2015•2016

FACULTEIT GENEESKUNDE EN LEVENSWETENSCHAPPEN

master in de revalidatiewetenschappen en de kinesitherapie

Masterproef

Evaluation of scapulothoracic kinematics in overhead athletes with and without GIRD based on a clinical measurement protocol: a reliability and cross-sectional study

Promotor :
dr. Liesbet DE BAETS

Matthias Didden , Bram Vanhees

Scriptie ingediend tot het behalen van de graad van master in de revalidatiewetenschappen en de kinesitherapie

Universiteit Hasselt | Campus Hasselt | Martelarenlaan 42 | BE-3500 Hasselt
Universiteit Hasselt | Campus Diepenbeek | Agoralaan Gebouw D | BE-3590 Diepenbeek

2015•2016
FACULTEIT GENEESKUNDE EN LEVENSWETENSCHAPPEN
master in de revalidatiewetenschappen en de kinesitherapie

Masterproef

Evaluation of scapulothoracic kinematics in overhead athletes with and without GIRD based on a clinical measurement protocol: a reliability and cross-sectional study

Promotor :
dr. Liesbet DE BAETS

Matthias Didden , Bram Vanhees
Scriptie ingediend tot het behalen van de graad van master in de revalidatiewetenschappen en de kinesitherapie

Evaluation of scapulothoracic kinematics in overhead athletes with and without GIRD based on a clinical measurement protocol: a reliability and cross-sectional study

Didden Matthias

Vanhees Bram

Promotor: dr. De Baets Liesbet

ACKNOWLEDGEMENT

We wish to acknowledge dr. De Baets L. for her help, support and advice during this master thesis project. Without her perseverance and determination to help, we wouldn’t be able to continue our master thesis project and theme which we’ve started during master period one.

We would also like to thank the REVAL centre and staff (University of Hasselt) for their logistic support and provision of a space to conduct the measurements.

Diest	15/06/2016	D.M.
Diepenbeek		V.B.

RESEARCH CONTEXT

A reliability and cross-sectional comparative study was set up to test the inter-rater reliability and discriminative validity of a clinical measurement protocol in overhead athletes with and without the presence of a glenohumeral internal rotation deficit (GIRD). The shoulder region is a common affected region of pathology in overhead athletes. The complex biomechanical characteristics of the shoulder girdle and its dominant function in overhead sports play a major influencing role. There are also multiple contributing risk factors which could result in shoulder pathology. A frequently discussed factor is the presence of GIRD (Cools, Johansson, Borms, & Maenhout, 2015; Kinsella, Thomas, Huffman, & Kelly, 2014; Maenhout, Van Eessel, Van Dyck, Vanraes, & Cools, 2012). Currently, a reliable, inexpensive, clinically applicable and easy to use measurement protocol for preventive screening is lacking. The presence of such a reliable and affordable measurement protocol can create the possibility to screen athletes at regular points in time or to do a follow-up during rehabilitation.

Therefore, this study aimed to set up a clinical measurement protocol consisting of different measurement techniques which take the kinematics in and around the shoulder complex into account. This protocol was tested first on inter-rater reliability and afterwards it was used to compare kinematics, strength and motion between a GIRD and non-GIRD group of overhead athletes without shoulder pain.

This research is a duo-thesis written by Matthias Didden (MD) and Bram Vanhees (BV), as part of a master 'Rehabilitation Sciences and Physiotherapy', specialization 'musculoskeletal rehabilitation' performed at the University of Hasselt under the lead of dr. De Baets, L. It was not a part of a larger ongoing study.

The study design and the clinical measurement protocol were determined by the promotor dr. De Baets, L., and was critically reviewed by both master students. The master students executed participant recruitment independently by email, based on inclusion- and exclusion criteria which had been approved by the promotor. Data-acquisition of the reliability study was performed by one master student and promotor dr. De Baets, L. Data-acquisition of the comparative study was largely performed by the master students independently with assistance of the promotor. Data analysis was conducted by one master student, under supervision of dr. De Baets. The analysis and interpretation of the results was carried out by both master students. Both students also described the analysis academically in form of this reliability and discriminant validity study. Promotor dr. De Baets, L. critically guided this process and occasionally gave advice to optimize the academic writing en improve transparent representation of the results.

References

Cools, A. M., Johansson, F. R., Borms, D., & Maenhout, A. (2015). Prevention of shoulder injuries in overhead athletes: a science-based approach. *Braz J Phys Ther*, 0. doi: 10.1590/bjpt-rbf.2014.0109

Kinsella, S. D., Thomas, S. J., Huffman, G. R., & Kelly, J. D. t. (2014). The thrower's shoulder. *Orthop Clin North Am, 45*(3), 387-401. doi: 10.1016/j.ocl.2014.04.003

Maenhout, A., Van Eessel, V., Van Dyck, L., Vanraes, A., & Cools, A. (2012). Quantifying acromiohumeral distance in overhead athletes with glenohumeral internal rotation loss and the influence of a stretching program. *Am J Sports Med, 40*(9), 2105-2112. doi: 10.1177/0363546512454530

ABSTRACT

Background: Shoulder pathology is commonly reported in overhead athletes. In this population, glenohumeral internal rotation deficit (GIRD) on the dominant side is well documented. This mobility limitation has been shown to alter glenohumeral and scapulothoracic kinematics. A clinical reliable scapulothoracic measurement protocol to apply on overhead athletes during assessment or follow-up during rehabilitation is lacking at the moment.

Objectives: To test the reliability and discriminant validity of selected clinical scapulothoracic and scapulohumeral measurements in overhead athletes with and without GIRD.

Participants: 51 athletes from seven different overhead sports were recruited and participated in the discriminant validity study. 12 of them also participated in the reliability study.

