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Genk (06/06/2017) D.Z.

Beringen C.D.

Research context

Sports are an essential part of the society and lead to higher general health in all age categories. The society want, for financial reasons, as much people as possible doing sports and if possible without getting injured. Injuries are one of the major risk factors for quitting sports. Unfortunate, injuries are a part of doing sports and cannot be avoided, but the athletes can limit injuries by injury prevention. Injury prevention could decrease the number of injured athletes when we know which variables are of importance. This study is interested in the complex biomechanics of the shoulder joint and its important role in overhead athletes. The focus lies on comparing overhead athletes with painful shoulders and overhead athletes with non-painful shoulders. Shoulder injuries are frequently seen in overhead athletes because of the repetitive extreme movements and biomechanical changes. The objective of this study is to investigate the risk factors for shoulder pain by determining differences in movement characteristics and in force of some major stabilizing shoulder muscles between painful shoulders and non-painful shoulders.

The study design and method were determined by the co-promotor Dr. De Baets L. Both master students critically reviewed the method. Concerns during the measurement protocol were reported and discussed. Some adjustments were made in dialog with the co-promotor. Recruitment of participants was independently performed by the master students with use of social media, a poster and word of mouth advertising. Data-acquisition is autonomous executed by the master students. Only in case of doubt, Dr. De Baets L. was consulted. The students searched and visited several sports clubs. During the visit, each athlete underwent a field test for measuring the range of motion of the shoulder. Only athletes with shoulder pain were recruited for further investigation at the University of Hasselt. In the final stadium of this research, these extended investigations were also done at the sports clubs to maximize the number of participants and to create matched couples. Data processing preparations were performed by the master students. The data was arranged in an excel file for statistical analysis. Both master students, together with Dr. De Baets, L., performed statistics. Academic writing of this research was critically guided and advice was given by Dr. De Baets, L.

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1 Abstract

Background: Shoulder pathology is frequently seen in overhead athletes. By comparing the kinematics and strength of painful shoulders with non-painful shoulders in this population, risk factors can be derived.

Objectives: To identify differences in kinematics or muscle strength of the scapulothoracic and glenohumeral joint in overhead athletes with and without shoulder pain. A second research objective was to identify relations between the different kinematics or muscle strength measures of the scapulothoracic and glenohumeral joint in this population.

Participants: From the 106 reached overhead athletes of five different overhead sports, 34 athletes had shoulder pain and 72 were pain free. Eventually 34 athletes met the inclusion criteria and participated in this study (pain group (n=17) and no-pain group (n=17)).

Measurements: A clinical scapular measurement and observation protocol (CSMOP) based on four categories was developed: glenohumeral range of motion (GHROM), scapulothoracic range of motion (STROM), glenohumeral muscle strength (GHforce) and scapulothoracic muscle strength (STforce). The following tests were used: rotation glenohumeral joint, maximal active humerothoracic elevation, acromial index (AI), observation of the trunk and scapular dyskinesia during active bilateral forward flexion, forward trunk inclination, clavicula inclination at rest, scapular upward/ downward rotation at rest and during 30°, 45°, 60°, 90° and 120° abduction, scapular anterior/posterior tilt at rest, shoulder internal/ external rotation strength, serratus anterior strength and trapezius ascending part strength.

Results: Participants with shoulder pain had significant more presence of scapular dyskinesia (p=0,018), trunk axial rotation (p=0,037) and less scapular upward rotation in 90° abduction (p=0,041).

Conclusion: The most important variable for developing shoulder pain is scapular dyskinesia. Less scapulothoracic and glenohumeral muscle strength and total range of rotational motion are no risk factors for developing shoulder pain in overhead athletes. For the prevention of shoulder injuries, it is recommended to treat and smoothen the scapulothoracic rhythm of overhead athletes.

2 Introduction

Musculoskeletal pathologies are disorders that can affect different structures. Structures that can be affected are: muscles, ligaments, tendons, bone tissue, cartilage or joint capsule. Musculoskeletal pathologies of the upper extremity and lower extremity are frequently seen in sports. This research focuses on disorders of the upper extremity, more specific the shoulder complex.

The shoulder complex is a complicated joint. It exists of four individual joints: sternoclavicular joint, acromioclavicular joint, scapulothoracic joint and glenohumeral joint. The glenohumeral joint consists of a large humeral head and a relative small glenoid fossa. Because of this, the glenohumeral joint is highly mobile but very unstable. Passive stability is enlarged by ligaments in the joint capsule and by the glenoid labrum. The active stabilization is done by a group of muscles, i.e. the rotator cuff (supraspinatus, infraspinatus, subscapularis and teres minor). The scapulothoracic joint on the other hand is a pseudo-articulation, and movement in this 'joint' is a combination of movement in the acromioclavicular and sternoclavicular joint. The triangular shaped scapula has three borders: the medial border which is in ideal conditions parallel to the spinal column, the lateral border and the superior border. The lateral and superior border come together in the glenoid fossa and articulates with the humeral head (Neumann, 2010). Several scapulothoracic muscles (m. levator scapulae, m. serratus anterior, m. trapezius, m. rhomboid and m. pectoralis minor) stabilize the scapula against the thorax and provide a proper scapulothoracic rhythm. Given the interaction between the glenohumeral and scapulothoracic joint, scapulothoracic control is essential for proper glenohumeral movement. This means that scapular dyskinesia, i.e. improper positioning and movement of the scapula on the thorax, can contribute to shoulder pathology (Chorley, Eccles, & Scurfield, 2017).

Scapular dyskinesia describes the loss of control of normal scapular physiology, mechanics and motion. Alterations in force or flexibility of soft tissues are the most common causative mechanisms. Tightness of the pectoralis minor or the short head of the biceps brachii can pull the scapula in to anterior tilt. Reduced activation of the serratus anterior or altered activation of the trapezius can contribute to loss of posterior tilt and upward rotation, which are necessary for proper scapular movement (Kibler, Sciascia, & Wilkes, 2012). These alterations in soft tissues may occur due to muscle overuse during repetitively motions. According to

Burn, McCulloch, Lintner, Liberman, and Harris (2016), the prevalence of scapular dyskinesia is more often seen in overhead athletes (61%) compared with non-overhead athletes (33%) and it is believed to be a risk factor for developing shoulder pain.

Besides scapular dyskinesia, alterations in range of glenohumeral rotational motion is described in overhead athletes. Biomechanical adaptations in overhead athletes seems to demonstrate an external rotation gain and a glenohumeral internal rotation deficit, likely due morphological adaptations like anterior hyperlaxity, posterior shoulder immobility, humeral retroversion and scapular dyskinesia. However, associations between these biomechanical and morphological adaptations are still not clearly identified (Challoumas, Stavrou, & Dimitrakakis, 2017). In an attempt to better understand the adaptations in shoulder rotation, Kibler et al. (2013) introduced the concept of total range of rotational glenohumeral motion (glenohumeral internal rotation + glenohumeral external rotation). More specifically, the total range of rotational motion should not exceed 186° and a 5° asymmetry in dominant vs non-dominant shoulder has been shown to be predictive of increased injury risk.

