major and minor

Scapula rotation	serratus anterior (upward and externally) trapezius descending and ascending parts (upward, externally), transverse part (externally) levator scapulae (downward) rhomboid major and minor (downward) pectoralis major and minor (internally), pectoralis minor (downward)
Scapula elevation	trapezius descending part levator scapulae
Scapula depression	trapezius ascending part
Elevation of body towards arm when climbing	latissimus dorsi

APPENDIX 2

Feedback on the initial test run of the independent study package

"*The material was well structured and explained. The pictures and videos also helped to understand the topic a little bit better and in general the material was very interesting and informative*."

"*The Moodle material was compiled in a very understanding way, suitable for both students and physiotherapy professionals who want to learn more in the area of shoulder rehabilitation and overhead sports. The page layout and learning modules added to the learning experience, as pictures and videos made the theory much easier to understand, than a typical textbook or PowerPoint presentation. I liked the idea of mini-quizzes after each chapter, because of engagement with the material, promoting better memorizing.*"

"The msk moodle module, by Elina Pettersson, introduces musculoskeletal related shoulder issues in overhead sports. The module clearly describes the needed background – shoulder girdle anatomy, muscles involved as well as the "normal" structural changes related to long lasting sport-specific training. In addition, the module provides a clear information concerning possible injury mechanisms and how to prevent or decrease the risk of these injuries stressing the need to focus on the whole-body mechanisms when performing the sport-specific movements, not focusing only on single muscle group. At the end, the module provides clear testing options and suggested variations of possible therapeutic exercises to "treat" the body deficiencies (muscle control, coordination, balance etc.). Overall, the module provides an excellent addition to musculoskeletal studies provided at Satakunta University of Applied Sciences."

Feedback questionnaires of the workshop

Feedback questionnaire

Workshop 3.11.2020: Shoulder injury prevention in overhead sports

5 = completely agree, 4 = partially agree, 3 = I don't know, 2 = partially disagree, 1 = completely disagree

		5	4	3	2	1
Q1	I found the information useful		●			
Q2	I got enough information	●				
Q3	The information was presented in an understandable manner	●				
Q4	The questions were answered properly	●				
Q5	I found the practical part useful	●				
Q6	The practical part was demonstrated properly		●			
Q7	I got new ideas/perspectives on injury prevention	●				
Q8	I can use the information from today in my future work	●				
Q9	I would recommend the workshop for other students	●				
Q10	Would you like to give any other feedback? Feel free to write your comments below!					

Feedback questionnaire

Workshop 3.11.2020: Shoulder injury prevention in overhead sports

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Q8	I can use the information from today in my future work	●				
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Q10	Would you like to give any other feedback? Feel free to write your comments below!					

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Q6	The practical part was demonstrated properly	●				
Q7	I got new ideas/perspectives on injury prevention			●		
Q8	I can use the information from today in my future work	●				
Q9	I would recommend the workshop for other students	●				
Q10	Would you like to give any other feedback? Feel free to write your comments below!			●		

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		5	4	3	2	1
Q1	I found the information useful	X				
Q2	I got enough information	X				
Q3	The information was presented in an understandable manner	X				
Q4	The questions were answered properly	X				
Q5	I found the practical part useful	X				
Q6	The practical part was demonstrated properly	X				
Q7	I got new ideas/perspectives on injury prevention	X				
Q8	I can use the information from today in my future work	X				
Q9	I would recommend the workshop for other students	X				
Q10	Would you like to give any other feedback? Feel free to write your comments below!					

Feedback questionnaire

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Q4	The questions were answered properly	X				
Q5	I found the practical part useful	X				
Q6	The practical part was demonstrated properly	X				
Q7	I got new ideas/perspectives on injury prevention	X				
Q8	I can use the information from today in my future work	X				
Q9	I would recommend the workshop for other students	X				
Q10	Would you like to give any other feedback? Feel free to write your comments below!					

Thank You!!