Measurements: A clinical scapular measurement and observation protocol (CSMOP) was composed consisting of 11 tests (glenohumeral internal rotation ROM, acromial index, pectoralis minor index, glenohumeral external and internal rotation strength, forward trunk and clavicular inclinometry, scapular upward rotation and scapular tilt at 0°, 30°, 45°, 60°, 90° and 120°, observation of trunk rotation, lateral flexion, shift or scapular dyskinesis at rest or during unilateral and bilateral arm elevation and humerothoracic elevation).

Results: In the reliability study, ICCs were sufficiently reliable (>0.70) except for the pectoralis minor index (0.66), clavicular inclinometry (0.48) and scapular upward rotation at 30° (0.67). Kappa scores indicated sufficient reliability (>0.70) for all tests except for the observation of trunk shift at rest (0.54).

In the discriminant validity study, the GIRD group had significantly less internal rotation (p= .01), more forward trunk inclination in rest position (p= .03), less scapular lateral flexion at 120° (p= .03) and less maximal humerothoracic elevation (p= .04).

Conclusion: The use of this reliable CSMOP provides a base for clinical scapulothoracic assessment and emphasises the importance to assess the whole kinetic chain that is involved during overhead movements. Future studies are needed to optimize the protocol.

INTRODUCTION

The shoulder is a common source of pathology in overhead athletes (Almeida et al., 2013; Amin et al., 2015; Kinsella et al., 2014; Mohseni-Bandpei, Keshavarz, Minoonejhad, Mohsenifar, & Shakeri, 2012). It is a very complex joint due to its anatomy and need to balance between mobility and stability, especially in sport-specific movements (e.g. a throwing motion or a serve) (Cools, Johansson, et al., 2015; Ellenbecker, Roetert, Bailie, Davies, & Brown, 2002; Kinsella et al., 2014). Due to these complex characteristics, chronic shoulder injuries are mostly multifactorial (Cools, Johansson, et al., 2015). Given the repetitive nature of movements performed in their overhead sports, athletes are susceptible to sport-specific adaptations on their dominant shoulder, i.e. both strength and flexibility alterations are reported adaptations (Almeida et al., 2013). Both adjustments are furthermore seen in healthy and pathological overhead athletes (Amin et al., 2015; Bigliani et al., 1997; Ellenbecker et al., 2002; Maenhout et al., 2012; Myers, Laudner, Pasquale, Bradley, & Lephart, 2006; Thomas, Swanik, Swanik, Huxel, & Kelly, 2010). An example of a common flexibility adaptation is the glenohumeral internal rotation deficit (GIRD) at the dominant shoulder, often accompanied with an increase in external rotation range of motion. The direct cause for the development of GIRD is currently unclear. Some believe that GIRD is a result of an acquired thickened posterior capsule (Maenhout et al., 2012; Meister, 2000; Myers et al., 2006; Thomas et al., 2010; Tyler, Nicholas, Roy, & Gleim, 2000) or tightness of the posterior rotator cuff (Burkhart, Morgan, & Kibler, 2003a, 2003b, 2003c; Noonan et al., 2015). The increase of external rotation is believed to be caused by repetitive stretching of the anterior capsule (Thomas et al., 2010). Others on the other side believe that the development of GIRD and the increase in external rotation are caused by increased humeral retroversion (Maenhout et al., 2012; Noonan et al., 2015; Reagan et al., 2002; Thomas et al., 2010).

Based on a review of the literature, the amount of GIRD between dominant and non-dominant shoulder in athletes without a history of shoulder injuries varies between 10 to 15 degrees (Crockett et al., 2002; Myers et al., 2006; Reagan et al., 2002; Tyler et al., 2000). Loss of glenohumeral internal rotation can be associated with altered kinematics of both the glenohumeral and scapulothoracic joint (Harryman et al., 1990; Maenhout et al., 2012). Currently, it is believed that an unstable scapula is a significant contributing factor to shoulder injuries (Kibler, Ludewig, et al., 2013; Ludewig et al., 2009). The scapula has to act as a stable base for optimal glenohumeral functioning during arm movements (Kibler, Kuhn, et al., 2013). Several studies concluded that the presence of scapular dyskinesis, altered scapular movement patterns or lack of scapular stability is correlated with shoulder pathologies like impingement or rotator cuff lesions (Kibler, Ludewig, et al., 2013). However, McQuade, Borstad, and de Oliveira (2016) explored a more critical view on the concept of scapular stability in their scapula perspective. According to this article, scapular stability should be questioned due to the lack of evidence on the existence of an ideal scapular position or the effect of isolated scapulothoracic muscle strengthening on shoulder pathologies.

The monitoring of trunk posture, shoulder motion, shoulder strength and scapular kinematics in the screening and follow-up during rehabilitation of overhead athletes seem valuable in a clinical setting. Especially given the interaction of multiple joints and the vulnerability of the shoulder complex due to the demands of the sports. Different types of techniques to measure scapular kinematics and glenohumeral strength and motion are described in the literature. Most of these are expensive and time consuming three-dimensional assessment techniques in specialized movement laboratories. Unfortunately, these measurement techniques are not applicable in a clinical setting for physiotherapists (Nijs, Roussel, Struyf, Mottram, & Meeusen, 2007; Struyf, Nijs, De Graeve, Mottram, & Meeusen, 2011; Watson, Balster, Finch, & Dalziel, 2005). A minority of studies in literature used two-dimensional measurements which are utilisable in the clinical practice (Nijs, Roussel, Vermeulen, & Souvereyns, 2005; Watson et al., 2005). Because of the inconsistent information in scientific literature concerning the reliability of some measurement techniques, and the lack of a protocol including the trunk, a new clinical scapular measurement and observation protocol (CSMOP) was developed in this study.