Finally, apart from alterations in movement, alterations in load transfer at the level of the shoulder joint are also seen in overhead athletes. For example, it is described that a reduced external rotation strength decreases an athlete's tolerance in handball for amount of load before injury occurs. Furthermore, a higher load-impact is associated with an increased rate of shoulder injuries in youth handball players (Moller et al., 2017).

In conclusion, shoulder pain in overhead athletes is believed to be related to movement and muscle strength of both the glenohumeral as scapulothoracic joint. Therefore, the following hypothesis was made: alterations in muscle strength and/or kinematics in the shoulder joint will be seen more frequently in overhead athletes with shoulder pain as compared to overhead athletes without shoulder pain. More specifically, it is hypothesized that overhead athletes with shoulder pain will show more scapular dyskinesia, decreased total range of shoulder rotational motion, and less strength in major scapulothoracic and glenohumeral stabilizing muscles. Furthermore, it is of interest to examine the relation between scapulothoracic kinematics (scapular dyskinesia), glenohumeral rotational movement and muscle strength in major scapulothoracic and glenohumeral stabilizing muscles in overhead athletes with and without shoulder pain. It is hypothesized that scapulothoracic and glenohumeral kinematics are correlated to scapulothoracic and glenohumeral strength.

3 Method

Approval for this study (B243201630229) was given by the ethical committee of Jessa Hospital Hasselt at 21/11/2016. All participants agreed the informed consent.

3.1 Participants

Overhead athletes with shoulder pain (group 1) and age, gender and sport matched controls without shoulder pain (group 2) were recruited using the social network of the master students. The master students used social media, word of mouth advertising and developed a poster. Several sports teams were contacted and asked to join the study.

Participants were included based on the following criteria: (1) overhead athletes (volleyball, handball, water polo, tennis and badminton), (2) minimal of 2 hours/ week participating, (3) between 18-30 years, (4) painful shoulder (dominant sport side) (group 1) or non-painful shoulder (dominant sport side) (group 2). Participants were excluded in case of (1) neurologic diseases (CVA, MS, etc.) or (2) vertebral column surgery in the past. Athletes who were interested to participate and who adhered to the inclusion criteria were invited for an extensive assessment at the University of Hasselt.

Appointments for measurement were made by social media between the researchers and participants. Participants with pain were examined first, then the age-gender-sport matched athletes without pain were examined.

3.2 Procedure

Similar outcome measurements were determined for group 1 and group 2. Outcomes were kinematics of the glenohumeral joint (GHROM) and the scapulothoracic joint (STROM). Furthermore, force related outcomes were included in the protocol, i.e. muscle strength of the internal/external rotators of the glenohumeral joint (GHforce) and stabilizing muscles at the level of the scapulothoracic joint (serratus anterior and the ascending part of the trapezius muscles) (STforce).

The measurements were executed by two last year master students of the Hasselt's University education 'Rehabilitation Science and Physiotherapy' with a specialization in 'musculoskeletal rehabilitation in sports'.

Before the assessments, the two assessors were familiarized with the procedures during a two-hour practicing session with their co-promoter. Measurements were conducted by two therapists: therapist A performed the effective measurement while therapist B checked the conducted measurement and wrote the outcomes on the participant's individual protocol sheet which is presented in Figure 2 in Appendix A. Furthermore, measurements were conducted before athletes' training sessions to avoid the influence of training on the mobility or strength of the shoulder joint. Also, the measurements were started at the dominant sport shoulder to standardize the research protocol. In the paragraph below, the different measures of the clinical protocol, including measures for GHROM, STROM, GHforce and STforce, are described.

GHROM

Rotation glenohumeral joint

The inclinometer (Plurimeter-V gravity inclinometer, Dr Rippstein, Switzerland) was used for the measurement of the glenohumeral rotation. The inclinometer gives the amount of glenohumeral internal and external rotation, expressed in degrees. With the participants in supine position and the shoulder in 90° abduction, the inclinometer was placed by the therapist with one hand against the forearm just proximal of the styloid processes. The other hand was used to palpate the coracoid process and the glenohumeral joint to indicate the end range of motion of the glenohumeral joint and the start of scapulothoracic movement. Subsequently the amount of rotation was read from the inclinometer (Cools et al., 2014). The conduction is presented in Figure 3-4 in Appendix B.

Maximal active humerothoracic elevation

The maximal humerothoracic elevation was assessed with a goniometer, expressed in degrees. While standing upright in a resting position, the participants were instructed to perform a maximal unilateral anteflexion with the thumb pointing upward. One arm of the goniometer was placed parallel to the humerus and the other arm parallel to the trunk. The maximal range of active humerothoracic elevation in the sagittal plane (forward flexion) was read from a goniometer (degrees). The conduction is presented in Figure 5 in Appendix B.

STROM

Acromial index (AI)

The AI is a measurement of forward shoulder posture. It measures the distance from the table to the posterior acromial angle of the scapula. For this measurement, a sliding caliper was used and the outcomes were expressed in centimeters (cm). With the participants in supine position, the arms alongside the body and the palm of the hand on the table, they were instructed to stay relaxed. The posterior acromial angle was palpated with the index finger by the therapist while the sliding caliper was placed perpendicular on the table against the shoulder. The distance (cm) was read when the sliding caliper and the index finger of the therapist made contact. This distance (cm) was divided by the subject height (cm) and multiplied by 100. The outcome was defined as the AI (no unit) (Nijs, Roussel, Vermeulen, & Souvereyns, 2005). The conduction is presented in Figure 6-7 in Appendix B.

Observation of trunk movement and scapular dyskinesia during active bilateral forward flexion

All participants were observed for trunk posture and scapular dyskinesia. Persons were observed from a posterior horizontal plane. The movement was recorded with a smartphone (Samsung Galaxy S6 – 16 megapixel 1080P camera). The video recording was done to reanalyze the movement in case of ambiguity. All participants were asked for permission to record their movement and they were informed that the use of this video was strictly for scientific purposes.

Participants were instructed to perform a bilateral shoulder anteflexion with a weight on the dominant side (0.75kg) and to repeat this movement five times. The therapist observed the trunk for axial rotation, lateral shift or lateral rotation and the scapula for the presence of scapular dyskinesia. Both therapists evaluated the movement and communicated their thoughts with each other. Scapular dyskinesia was scored if there was a presence of winging (prominence of the medial border away from the thorax), dysrhythmia (premature, or excessive, or stuttering motion during elevation and lowering) or tilting (prominence of the inferior angle away or towards the thorax) (Kibler et al., 2002). When there was no presence of the above-mentioned movements, it was rated as ‘0’. In case dyskinesia was observed, a score of ‘1’ was given. In case of trunk axial rotation, lateral shift or lateral flexion, a score of ‘1’ or ‘2’ was given, with ‘1’ defined as towards the dominant arm side and ‘2’ away from the dominant arm side. In case the trunk did not move, a score of '0' was given. The conduction is presented in Figure 8 of Appendix B.