Feedback questionnaire

Workshop 3.11.2020: Shoulder injury prevention in overhead sports

5 = completely agree, 4 = partially agree, 3 = I don't know, 2 = partially disagree, 1 = completely disagree

		5	4	3	2	1
Q1	I found the information useful	X				
Q2	I got enough information	X				
Q3	The information was presented in an understandable manner	X				
Q4	The questions were answered properly	X				
Q5	I found the practical part useful	X				
Q6	The practical part was demonstrated properly	X				
Q7	I got new ideas/perspectives on injury prevention	X				
Q8	I can use the information from today in my future work	X				
Q9	I would recommend the workshop for other students	X				
Q10	Would you like to give any other feedback? Feel free to write your comments below!	X	X			

thnx

very good

Thanks, what about

the more workshops

Feedback questionnaire

Workshop 3.11.2020: Shoulder injury prevention in overhead sports

5 = completely agree, 4 = partially agree, 3 = I don't know, 2 = partially disagree, 1 = completely disagree

		5	4	3	2	1
Q1	I found the information useful	X				
Q2	I got enough information	X				
Q3	The information was presented in an understandable manner	X				
Q4	The questions were answered properly	X				
Q5	I found the practical part useful	X				
Q6	The practical part was demonstrated properly	X				
Q7	I got new ideas/perspectives on injury prevention	X				
Q8	I can use the information from today in my future work	X				
Q9	I would recommend the workshop for other students	X				
Q10	Would you like to give any other feedback? Feel free to write your comments below!					

Very nice!

Feedback questionnaire

Workshop 3.11.2020: Shoulder injury prevention in overhead sports

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		5	4	3	2	1
Q1	I found the information useful	✓				
Q2	I got enough information	✓				
Q3	The information was presented in an understandable manner	✓				
Q4	The questions were answered properly	✓				
Q5	I found the practical part useful	✓				
Q6	The practical part was demonstrated properly	✓				
Q7	I got new ideas/perspectives on injury prevention	✓				
Q8	I can use the information from today in my future work	✓				
Q9	I would recommend the workshop for other students	✓				
Q10	Would you like to give any other feedback? Feel free to write your comments below!	☺				

Thank you!

Feedback questionnaire

Workshop 3.11.2020: Shoulder injury prevention in overhead sports

5 = completely agree, 4 = partially agree, 3 = I don't know, 2 = partially disagree, 1 = completely disagree

		5	4	3	2	1
Q1	I found the information useful	x				
Q2	I got enough information		x			
Q3	The information was presented in an understandable manner	x				
Q4	The questions were answered properly	x				
Q5	I found the practical part useful		x			
Q6	The practical part was demonstrated properly	x				
Q7	I got new ideas/perspectives on injury prevention		x			
Q8	I can use the information from today in my future work		x			
Q9	I would recommend the workshop for other students	x				
Q10	Would you like to give any other feedback? Feel free to write your comments below!					

Very comprehensive and clear teaching!

Feedback questionnaire

Workshop 3.11.2020: Shoulder injury prevention in overhead sports

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		5	4	3	2	1
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Q7	I got new ideas/perspectives on injury prevention	●				
Q8	I can use the information from today in my future work	●				
Q9	I would recommend the workshop for other students	●				
Q10	Would you like to give any other feedback? Feel free to write your comments below!					

good overview. but not so much time to practice each exercises

Feedback questionnaire

Workshop 3.11.2020: Shoulder injury prevention in overhead sports

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Q6	The practical part was demonstrated properly	X				
Q7	I got new ideas/perspectives on injury prevention	X				
Q8	I can use the information from today in my future work	X				
Q9	I would recommend the workshop for other students	X				
Q10	Would you like to give any other feedback? Feel free to write your comments below!					

Would like to have more time to go over the test and exercises. We had to rush a bit in the end. Otherwise relative, up to date info.

Feedback questionnaire

Workshop 3.11.2020: Shoulder injury prevention in overhead sports

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Q8	I can use the information from today in my future work	●				
Q9	I would recommend the workshop for other students	●				
Q10	Would you like to give any other feedback? Feel free to write your comments below!					

Should have more time for this, theres a lot more to be showed :)