The objective of this study was twofold. First, we wanted to examine the reliability of the included clinical measurements in the CSMOP in overhead athletes with and without GIRD. Secondly, we were interested in the discriminative validity of the CSMOP.

METHODS

Participants

Overhead athletes were recruited from the University of Hasselt and via relatives. To be eligible for study-participation, participants were screened based on the following inclusion criteria: (1) aged between 18 and 30, (2) participating in an overhead sport for at least two hours a week. Participants were excluded from the study if one of the following exclusion criteria were met: (1) a known history of neurologic disease, arthritis, connective tissue disorder (2) shoulder, neck or upper back injury during the previous year, (3) shoulder, neck or upper back surgery during lifetime, (4) experience of shoulder pain during the past six months for which they consulted a medical doctor, (5) BMI exceeding 28.

Participants were assigned either to the GIRD or NO GIRD group, depending on the difference in glenohumeral internal rotation range of motion between dominant and non-dominant arm. Overhead athletes in which the difference was 15° or more were assigned to the GIRD group.

All students of the University of Hasselt were recruited by mail (approximately 5500 students), 57 overhead athletes responded and were screened for eligibility. After the screening, all of the remaining 51 overhead athletes agreed to participate. Appointments for measurement sessions were made between the participant and the researcher by phone and email.

A written informed consent, approved by the Ethical Committee of the University Hospital Leuven, was obtained from all participants prior to the measurements.

Design Overview

The purpose of this study was to set up a reliability study to test the inter-rater reliability and precision of the CSMOP. On the other hand, a discriminant validity study was done by comparing sufficient reliable measures of the CSMOP between a GIRD and NO GIRD group. The flow chart of the research design is presented in Figure 1.

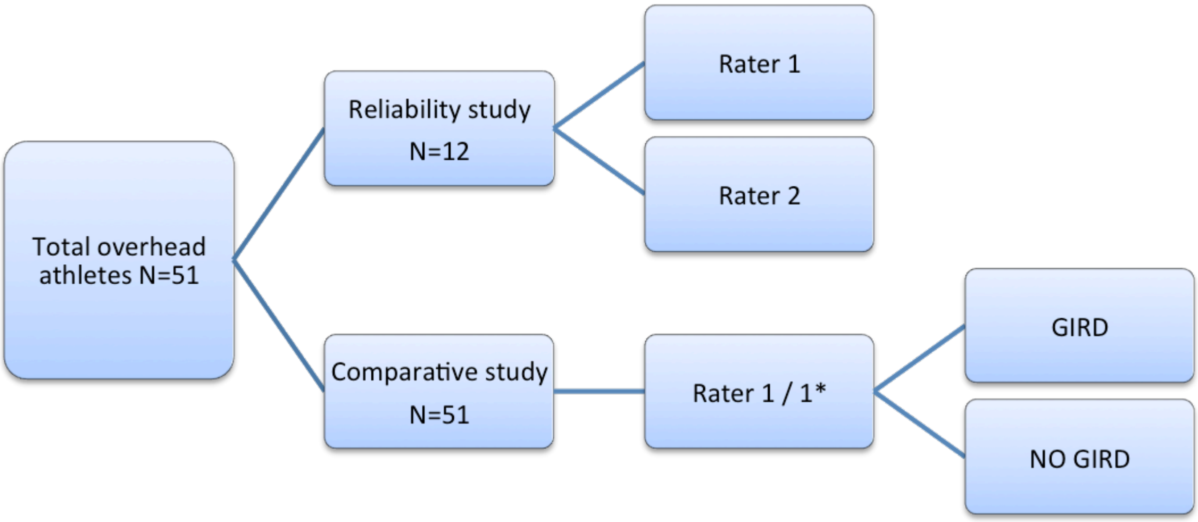

Figure 1: research design (rater 1 = BV; rater 2= LDB, rater 1*= MD)

Reliability Study

Twelve overhead athletes were measured by two independent researches, to obtain inter-rater reliability and precision values for each measurement technique. The measurements were conducted by a novice rater (rater 1) and experienced rater (rater 2). The novice rater got training (approximately 4h) in how to execute the different tests of CSMOP before the start of the measurements. All measurements were performed first by rater 1, followed by rater 2. Each rater was blinded to the results of the other. A standardized exception was made for the strength measurements, were rater 2 performed these measurements at the end of the protocol to minimalize the impact of muscle fatigue on the performance.

Discriminant validity: GIRD – NO GIRD comparative study

Fifty-one overhead athletes were assessed in this study. After the measurement session, the difference in glenohumeral internal rotation between dominant and non-dominant arm was calculated. Overhead athletes in which the difference was more than 15° were assigned to the GIRD group. The measurements were performed by rater 1 (which also participated in the reliability study) and rater 1*, who also received a 4h training session in advance.

Procedure

Clinical Scapular Measurement and Observation Protocol (CSMOP)

Measurements were conducted by two last year master students of the university education ‘Rehabilitation Sciences and Physiotherapy’, specialization ‘musculoskeletal rehabilitation’. Before the start of the data collection, both students practiced all measurement techniques during two practical sessions of each two hours. Primary outcomes were the scapular kinematics (scapular upward rotation and anterior-posterior (AP) scapular tilting) during shoulder abduction. Furthermore, we were also interested in the following secondary outcome measurements: ratio of external and internal rotational strength, posture of the trunk and the clavicula at rest, position and the presence of scapular dyskinesis both at rest and during unilateral/bilateral arm movement.

The CSMOP consisted of eleven different clinical measures, described below in the order of execution. The entire assessment lasted 20 minutes. Illustrations of the different tests can be found in the Appendix A.