Forward trunk inclination

The inclinometer (Plurimeter -V gravity inclinometer, Dr Rippstein, Switzerland) was used to measure the amount of inclination of the trunk and clavicula at rest. All participants were instructed to take a natural relaxed posture with the arms alongside the body. The inclinometer was placed on the sternum underneath the manubrium to measure the amount of trunk inclination. Lower values corresponded to a less upright sternal position (more thoracic kyphosis, more sloughed position) (Suzuki et al., 2016). The conduction is presented in Figure 9 of Appendix B.

Clavicular inclination at rest

To measure the inclination of the clavicula, two benchmarks were made, one on the acromioclavicular joint and one on the sternoclavicular joint, to draw an imaginary line between the two benchmarks, while persons were standing in a natural relaxed posture with the arms alongside the body. The inclinometer (Plurimeter -V gravity inclinometer, Dr Rippstein, Switzerland) was manually placed on this imaginary line and the amount of elevation/depression of the clavicula was read. The conduction is presented in Figure 10 of Appendix B.

Scapular upward/ downward rotation at rest

The inclinometer (Plurimeter -V gravity inclinometer, Dr Rippstein, Switzerland) was used to assess the amount of scapular upward/ downward rotation at rest. Participants were instructed to take a natural relaxed posture with the arms alongside the body. The inclinometer was placed on the spina scapula by the therapist. The amount of upward/downward rotation was read from the inclinometer. A negative value was scored if a downward rotation was present to standardize the protocol.

Scapular anterior/posterior tilt at rest

The inclinometer (Plurimeter -V gravity inclinometer, Dr Rippstein, Switzerland) was used to assess the amount of scapular anterior/ posterior tilt at rest. Participants were instructed to take a natural relaxed posture with the arms alongside the body. The inclinometer was placed vertically against the medial border of the scapula by the therapist. The amount of anterior/posterior tilt was read from the inclinometer. A negative value was scored if a posterior tilt was present to standardize the protocol (Scibek & Carcia, 2014). The conduction is presented in Figure 11 of Appendix B.

Active unilateral upward rotation during abduction

Two inclinometers were used by two therapists simultaneously to assess the amount of upward rotation of the scapula. While one therapist (A) measured the amount of upward rotation by placing the inclinometer on the spina scapula, the other therapist (B), placed a second inclinometer on the lateral side of the humerus, at the level of the deltoid muscle insertion. The participants were instructed to perform an abduction movement with the thumb pointing upward and to stop at 30°, 45°, 60°, 90° and 120° of abduction (Watson, Balster, Finch, & Dalziel, 2005). The conduction is presented in Figure 12 of Appendix B.

GHforce

Internal/ external rotation strength

Rotational strength measurements were conducted with the Hand-Held Dynamometer (MicroFET). This device measures the peak force of a movement, expressed in Newton. Three repetitions of five seconds of maximal voluntary effort were conducted to take an average, although a trial session of one repetition was performed first. With the participants in supine position, the Hand-Held Dynamometer (MicroFET) was placed against the forearm, proximal of the styloid processes by the therapist. The strength was gradually increased within five seconds and up to maximal effort at three seconds followed by slowly decreasing resistance. The participants were instructed to perform a clear internal/ external rotation and to stabilize the upper arm, shoulder, scapula, and trunk during the task execution (Couppe et al., 2014). The conduction is presented in Figure 13-14 of Appendix B.

STforce

Serratus anterior strength

Strength of the serratus anterior muscle was assessed with the Hand-Held Dynamometer (MicroFET). Three repetitions of five seconds of maximal voluntary effort were conducted to take an average, although a trial session of one repetition was performed first. With the participants in supine position, with the arm in 90° of glenohumeral anteflexion, elbow in extension and wrist in dorsal flexion, the Hand-Held Dynamometer (MicroFET) was placed in the palm of the hand. The participants were instructed to execute a protraction movement towards the ceiling against resistance given by the therapist. The conduction is presented in Figure 15 of Appendix B.

Trapezius ascending part strength

Strength of the ascending part of the trapezius muscle was assessed with the Hand-Held Dynamometer (MicroFET). Three repetitions of five seconds of maximal voluntary effort were conducted to take an average, although a trial session of one repetition was performed first. With the participants in prone position and the shoulder in 135° glenohumeral abduction, the Hand-Held Dynamometer (MicroFET) was placed on the middle of the forearm at the dorsal side. The participants were instructed to bring the scapula towards the opposite buttock by pushing the abducted arm towards the ceiling. The conduction is presented in Figure 16 of Appendix B.

4 Statistical analysis

IBM SPSS Statistics 24 was used for statistical analysis. Normality was tested by the Shapiro-Wilk test. Non-parametric testing was executed because of the non-normal distribution of data and the small sample sizes (n<30). The Mann-Whitney U test was used to compare independent groups. The Spearman test was used to determine the correlations between the variables. Alpha was set at 0,05. P-values < 0,05 were considered significant. Correlations were scored by a division of 5 categories: very high correlation (>0.90), high correlation (0.70-0.89), moderate correlation (0.50-0.69), low correlation (0.30-0.49) and very low correlation (<0.29).

5 Results

5.1 Participants

106 overhead athletes were reached through the different recruitment channels. From these 106 overhead athletes, 34 athletes had shoulder pain and 72 were pain free. From the 34 participants with pain, 15 participants could not join the study due to different reasons (work, school, lack of transport or interest). As such, 19 participants with pain joined the study. Finally, two athletes with pain could not be matched, leading to a total of 17 athletes with and 17 athletes without shoulder pain. Couples (n=17) were made of individuals with painful shoulders and shoulders of healthy individuals based on identical characteristics (age, gender and sport discipline). Descriptive characteristics are presented in Table 1. The flowchart of the participant recruitment is presented in Figure 1.