Test 1: Glenohumeral internal rotation

The amount of glenohumeral internal rotation was measured with an inclinometer (Plurimeter -V gravity inclinometer, Dr Rippstein, Switzerland). The participants were lying supine, in 90° shoulder abduction. The inclinometer was placed on the ulnar side of the forearm, beneath the styloid process, by the first therapist. A second therapist controlled possible scapular compensation by fixating the coracoid process. The first therapist passively performed an internal rotation. The amount of internal rotation was read from the inclinometer. The dominant shoulder was measured first (Cools et al., 2014).

Test 2: Acromial Index (AI)

The acromial index was assessed with the participant lying supine, the arms relaxed alongside the body with the palm of the hand supported on the table. The participant was instructed to stay relaxed during the measurement. In this position, the posterior acromial angle was palpated and the vertical distance between this angle and the table (cm) was measured with a sliding calliper. This distance (cm) was divided by the subject height (cm) and multiplied by 100. The outcome was defined as the AI (no unit) (Nijs et al., 2005).

Test 3: Pectoralis minor index (PMI)

The PMI was assessed with the participant lying supine, the arms relaxed alongside the body with the palm of the hand placed on the table. The resting length of the pectoralis minor muscle was assessed by measuring the distance between the inferior medial tip of the coracoid process and the caudal edge of rib four at the sternal attachment, with a measurement tape. Both reference points were first palpated and marked using a dermographic pencil. Participants were instructed to exhale and to hold at their deepest position. At this moment the pectoralis minor resting length was measured. The PMI (no unit) was defined as the pectoralis minor resting length (cm) divided by the subject height (cm) and multiplied by 100 (Borstad & Ludewig, 2005; Struyf et al., 2014).

Test 4: Internal/external rotation strength

To examine shoulder rotational strength, a Hand Held Dynamometer (MicroFET) was placed two cm proximal of the processus styloideus ulnae, on the dorsal (ER strength) or ventral (IR strength) forearm. Three repetitions of five seconds of maximal voluntary effort were performed using a “make” test (gradually increasing resistance up to maximum without “breaking” the subject's strength). A 10-second resting period was given in between trials. Participants were instructed to stabilize the upper arm, shoulder, scapula, and trunk during the task execution (Couppe et al., 2014).

Test 5: Forward trunk inclination and clavicula inclination at rest position

Trunk inclination was assessed with an inclinometer (Plurimeter -V gravity inclinometer, Dr Rippstein, Switzerland), while the participant stood upright with the arms at the side. The inclinometer was placed on the sternum, underneath the manubrium. The amount of sternal (trunk) inclination was read from the inclinometer. Lower values corresponded to a less upright sternal position (more thoracic kyphosis, more sloughed position) (Suzuki et al., 2015).

The amount of clavicular upward/downward inclination was measured with an inclinometer (Plurimeter -V gravity inclinometer, Dr Rippstein, Switzerland), while the participant stood upright. The inclinometer was manually placed on an imaginary line between the middle of the acromioclavicular joint and the sternoclavicular joint. The researcher read the amount of upward/downward clavicular inclination from the inclinometer.

Test 6: Scapular upward rotation

Scapular upward rotation was assessed with an inclinometer (Plurimeter -V gravity inclinometer, Dr Rippstein, Switzerland), while participants stood upright. The first inclinometer was held manually on the scapular spine by the first researcher. A second inclinometer was placed manually on the lateral side of the humerus, at the level of the deltoid muscle insertion, by the second researcher. The participant was asked to perform an elevation of the arm in the frontal plane with the elbow extended and the thumb pointing upward. The amount of upward rotation (degrees) was read from the first inclinometer at rest (arm alongside the body), and at 30°, 45°, 60°, 90° and 120° of abduction (Watson et al., 2005).

Test 7: Anterior-Posterior (A-P) Scapular tilt

Scapular A-P tilt was assessed with an inclinometer (Plurimeter -V gravity inclinometer, Dr Rippstein, Switzerland), while participants stood upright. The first inclinometer was placed manually on the medial border of the scapula by the first researcher. A second inclinometer was placed manually on the lateral side of the humerus, at the level of the deltoid muscle insertion, by the second researcher. While the participant elevated the arm in the frontal plane with an extended elbow and the thumb pointing upward, the second physiotherapist instructed the participant to stop his arm at respectively 30°, 45°, 60°, 90° and 120° of abduction. The amount of scapular anterior-posterior scapular tilt was read from the inclinometer of the first researcher at respectively 30°, 45°, 60°, 90° and 120° of abduction (Scibek & Carcia, 2014).

Test 8: Maximal humerothoracic elevation

While standing upright in a resting position, the subject was instructed to elevate the arm as high possible. The maximal range of active humerothoracic elevation in the sagittal plane (forward flexion) was read from a goniometer (degrees). Subjects were instructed to extend the elbow and to keep the thumb pointing upward during movement.

Test 9: Observation of trunk and scapular dyskinesis at rest position

Participants were asked to stand in a relaxed posture with the arms at the side. A researcher observed the trunk for axial rotation, lateral shift and lateral flexion, and the dominant scapula for the presence of scapular dyskinesis. Dyskinesis was defined as the presence or absence of winging (prominence of any portion of the medial border or inferior angle away from the thorax). When a deviation or dyskinesis was present, a score of 0 was given. The test score '1' was given in case of a normal posture or when dyskinesis was absent.

Test 10: Observation of trunk and scapular dyskinesis during unilateral arm movement

To assess the scapula and the trunk posture during movement, the Scapular Dyskinesis test (SDT) was used. Participants were asked to perform a weighted (1kg) shoulder anteflexion with their dominant arm and to repeat this movement five times. Researchers also recorded this movement, so that the video could be reanalysed in case of ambiguity. Researchers observed the trunk for axial rotation, lateral shift or lateral flexion and the scapula for the presence of scapular dyskinesis (presence or absence of winging (prominence of any portion of the medial border or inferior angle away from the thorax) or dysrhythmia (premature, or excessive, or stuttering motion during elevation and lowering) (Kibler et al., 2002). When there was no increase in trunk axial rotation, lateral shift or lateral flexion during the movement as compared to the observation in relaxed posture, trunk was rated OK (score 1). Otherwise, in case of trunk deviation or scapular dyskinesis, a score of 0 was given.

Test 11: Observation of scapular dyskinesis during bilateral arm movement

Participants were asked to perform a bilateral weighted (1kg) shoulder anteflexion and to repeat this movement five times. During the movements, researchers were only interested in scapular dyskinesis on the dominant side (Kibler et al., 2002). When scapular dyskinesis was present, the performance was rated with a 0-score. A normal movement pattern was rated with a 1-score.

Statistical analysis

A priori, a power analysis was conducted with Gpower 3.1.ink. Following parameters were used: a power of 0.80, a p-value of 0.05, an effect size of 21.69° scapular upward rotation with a standard deviation of 5.53° for the GIRD group and an effect size of 26.79° scapular upward rotation with a standard deviation of 5.19° for the no GIRD group. Effect size and standard deviations were based on the results of the paper from Thomas et al. (2010) on scapular upward rotation at 90°. This resulted in an estimated sample size of 15 participants for each group.

IBM SPSS Statistics 22 was used for statistical analysis. Descriptive statistics were used to report demographic data of each group. An independent samples t-test was used to analyse differences between groups for age, height, weight, BMI and total hours of sport/week. Inter-rater reliability and precision was assessed for all outcome measures. Intra-class correlation coefficients ($ICC_{2,k}$) (reliability), standard errors of measurement (SEM) and minimal detectable change (MDC) (precision) were calculated for continuous variables. Kappa (K) values were calculated for ordinal variables (De Baets, Jaspers, & Van Deun, 2016). An ICC or K value above 0.70 on a test was considered to indicate sufficient reliability or agreement for that specific test to be used in future clinical research (De Baets et al., 2016). Normality was tested by the Kolmogorov-Smirnov test. Group differences for the between group comparison were conducted with an independent samples t-test in case of normal distribution and a Mann-Whitney U test in case of non-normal distribution. P-values were considered significant when alpha < 0.05.

RESULTS

Participants

Demographic characteristics and data on sports activity participation of the athletes are presented in Table 1. Overall, 51 overhead athletes could be included in this master paper. Based on the methodology criteria, 11 of them were assigned to the GIRD group. The other 40 overhead athletes were assigned to the NO GIRD group. There were no significant differences found between groups at baseline for age, weight, height, Body Mass Index (BMI) and total hours of sports/week. In the GIRD group, there were no tchoekball and basketball players, while baseball players were lacking in the NO GIRD group.

Table 1: Demographics and Sports Activity Information

Variables	GIRD GROUP (N=11)	NO GIRD GROUP (N=40)	P-value
Age, years (mean, SD)	20.27 (±1.42)	21.82 (±2.73)	0.08
Sex (M/F)	7/4	16/24	
Height (cm) (mean, SD)	176.18 (±7.15)	176.10 (±7.74)	0.97
Weight (kg) (mean, SD)	69.38 (±8.83)	71.65 (±11.70)	0.55
Body Mass Index, kg/m^2(mean, SD)	22.11 (±1.61)	23.10 (±2.61)	0.15
Dominant Side (L/R)	0/11	5/35	
Sports Discipline			
→ Handball	N = 5	N = 8	
→ Volleyball	N = 2	N = 20	
→ Tchoekball	N = 0	N = 1	
→ Badminton	N = 1	N = 2	
→ Baseball	N = 1	N = 0	
→ Waterpolo	N = 2	N = 2	
→ Basketball	N = 0	N = 7	
Total hours sport/week (mean, SD)	6.27 (±2.57)	6.08 (±2.23)	0.83

Abbreviations: SD= standard deviation; M= male; F= female; cm= centimetres; kg= kilograms; L= left; R= right, m= metres

Reliability analysis

Inter-rater reliability data was tested on a group of 12 overhead athletes (six GIRD/ six NO GIRD) and there were no data missing. Mean and standard deviation (SD) for each test and each rater separately are presented in the Appendix A Tables 1 and 2. Outcomes of reliability and precision statistics (ICC-, SEM-, and MDC-values) are presented in Table 2. Following measurement techniques were found to be sufficient reliable (ICC >0.70): Test 1: internal rotation (ICC= 0.95); Test 2: acromial index/length (ICC= 0.94); Test 4: strength internal rotation (ICC= 0.94), strength external rotation (ICC= 0.96), strength ratio (ICC= 0.72); Test 5: forward trunk inclination (ICC= 0.93); Test 6: inclinometry scapular upward rotation in rest position (ICC= 0.74), 45° (ICC= 0.70), 60° (ICC= 0.93), 90° (ICC= 0.77), 120° (ICC= 0.77), Test 7: inclinometry scapular tilt in rest position (ICC= 0.93), 30° (ICC= 0.83), 45° (ICC= O.84), 60° (ICC= 0.74), 90° (ICC= 0.80), 120° (ICC= 0.80); Test 8: maximal humerothoracic elevation (ICC= 0.76).

Following observation techniques were found sufficient reliable (k>0.70): Test 9: observation in rest position of trunk lateral flexion (k= 1), trunk rotation (k= 0.79) and scapular dyskinesis (k= 1); Test 10: observation of trunk lateral flexion (k=1), trunk rotation (k=1) and trunk shift (k= 0.75) and scapular dyskinesis with unilateral arm elevation (k= 0.75); Test 11: scapular dyskinesis with bilateral arm elevation (k= 1).