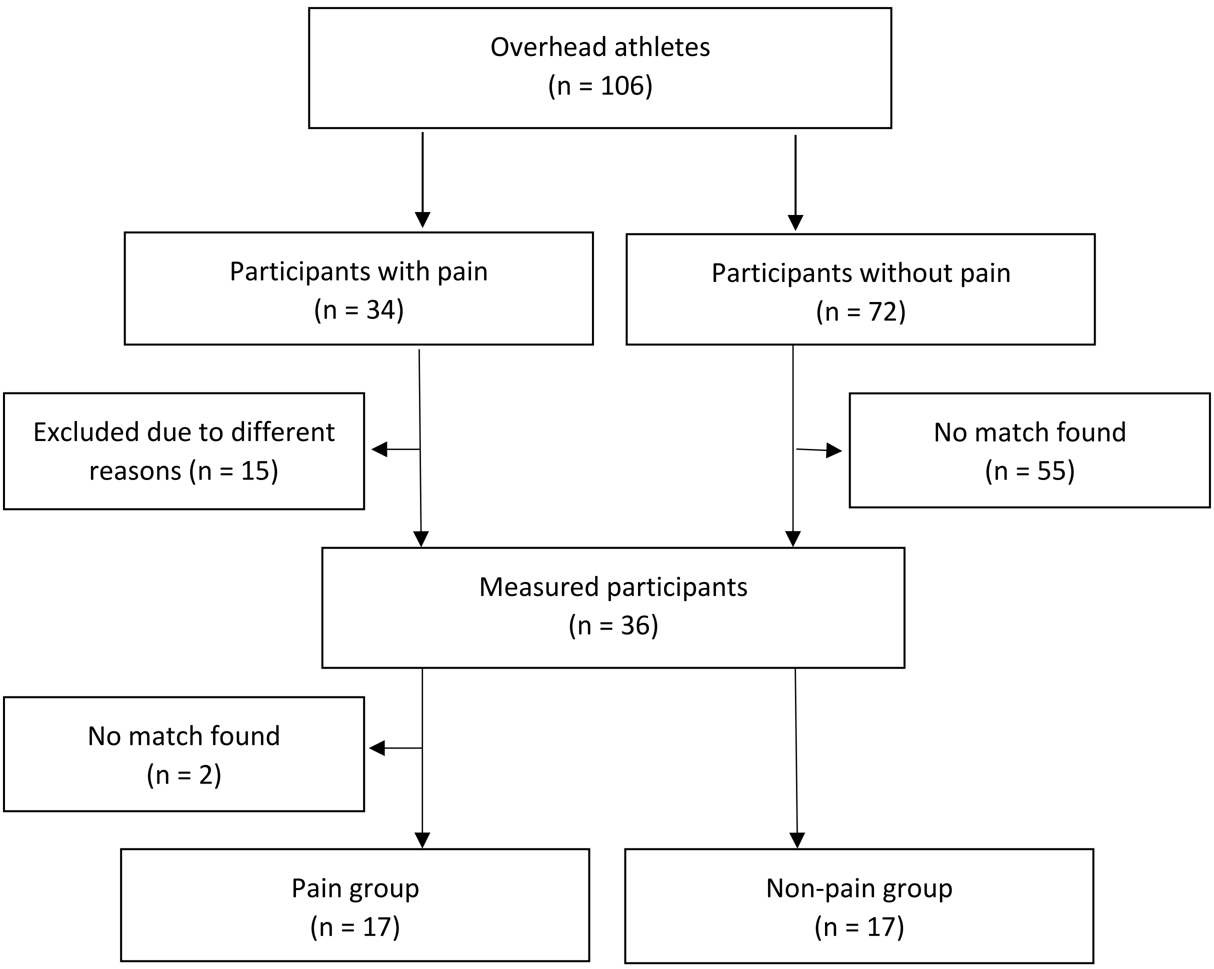

Figure 1: Flowchart participant recruitment

Participant characteristics between group 1 and group 2 were compared and presented in Table 1.

Table 1: Participant characteristics

	PAIN MEAN (SD)	NO-PAIN MEAN (SD)
Descriptive variables		
Age (years)	23 (3.25)	22.47 (2.63)
Length (centimeters)	178.73 (9.32)	176.71 (10.70)
Bodyweight (kilograms)	73.15 (16.04)	68.7 (14.67)
Training hours/week (hours)	5.89 (1.69)	6.34 (2.87)
Gender		
Men	6	6
Female	11	11
Sports discipline		
Volleyball	9	9
Handball	5	5
Water polo	1	1
Tennis	1	1
Badminton	1	1

Abbreviations: SD= standard deviation

5.2 Group differences

Mean (SD) and the median of the outcomes on the different measures for both study groups are presented in Table 2 and Table 3.

Table 2: Measurement values between groups

	PAIN MEAN (SD)	MEDIAN PAIN	NO-PAIN MEAN (SD)	MEDIAN NO-PAIN
Range of motion (degrees)				
ROM internal rotation in 90°	53.63 (11.53)	54	56.89 (10.16)	56
ROM external rotation in 90°	95.16 (13)	98	94.21 (12.04)	90
Total rotational ROM	148.79 (16.25)	152	151.11 (16.54)	156
Strength (Newton)				
Internal rotation	150.49 (45.72)	137.87	179.18 (98.55)	145.73
External rotation	116.91 (31.57)	108.83	131.47 (58.72)	110.43
Serratus anterior	285.88 (110.88)	285.55	280.72 (92.79)	264.62
Lower trapezius	65.49 (27.36)	53.8	60.39 (22.96)	59.82
Inclinometry & goniometry (degrees)				
AC-index (centimeters)	7.18 (1.19)	7	7.52 (1.12)	7.3
Clavicula inclinometry	11.16 (3.06)	11	13.79 (5.59)	14
Scapular rotation	-0.21 (3.31)	0	1.37 (2.52)	2
Scapular tilt	14.79 (5.16)	14	13.47 (3.89)	12
Inclinometry trunk	21.89 (4.32)	22	21.58 (4.49)	20
Active: scapular lateral rot 30°	0.63 (5.20)	2	1.84 (3.10)	3
Active: scapular lateral rot 45°	3.53 (5.07)	5	5.05 (3.01)	6
Active: scapular lateral rot 60°	7.16 (5.24)	8	9.16 (3.91)	10
Active: scapular lateral rot 90°*****	16.74 (5.34)	16	19.89 (4.41)	18
Active: scapular lateral rot 120°	29.79 (7.02)	30	30.68 (5.56)	30
Goniometry anteflexion	154.21 (14.01)	155	154.95 (11.47)	154

Abbreviations: SD= standard deviation, ROM= range of motion, rot= rotation, *****= significant different between groups

Table 3: Observation outcomes between groups, expressed in percentages

	PAIN	NO-PAIN
Trunk (percentage)		
Lateral flexion (%)	0	6
Axial rotation (%)*	35	6
Lateral shift (%)	0	6
Scapula (percentage)		
Dyskinesia (%)*	53	18

Abbreviations: *= significant different between groups

In participants with shoulder pain, scapular dyskinesia was significantly more frequent observed (p=0,018). The total range of motion and total force generation was not significantly different between groups. Further, trunk axial rotation (p=0,037) was significantly more observed in athletes with pain and less upward rotation with the shoulder in 90° abduction was seen in athletes with pain (p=0,041).