Table 2. Reliability of the CSMOP

	Test name		ICC (95% CI)	SEM	MDC	K(appa)
Test 1:	Internal rotation (°)		**0.95** (0.83-0.99)	2.49	6.90	
Test 2:	Acromial index/length (cm)		**0.94** (0.81-0.98)	0.17	0.47	
Test 3:	Pectoralis minor /length (cm)		0.66 (0.10-0.90)	0.46	1.28	
Test 4:	Strength (kg)	Internal rot.	**0.94** (0.81-0.98)	1.10	3.05	
		External rot.	**0.96** (0.87-0.99)	0.80	2.21	
		Ratio ER/IR	**0.72** (0.27-0.91)	0.08	0.22	
Test 5:	Inclinometry (rest) (cm)	Trunk	**0.93** (0.79-0.98)	1.18	3.27	
		Clavicula	0.48 (-0.13-0.82)	2.38	6.60	
Test 6:	Inclinometry scapular upward rotation (°)	Rest	**0.74** (0.34-0.92)	1.75	4.85	
		30°	0.67 (0.18-0.90)	2.07	5.74	
		45°	**0.70** (0.24-0.90)	2.43	6.74	
		60°	**0.93** (0.77-0.98)	1.35	3.74	
		90°	**0.77** (0.39-0.93)	2.61	7.23	
		120°	**0.77** (0.40-0.93)	2.62	7.26	
Test 7:	Inclinometry scapular A-P tilt (°)	Rest	**0.93** (0.78-0.98)	1.66	4.60	
		30°	**0.83** (0.48-0.95)	2.25	6.24	
		45°	**0.84** (0.54-0.95)	2.21	6.13	
		60°	**0.74** (0.35-0.92)	3.16	8.76	
		90°	**0.80** (0.45-0.94)	3.04	8.43	
		120°	**0.80** (0.46-0.94)	3.47	9.62	
Test 8:	Maximal humerothoracic elevation (°)		**0.76** (0.38-0.92)	4.06	11.25	

Continued

***Continued* Table 2. Reliability of the CSMOP**

	Test name		ICC (95% CI)	SEM	MDC	K(appa)
Test 9:	Observation rest position	Trunk LF				**1**
		Trunk rotation				**0.79**
		Trunk shift				0.54
		Scapular dyskinesis				**1**
Test 10:	Observation unilateral arm movement	Trunk LF				**1**
		Trunk rotation				**1**
		Trunk shift				**0.75**
		Scapular dyskinesis				**0.75**
Test 11:	Observation bilateral arm movement	Scapular dyskinesis				**1**

Abbrevations: ICC= Intraclass correlation coefficient; CI= confidence interval; SEM= standard error of the measurement; MDC= minimal detectable change; K= kappa; IR= glenohumeral internal rotation; ER= glenohumeral external rotation; A-P= anterior-posterior; LF= lateral flexion

Figures of sufficient reliable tests (ICC or K > 0.70) are presented in bold.

Discriminant validity: differences between GIRD and NO GIRD group

All results of the between-group comparison are presented in Table 3. However, only measurement and observation techniques which were sufficiently reliable were considered in this study. The results with elimination of the insufficient reliable measurements are presented in Table 4. Mean and standard deviation (SD) for each test and each group separately are presented in the Appendix B Tables 3 and 4. All data were normally distributed.

The GIRD group had significantly less internal glenohumeral rotation (p= .01), less upright trunk posture as measured with inclinometry (p= .03), less scapular upward rotation at 120° of abduction (p= .03) and less maximal humerothoracic elevation (p= .04). The difference in trunk forward posture was 3.64°, which is more than the SEM and MDC. The difference in scapular upward rotation was however only 6.23° which is less than the MDC but greater than the SEM. The difference in humerothoracic elevation was 6.01° which was also less than the MDC, but greater than the SEM. There were no significant differences found for the other tests (p= .09 – 1.00).

Table 3: Results independent T-test between GIRD (N=11) and NO GIRD (N=40) group

	Test name		Sig. (2-tailed)	Mean difference	Std. error difference	95% CI of the difference
Test 1:	Internal rotation		0.01**	- 11.76	3.39	-19.08 / -4.44
Test 2:	Acromial index/length		0.29	-0.28	0.25	-0.81 / 0.25
Test 3:	Pectoralis minor /length		0.83	-0.06	0.28	-0.66 / 0.53
Test 4:	Strength	Internal rot.	0.93	0.10	1.09	-2.19 / 2.38
		External rot.	0.74	-0.32	0.95	-2.32 / 1.68
		Ratio ER/IR	0.51	-0.03	0.05	-0.13 / 0.06
Test 5:	Inclinometry (rest)	Trunk	0.03*	-3.36	1.63	-6.91 / -0.36
		Clavicula	0.04*	-4.87	2.01	-8.81 / -0.16
Test 6:	Inclinometry scapular upward rotation	Rest	0.39	-1.44	1.62	-4.87/ 1.97
		30°	0.47	-1.45	1.95	-5.54 / 2.65
		45°	0.32	-1.80	1.80	-5.48 / 1.88
		60°	0.09	-3.61	2.02	-7.81 / 0.56
		90°	0.12	-4.65	2.90	-10.46 / 1.17
		120°	0.03*	-5.77	2.50	-10.95 / -0.60
Test 7:	Inclinometry scapular A-P tilt	Rest	0.91	-0.15	1.28	-2.79 / 2.48
		30°	0.78	-0.45	1.55	-3.69 / 2.80
		45°	0.42	-1.28	1.53	-4.50 / 1.94
		60°	0.38	-1.51	1.69	-5.03 / 2.01
		90°	0.21	-2.01	1.54	-5.23 / 1.21
		120°	0.09	-2.47	1.41	-5.36 / 0.42
Test 8:	Maximal humerothoracic elevation		0.04*	-6.01	2.82	-11.72 / -0.30

Continued

Continued **Table 3: Results independent T-test between GIRD (N=11) and NO GIRD (N=40) group**

Test name			Sig. (2-tailed)	Mean difference	Std. error difference	95% CI of the difference
Test 9:	Observation rest position	Trunk LF	1.00	0.00	0.21	-0.47 / 0.47
		Trunk rotation	0.51	0.25	0.37	-0.54 / 1.04
		Trunk shift	0.91	-0.03	0.22	-0.50 / 0.45
		Scapular dyskinesis	0.70	0.07	0.17	-0.31 / 0.45
Test 10:	Observation unilateral arm movement	Trunk LF	0.32	-0.05	0.05	-0.15 / 0.05
		Trunk rotation	1.00	0.00	0.00	0.00
		Trunk shift	1.00	0.00	0.00	0.00
		Scapular dyskinesis	0.95	-0.01	0.17	-0.37 / 0.35
Test 11:	Observation bilateral arm movement	Scapular dyskinesis	0.50	0.12	0.18	-0.25 / 0.50

Abbreviations: ER= glenohumeral external rotation; IR= glenohumeral internal rotation; A-P= anterior-posterior; LF= lateral flexion

* = $p < 0.05$; ** = $p < 0.01$

Table 4: results independent T-test between GIRD (N=11) and NO GIRD (N=40) group corrected regarding sufficient reliability

	Test name		Sig. (2-tailed)	Mean difference	Std. error difference	95% CI of the difference
Test 1:	Internal rotation		0.01**	- 11.76	3.39	-19.08 / -4.44
Test 2:	Acromial index/length		0.29	-0.28	0.25	-0.81 / 0.25
~~Test 3:~~	~~Pectoralis minor /length~~		0.83	-0.06	0.28	-0.66 / 0.53
Test 4:	Strength	Internal rot.	0.93	0.10	1.09	-2.19 / 2.38
		External rot.	0.74	-0.32	0.95	-2.32 / 1.68
		Ratio ER/IR	0.51	-0.03	0.05	-0.13 / 0.06
Test 5:	Inclinometry	Trunk	0.03*	-3.36	1.63	-6.91 / -0.36
	(rest)	~~Clavicula~~	0.04*	-4.87	2.01	-8.81 / -0.16
Test 6:	Inclinometry	Rest	0.39	-1.44	1.62	-4.87/ 1.97
	scapular	~~30°~~	0.47	-1.45	1.95	-5.54 / 2.65
	upward	45°	0.32	-1.80	1.80	-5.48 / 1.88
	rotation	60°	0.09	-3.61	2.02	-7.81 / 0.56
		90°	0.12	-4.65	2.90	-10.46 / 1.17
		120°	0.03*	-5.77	2.50	-10.95 / -0.60
Test 7:	Inclinometry	Rest	0.91	-0.15	1.28	-2.79 / 2.48
	scapular A-P	30°	0.78	-0.45	1.55	-3.69 / 2.80
	tilt	45°	0.42	-1.28	1.53	-4.50 / 1.94
		60°	0.38	-1.51	1.69	-5.03 / 2.01
		90°	0.21	-2.01	1.54	-5.23 / 1.21
		120°	0.09	-2.47	1.41	-5.36 / 0.42
Test 8:	Maximal humerothoracic elevation		0.04*	-6.01	2.82	-11.72 / -0.30

Continued

***Continued* Table 4: results independent T-test between GIRD (N=11) and NO GIRD (N=40) group corrected regarding sufficient reliability**

	Test name		**Sig. (2-tailed)**	**Mean difference**	**Std. error difference**	**95% CI of the difference**
Test 9:	Observation rest position	Trunk LF	1.00	0.00	0.21	-0.47 / 0.47
		Trunk rotation	0.51	0.25	0.37	-0.54 / 1.04
		~~Trunk shift~~	0.91	-0.03	0.22	-0.50 / 0.45
		Scapular dyskinesis	0.70	0.07	0.17	-0.31 / 0.45
Test 10:	Observation unilateral arm movement	Trunk LF	0.32	-0.05	0.05	-0.15 / 0.05
		Trunk rotation	1.00	0.00	0.00	0.00
		Trunk shift	1.00	0.00	0.00	0.00
		Scapular dyskinesis	0.95	-0.01	0.17	-0.37 / 0.35
Test 11:	Observation bilateral arm movement	Scapular dyskinesis	0.50	0.12	0.18	-0.25 / 0.50

Abbreviations: IR= glenohumeral internal rotation; ER glenohumeral external rotation; A-P: anterior-posterior; LF (lateral flexion)

* = $p < 0.05$; ** = $p < 0.01$

Crossed measurements were not sufficient reliable (cfr. reliability study; Table 2)

DISCUSSION

Several studies have demonstrated that postural asymmetry is present in overhead athletes. This asymmetry becomes often apparent in sport-specific dynamic situations or tasks. For overhead athletes, the most relevant and frequently used dynamic task is a throwing motion. During this motion, asymmetry between dominant and non-dominant side is apparent and is related to scapular position and motion (Burkhart et al., 2003a, 2003b, 2003c; Kibler, Kuhn, et al., 2013; Maenhout et al., 2012). A loss of glenohumeral internal rotation at the dominant side has received most attention in literature because it is a key to normal force development. It also has a significant influence on glenohumeral and scapulothoracic kinematics and is often associated with shoulder injury (Burkhart et al., 2003a, 2003b, 2003c; Kibler, Kuhn, et al., 2013; Maenhout et al., 2012). The study used a glenohumeral internal rotation deficit of 15° on the dominant arm as compared to the non-dominant arm to differentiate between two study groups. To assess whether the glenohumeral and scapulothoracic kinematic differences, which are described above, could be measured with clinical tests, a measurement protocol had to be composed. For this reason, the CSMOP was composed including different clinical tests which were selected based on acceptable psychometric properties in musculoskeletal rehabilitation and our assumption of clinical relevance on glenohumeral and scapulothoracic kinematics. However, to ensure the value of this protocol in a clinical decision-making process, its inter-rater reliability and ability to discriminate between study groups needed to be assessed and confirmed.