5.3 Correlations between variables

There is a significant correlation between trunk axial rotation and scapular anterior tilt at rest (p<0,01). This correlation was inverse and considered low (r=-0.426). There was also a significant correlation between scapular anterior tilt at rest and strength of serratus anterior (r=0,375) and lower trapezius (r=0,453) (p<0,05). The relation between scapular tilt at rest and strength was considered low. A significant correlation was seen between trunk lateral shift and strength measurements for internal (r=0,627) and external rotation (r=0.669) (p<0,01). The correlation was considered moderate. Scapula dyskinesia was significantly correlated with active unilateral upward rotation in 60° (r=-0.326) and 90° (r=-0,366) of abduction (p<0,05). This correlation was inverted and considered low. There was a mutual correlation (p<0,05) between all scapular upward rotation tests (at rest, 30°, 45°, 60, 90° and 120°) the correlation varied from low (r=0,363) to very high (r=0,953). However, there was no significant correlation between active unilateral upward rotation in 30° and 120° abduction. Also, no significant correlation was found between active unilateral upward rotation in 120° abduction with scapula upward rotation at rest. A significant correlation was found between total range of rotational motion and glenohumeral internal (r=0,647) and external rotation (r=0,743) (p<0,01). This correlation was considered moderate to high. Total range of rotational motion was also significantly correlated with humerothoracic elevation, this correlation was considered moderate (r=0,500) (p<0,01). All strength measurements are correlated mutually (p<0,05). These correlation scores varied from low (r=0,390) to high (r=0,745). Finally, the correlation between humerothoracic elevation and glenohumeral internal rotation (r=0,409) and total range of rotational motion was significant. This relation was considered low to moderate. An overview of the Spearman Correlation is presented in Table 4 of Appendix C.

6 Discussion

The objective of this study was to identify differences in kinematics or muscle strength of the scapulothoracic and glenohumeral joint in overhead athletes with and without shoulder pain. Shoulder injuries are often seen in overhead athletes due to biomechanical adaptations like: decreased internal rotation range of motion, increased external rotation range of motion, altered scapular position and muscular imbalance (Challoumas et al., 2017; Kibler et al., 2013; Tonin, Strazar, Burger, & Vidmar, 2013). These adaptations can influence the throwing motion of an overhead athlete and cause asymmetries between the dominant side and non-dominant side (Moreno-Perez, Moreside, Barbado, & Vera-Garcia, 2015). Whether these adaptations are also linked to the development of shoulder pain, is not known (Challoumas et al., 2017). Also, the relation between scapular position and injury is unknown. Whether scapular position is a cause or effect and how much adaptations of the kinematics are related to scapular dyskinesia (Kibler et al., 2013). Regarding this research objective, our study results indicated that athletes with shoulder pain had significantly more scapular dyskinesia, more trunk axial rotation and less upward rotation with the shoulder in 90° abduction. These alterations might be due to muscle weakness/ imbalance, muscle inhibition or a lack of technique when executing sport specific movements, can be interpreted as an inability of muscle coordination that contributes to scapular dyskinesia. Further, a lack of muscle coordination between the serratus anterior and the lower trapezius can contribute to less upward rotation. Also, there was no significant difference in total force generation and the amount of internal or external rotation between group 1 and group 2. Another result of this study showed that there was no significant difference in the total range of motion between group 1 and group 2. This is controversial with the findings of Shanley et al. (2011) were a significant decrease was found in the total range of motion in the painful shoulder.

A second research objective was to identify relations between the different measures of the protocol. The protocol contains a lot of individual clinical tests, making it an extensive measurement protocol and taking 30 minutes to execute. It is of interest to check whether measures are related, to diminish the number of tests in the protocol, and save time. Significant correlations were found between the different scapular upward rotation tests in different degrees of humeral elevation (at rest, 30°, 45°, 60°, 90° except for 120°). This can be

used to simplify the measurement protocol without missing important data and work more time efficiently.
However, although a relation between strength imbalances of glenohumeral muscles and an increased risk of shoulder injury is identified in the past, this study indicated a positive relation between the different force measurements (Edouard et al., 2013; Niederbracht, Shim, Sloniger, Paternostro-Bayles, & Short, 2008). If an athlete had a higher strength outcome for one force test, the other force test had also a higher strength outcome. This suggests that the amount of strength tests in the protocol can be reduced. However, care should be taken as correlations were calculated for the whole group of athletes (with and without shoulder pain). Also, EMG measurements would be of additional value, as they can measure specific muscle activity of the glenohumeral muscles to differentiate between these muscles. By using EMG measurements, mobilizing muscles can be distinguished from stabilizing muscles. This can be considered as an important factor during rehabilitation of painful shoulders.

During overhead sports the shoulder kinematics change, i.e. more external rotation and less internal rotation are frequently seen. Increased injury risk appeared only when there was a change in total amount of ROM (Challoumas et al., 2017). However, in this study no negative relation was found between internal and external rotation. This can be due the fact that the correlations were made on both groups together and not between the groups.

According to Seitz, McClelland, Jones, Jean, and Kardouni (2015) there is relation between less strength in the lower trapezius muscle and scapula dyskinesia. Also, a lack of upward rotation is associated with weakness of the lower trapezius and serratus anterior muscles. These correlations were not found in this study. However, care should be taken as correlations were calculated for the whole group of athletes (with and without shoulder pain). Also, scapular anterior tilt at rest was correlated with more strength in the serratus anterior and lower trapezius muscles. This can be contradictory interpreted because scapular dyskinesia was an active measurement and scapular tilt not and muscular hypertrophy on the scapula can also be a contributing factor that showed more anterior tilt during the static measurement.

Finally, scapula dyskinesia was significantly more seen in overhead athletes with pain and confirmed one part of the hypothesis. However, it is not clear if scapular dyskinesia is a symptom or cause of shoulder pain. These findings correspond with the findings of Burn et al. (2016), were 33% of the non-overhead athletes also show scapular dyskinesia.

Limitations

Despite the dynamic aspect of a throwing motion, nearly all tests in this research were static measurements. The only active test, observation during active forward flexion, was only executed five times. According to Pellegrini et al. (2013) scapular dyskinesia is more often seen in fatigued overhead athletes. This suggest that more repetitions are necessary to measure scapular dyskinesia. Also, velocity, load and peak force are contributing factors in the throwing motion as well, thus dynamic measurements are considered more functional than static measurements regarding overhead athletes. Interpretation of the correlations should be done carefully because statistical analyses was not done on two separated groups.

Furthermore, non-parametric testing was executed because of the non-normal distribution of data and small sample sizes (n<30). The reliability of the strength measurement of the M. serratus anterior and the AI were doubtful. The strength measurement for the M. serratus anterior was not considered valid because of high intra-subject differences, even when repeatedly measured by the same therapist and this measurement was depended of the examiners strength. Due to differences in strength between the two examiners, different values were obtained. A better alternative for the measurement of the serratus anterior would be a measurement against a static object. Also, the measurement of the AI was doubtful and depended on the amount of pressure used by the examiner. Because of the soft surface, the sliding caliper could be pushed deeper into the table. A better alternative to execute this measurement is to use a firm surface. Finally, no distinction was made in specific diagnosed shoulder injuries in the pain group.

Strengths

A homogeneous age-gender-sport control group was made. Both, professional and amateur overhead athletes were measured. Also, measurements were conducted by one examiner and controlled by a second examiner. Finally, reliable and valid material was used to conduct the measurements (De Baets, Jaspers, & Van Deun, 2016).

Future perspectives

It would be interesting to do the same research for one specific diagnosed shoulder injury. Another interesting addition will be a longitudinal follow up study where professional and amateur athletes are compared. Starting with pre-season measurements and a follow up during the season to see how many athletes develop shoulder pain. This can also be compared in different sport disciplines. Another interesting longitudinal follow up study would be a comparison between healthy overhead athletes with and without scapular dyskinesia to determine if scapular dyskinesia is a risk factor for shoulder pain.

Because of the dynamic aspect in sports it is recommended to test active stabilization and ROM of the shoulder complex, preferably in sport specific settings. It is important to measure the movement and stability of the shoulder complex when executing these motions. Injuries are mostly seen during the performance of these high speed and high load movements. This should be considered for further research.

To simplify the protocol unnecessary measurements could be deleted. The high positive correlations between the active unilateral upward rotation in different degrees of abduction can be reduced in one single measurement. It is suggested that the active unilateral upward rotation in 90° of abduction is used because of the significant less upward rotation in the pain group. Also, positive strength correlations were found between the force measurements. It is suggested to measure the ratio between mobilizing muscles and stabilizing muscles by using EMG measurements.

7 Conclusion

Considering the predetermined hypothesis, less strength in the major scapulothoracic and glenohumeral stabilizing muscles and total range of rotational motion are no risk factors for developing shoulder pain in overhead athletes. The most important variable for developing shoulder pain is scapular dyskinesia. For the prevention of shoulder injuries, it is recommended to treat and smoothen the scapulothoracic rhythm of overhead athletes.

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9 Appendices

- Appendix A: Clinical scapular measurement and observation protocol (CSMOP)
- Appendix B: Illustrations included in the CSMOP
- Appendix C: Pearson Correlation

9.1 Appendix A: Clinical scapular measurement and observation protocol (CSMOP)

Date:

Anamnesis				
Name:	Age:	Length:	Weight:	Gender: M/ F
Overhead sport:	Dominant sport side: R/ L	Pain/ NO pain: R/ L	Hours/ week:	Amount of years:

Examination									
Lying	Internal GH rot. 90°	R:	L:						
	External GH rot. 90°	R:	L:						
	Acromial index	R:	L:						
	Strength 0° ABD	Internal rotation	Right	1:	2:	3:			
			Left	1:	2:	3:			
		External rotation	Right	1:	2:	3:			
			Left	1:	2:	3:			
	Strength 90° anteflexion	Serratus anterior	Right	1:	2:	3:			
			Left	1:	2:	3:			
	Strength 135° ABD	Lower trap	Right	1:	2:	3:			
			Left	1:	2:	3:			
Standing	Observation	Active: Weighted bilateral FF (5x)	Trunk	Lateral flexion	OK	Right	Left		
				Axial rotation	OK	Right	Left		
				Lateral shift	OK	Right	Left		
			Scapula	Dyskinesia	Present	Absent			
	Inclinometry	Rest	Sternum						
			Clavicula	R:	L:				
			Scapula	Upw. rotation *(downw. rot. = -)*	R:	L:			
				Tilt *(post. tilt = -)*	R:	L:			
		Active: Abduction	Scapula lateral rotation	Right	30°:	45°:	60°:	90°:	120°:
				Left	30°:	45°:	60°:	90°:	120°:
	Goniometry	Humerothoracic elevation	Right:	Left:					

Comments:

Figure 1: Clinical scapular measurement and observation protocol (CSMOP)

Abbreviations: M= male, F= female, R= right, L= left, rot.= rotation, ABD= abduction, FF= forward flexion, Upw.= upward, downw.= downward

9.2 Appendix B: Illustrations included in the CSMOP

<u>GHROM measurements</u>

Rotation glenohumeral joint

Figure 2: Internal rotation

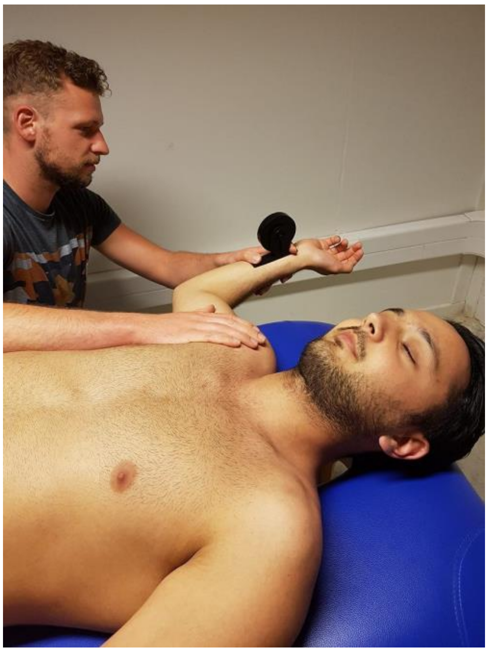

Figure 4: External rotation

Maximal active humerothoracic elevation

Figure 5: Maximal active humerothoracic elevation

STROM measurements

Acromial index (AI)

Figure 6: Acromial index (AI)

Figure 7: Acromial index (AI)

Observation of trunk movement and scapular dyskinesia during active bilateral forward flexion

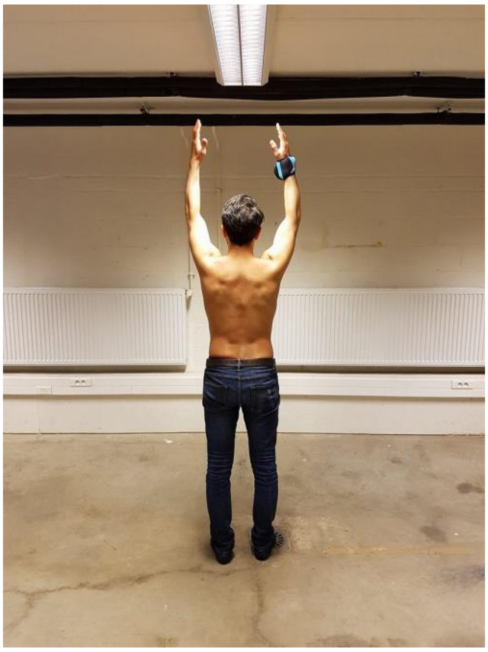

Figure 8: Observation of trunk movement and scapular dyskinesia

Forward trunk inclination

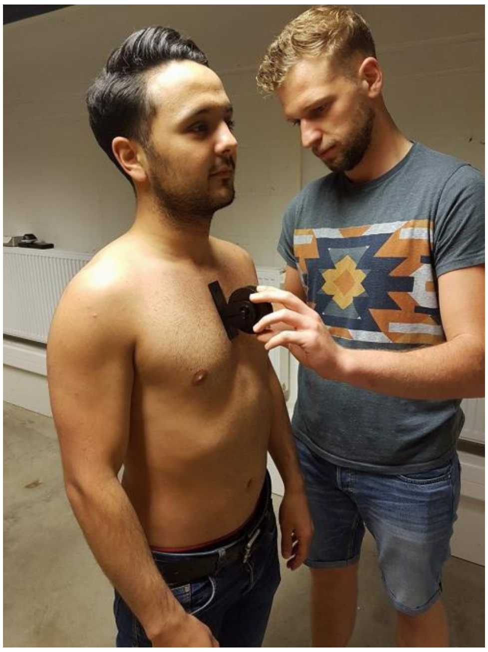

Figure 9: Forward trunk inclination

Clavicular inclination at rest

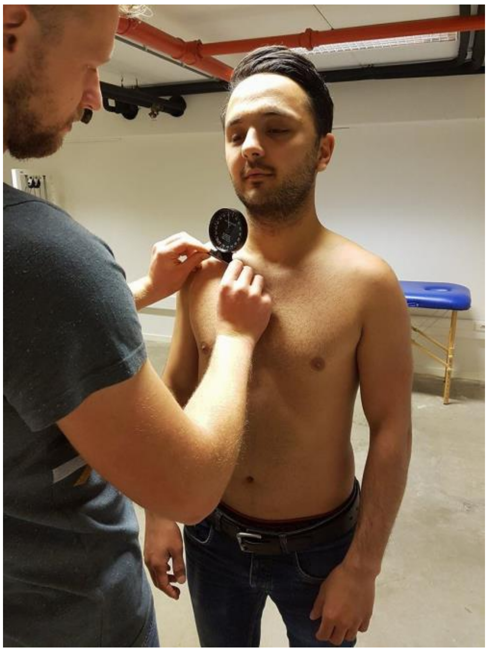

Figure 10: Clavicular inclination at rest

Scapular anterior/posterior tilt at rest

Figure 11: Scapular anterior/posterior tilt at rest

Active unilateral upward rotation during abduction

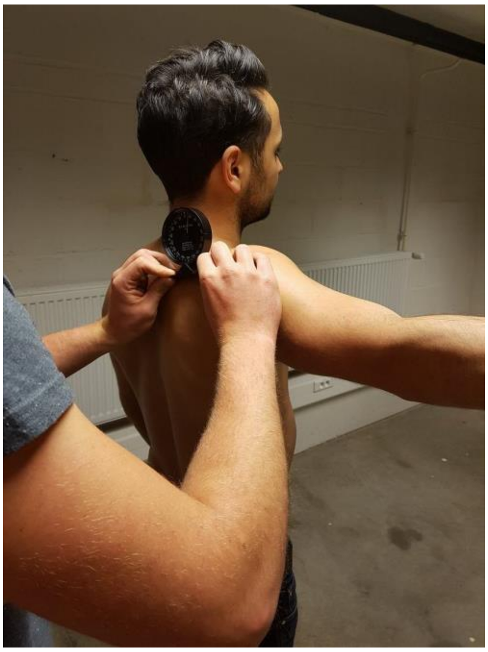

Figure 12: Active unilateral upward rotation during abduction

GHforce measurements

Internal/ external rotation strength

Figure 13: Internal rotation strength

Figure 14: External rotation strength

STforce measurements

Serratus anterior strength

Figure 15: Serratus anterior strength

Trapezius ascending part strength

Figure 16: Trapezius ascending part strength

9.3 Appendix C: Spearman Correlation

Table 4: Spearman Correlation

Spearman Correlation	AI DOM	Observation active bilateral FF: trunk lateral flexion	Trunk axial rotation	Trunk lateral shift	Scapular dyskinesia	Inclinometry: forward trunk inclination	Clavicular inclination DOM	Scapular upward/ downward rotation	Scapular anterior/ posterior tilt	Active unilateral upward rotation during abduction in 30° DOM	Active unilateral upward rotation during abduction in 45° DOM
AI DOM	1	0,068	0,048	0,144	-0,220	0,268	-0,036	-0,232	-0,123	-0,143	-0,101
Observation active bilateral FF											
Trunk lateral flexion	0,068	1	-0,074	-0,027	-0,119	-0,067	0,055	-0,253	-0,188	-0,126	-0,091
Trunk axial rotation	0,048	-0,074	1	-0,074	0,031	-0,038	-0,108	-0,050	**-,426****	0,175	0,132
Trunk lateral shift	0,144	-0,027	-0,074	1	-0,119	-0,143	0,091	-0,032	-0,078	-0,244	-0,171
Scapular dyskinesia	-0,220	-0,119	0,031	-0,119	1	-0,072	-0,075	-0,010	0,226	-0,225	-0,319
Inclinometry											
Forward trunk inclination	0,268	-0,067	-0,038	-0,143	-0,072	1	-0,020	-0,075	0,081	0,003	-0,039
Clavicular inclination DOM	-0,036	0,055	-0,108	0,091	-0,075	-0,020	1	0,111	0,206	0,075	0,048
Scapular upward/ downward rotation	-0,232	-0,253	-0,050	-0,032	-0,010	-0,075	0,111	1	-0,069	**,627****	**,572****
Scapular anterior/ posterior tilt	-0,123	-0,188	**-,426****	-0,078	0,226	0,081	0,206	-0,069	1	-0,259	-0,243
Active unilateral upward rotation during abduction in 30° DOM	-0,143	-0,126	0,175	-0,244	-0,225	0,003	0,075	**,627****	-0,259	1	**,953****
Active unilateral upward rotation during abduction in 45° DOM	-0,101	-0,091	0,132	-0,171	-0,319	-0,039	0,048	**,572****	-0,243	**,953****	1

Continued

Continued Table 4: Spearman Correlation

Spearman Correlation	Active unilateral upward rotation during abduction in 60° DOM	Active unilateral upward rotation during abduction in 90° DOM	Active unilateral upward rotation during abduction in 120° DOM	Glenohumeral internal rotation 90° DOM	Difference internal rotation DOM vs NOT DOM	Glenohumeral external rotation 90° DOM	Total ROM DOM	Strength: internal rotation DOM mean	Strength: external rotation DOM mean	Strength: SA DOM	Strength: LT DOM	Goniometry: humero-thoracic elevation DOM
AI DOM	-0,088	0,026	-0,070	0,285	-0,235	0,078	0,250	0,061	0,089	-0,163	-0,081	0,235
Observation active bilateral FF												
Trunk lateral flexion	-0,148	-0,207	-0,219	-0,234	-0,008	-0,171	-0,287	-0,156	-0,176	-0,157	-0,102	-0,008
Trunk axial rotation	0,107	-0,096	-0,117	-0,095	-0,245	0,104	0,016	-0,213	-0,145	-0,154	-0,311	-0,021
Trunk lateral shift	-0,006	0,186	0,207	0,226	-0,234	-0,063	0,103	**,627****	**,669****	0,007	0,252	-0,060
Scapular dyskinesia	**-,326***	**-,366***	-0,252	-0,246	0,126	-0,031	-0,188	0,140	0,060	0,199	0,105	-0,002
Inclinometry												
Forward trunk inclination	-0,102	-0,115	-0,113	0,291	-0,095	-0,012	0,186	-0,266	-0,257	-0,215	-0,151	0,269
Clavicular inclination DOM	-0,020	0,007	-0,162	0,223	-0,257	-0,227	-0,024	0,166	0,135	-0,192	-0,209	0,000
Scapular upward/ downward rotation	**,612****	**,505****	0,286	-0,001	-0,165	0,191	0,145	0,116	0,060	0,109	0,000	-0,112
Scapular anterior/ posterior tilt	-0,188	-0,069	0,055	0,087	-0,173	0,108	0,141	0,273	0,165	**,375***	**,453****	0,089
Active unilateral upward rotation during abduction in 30° DOM	**,854****	**,581****	0,254	0,091	0,043	0,068	0,113	-0,203	-0,135	0,110	-0,035	-0,037
Active unilateral upward rotation during abduction in 45° DOM	**,934****	**,701****	**,363***	0,042	-0,066	0,026	0,048	-0,116	-0,038	0,181	0,058	-0,138

Continued

Continued Table 4: Spearman Correlation

Spearman Correlation	AI DOM	Observation active bilateral FF: trunk lateral flexion	Trunk axial rotation	Trunk lateral shift	Scapular dyskinesia	Inclinometry: forward trunk inclination	Clavicular inclination DOM	Scapular upward/ downward rotation	Scapular anterior/ posterior tilt	Active unilateral upward rotation during abduction in 30° DOM	Active unilateral upward rotation during abduction in 45° DOM	Active unilateral upward rotation during abduction in 60° DOM
Active unilateral upward rotation during abduction in 60° DOM	-0,088	-0,148	0,107	-0,006	**-,326***	-0,102	-0,020	**,612****	-0,188	**,854****	**,934****	1
Active unilateral upward rotation during abduction in 90° DOM	0,026	-0,207	-0,096	0,186	**-,366***	-0,115	0,007	**,505****	-0,069	**,581****	**,701****	**,854****
Active unilateral upward rotation during abduction in 120° DOM	-0,070	-0,219	-0,117	0,207	-0,252	-0,113	-0,162	0,286	0,055	0,254	**,363***	**,558****
Glenohumeral internal rotation 90° DOM	0,285	-0,234	-0,095	0,226	-0,246	0,291	0,223	-0,001	0,087	0,091	0,042	0,045
Difference internal rotation DOM vs NOT DOM	-0,235	-0,008	-0,245	-0,234	0,126	-0,095	-0,257	-0,165	-0,173	0,043	-0,066	-0,176
Glenohumeral external rotation 90° DOM	0,078	-0,171	0,104	-0,063	-0,031	-0,012	-0,227	0,191	0,108	0,068	0,026	0,038
Total ROM DOM	0,250	-0,287	0,016	0,103	-0,188	0,186	-0,024	0,145	0,141	0,113	0,048	0,059
Strength												
Strength internal rotation DOM mean	0,061	-0,156	-0,213	**,627****	0,140	-0,266	0,166	0,116	0,273	-0,203	-0,116	-0,005
Strength external rotation DOM mean	0,089	-0,176	-0,145	**,669****	0,060	-0,257	0,135	0,060	0,165	-0,135	-0,038	0,042
Strength SA DOM	-0,163	-0,157	-0,154	0,007	0,199	-0,215	-0,192	0,109	**,375***	0,110	0,181	0,251
Strength LT DOM	-0,081	-0,102	-0,311	0,252	0,105	-0,151	-0,209	0,000	**,453****	-0,035	0,058	0,136
Goniometry												
Humerothoracic elevation DOM	0,235	-0,008	-0,021	-0,060	-0,002	0,269	0,000	-0,112	0,089	-0,037	-0,138	-0,252

Continued

Continued Table 4: Spearman Correlation

Spearman Correlation	Active unilateral upward rotation during abduction in 60° DOM	Active unilateral upward rotation during abduction in 90° DOM	Active unilateral upward rotation during abduction in 120° DOM	Glenohumeral internal rotation 90° DOM	Difference internal rotation DOM vs NOT DOM	Glenohumeral external rotation 90° DOM	Total ROM DOM	Strength: internal rotation DOM mean	Strength: external rotation DOM mean	Strength: SA DOM	Strength: LT DOM	Goniometry: humero-thoracic elevation DOM
Active unilateral upward rotation during abduction in 60° DOM	1	**,854****	**,558****	0,045	-0,176	0,038	0,059	-0,005	0,042	0,251	0,136	-0,252
Active unilateral upward rotation during abduction in 90° DOM	**,854****	1	**,764****	0,104	-0,233	-0,081	0,008	0,127	0,149	0,240	0,171	-0,303
Active unilateral upward rotation during abduction in 120° DOM	**,558****	**,764****	1	-0,027	-0,198	0,080	0,043	0,122	0,104	0,284	0,233	-0,281
Glenohumeral internal rotation 90° DOM	0,045	0,104	-0,027	1	-0,129	-0,029	**,647****	0,249	0,242	-0,031	0,061	**,409***
Difference internal rotation DOM vs NOT DOM	-0,176	-0,233	-0,198	-0,129	1	-0,091	-0,156	-0,239	-0,185	-0,023	-0,070	-0,006
Glenohumeral external rotation 90° DOM	0,038	-0,081	0,080	-0,029	-0,091	1	**,743****	0,057	0,050	0,267	0,150	0,297
Total ROM DOM	0,059	0,008	0,043	**,647****	-0,156	**,743****	1	0,210	0,200	0,184	0,156	**,500****
Strength												
Strength internal rotation DOM mean	-0,005	0,127	0,122	0,249	-0,239	0,057	0,210	1	**,915****	**,390***	**,638****	0,039
Strength external rotation DOM mean	0,042	0,149	0,104	0,242	-0,185	0,050	0,200	**,915****	1	**,451****	**,716****	0,128
Strength SA DOM	0,251	0,240	0,284	-0,031	-0,023	0,267	0,184	**,390***	**,451****	1	**,745****	0,286
Strength LT DOM	0,136	0,171	0,233	0,061	-0,070	0,150	0,156	**,638****	**,716****	**,745****	1	0,201
Goniometry												
Humerothoracic elevation DOM	-0,252	-0,303	-0,281	**,409***	-0,006	0,297	**,500****	0,039	0,128	0,286	0,201	1

Abbreviations: AI= acromial index, DOM= dominant side, NOT DOM= non-dominant side, FF= forward flexion, SA= Serratus anterior, LT= Lower trapezius

Auteursrechtelijke overeenkomst

Ik/wij verlenen het wereldwijde auteursrecht voor de ingediende eindverhandeling:
Scapulothoracic and glenohumeral movement and strength in painful and pain free shoulders in overhead athletes: a case control study

Richting: **master in de revalidatiewetenschappen en de kinesitherapie-revalidatiewetenschappen en kinesitherapie bij musculoskeletale aandoeningen**
Jaar: **2017**

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