In 11 of the 51 overhead sporting students which were measured, there was a GIRD of more than 15° present between dominant and non-dominant arm. Indicating that 21% of the total sample had an internal rotation deficit, this is comparable to other studies (Almeida et al., 2013; Whiteley & Oceguera, 2016).

Reflections on the reliability study

Despite the fact that the measurements were performed between a novice and an experienced rater, the inter-rater reliability of the CSMOP is generally acceptable. Only the pectoralis minor index (PMI), clavicular inclination at rest, inclinometry of scapular upward rotation at 30° and the observation of trunk shift in resting position were insufficient reliable and were therefore excluded from the between-groups comparison study. Borstad and Ludewig (2005) validated the PMI and Struyf et al. (2014) found a good intra-rater reliability but only a moderate inter-rater reliability for this technique. In the current study, we also found a lack of inter-rater reliability for the PMI. In our opinion, although the technique is a direct measure of the pectoralis minor length, palpation inaccuracies, rater's experience and dependence of the patient's breathing pattern have a major impact on the outcome.

The measurements concerning inclinometry of the clavicula showed unacceptable reliability. Inconsistent measurements may have been induced by clavicular S-shape. The inclinometer was held on an imaginary line between medial and lateral end of the clavicula. This perception may have caused inconsistent measurement between raters.

Regarding the tilt inclinometry measurement, Scibek and Carcia (2014) found that there was a moderate to good correlation between digital inclinometry measurements and electromagnetic tracking system measurements for scapular tilt, and confirmed as such a good criterion-based validity for inclinometry measurements for scapular tilt. Scibek and Carcia (2013) also found a high intra-rater reliability (ICC: 0.97-0.99). Our current study additionally found a rather high inter-rater reliability for inclinometry measurements for A-P tilt (ICC= 0.74-0.93). Nevertheless, we were surprised by the good inter-rater reliability results. In our view, correct positioning of the inclinometer on the medial border of the scapula in rest position and during movement were difficult, especially when a lot of lean muscle mass was present in the peri-scapular region. However, the standard deviation of all measurement positions between raters varied between 0.85-2.65°. This indicates that the within-group variability is quite low, which might account for the high ICC-scores, since low within-group variability typically results in high ICCs.

Observational clinical methods to determine scapular dyskinesis are frequently studied in musculoskeletal rehabilitation (Ellenbecker et al., 2012; Kibler, Ludewig, et al., 2013; Kibler et al., 2002; McClure, Tate, Kareha, Irwin, & Zlupko, 2009; Park et al., 2014; Uhl, Kibler, Gecewich, & Tripp, 2009). Kibler et al. (2002) described a 4-type based classification system, which was long time considered the golden standard evaluation. However, in this study we choose to use the yes/no method. This is another acceptable evaluation method which is nowadays gaining approval (McClure et al., 2009; A. R. Tate, McClure, Kareha, Irwin, &

Barbe, 2009; Uhl et al., 2009) and is easier to perform. All measurements in the protocol were sufficient reliable, with except for observation in rest position of lateral trunk shift. Our observational reliability values corresponded to scientific literature. In our opinion however, data could be influenced because the novice rater was trained by the experienced rater in advance. While performing the observations, we found this measurement rather difficult, especially in case of subtle dyskinesis or when subjects were well trained and bony landmarks were difficult to identify. Therefore we believe that this evaluation method is a rather suggestive and subjective evaluation method.

To draw conclusions concerning general applicability of this protocol, intra-rater reliability of the included tests must also be sufficiently high. Watson et al. (2005) and Johnson, McClure, and Karduna (2001) found intra-rater reliability values ranging from 0.81-0.94 for the scapular upward rotation measures in participants with and without shoulder pain. De Baets et al. (2016) found intra-rater values in the same range as the authors mentioned above in a stroke population. De Baets et al. (2016) also found high intra-rater scores for the acromial index (ICC= 0.86) and maximal humerothoracic elevation (ICC=0.99) measures. In the article of Struyf et al. (2009), the high intra-rater ICC for the acromial index was confirmed in an overhead athletes population. High intra-rater reliability for internal and external rotation strength measures were confirmed by the articles of Cools et al. (Cools et al., 2014; Cools, Vanderstukken, et al., 2015), reporting ICC-scores ranging from 0.86-0.99.
For the observational measures at rest and during movement, intra-rater reliability was varying in literature between low and high (k= 0.16-0.89) (De Baets et al., 2016; Ellenbecker et al., 2002; Kibler et al., 2002; Uhl et al., 2009). Therefore, based on our findings on inter-rater reliability and results from literature on intra-rater reliability, we consider the most tests of the CSMOP sufficiently reliable to apply on participant groups.

Reflections on the GIRD-NO GIRD comparative study

In overhead sports, the scapula plays an essential role in the functioning of the kinetic chain (integration of specific body segments and muscles). In the performance of an overhead task (like a throwing motion), the scapula is a pivotal link between central body parts, which produce stability and generate force, and smaller and more localised segments of the arm that produce mobility and perform a targeted action. Without a proper functioning kinetic chain, energy from the pelvic and trunk muscles cannot be successfully transferred (Kibler, Kuhn, et al., 2013). In our current study, we found several aspects of the kinetic chain which are different between both study groups. In the GIRD group, athletes had a significantly decreased upright thoracic posture (more kyphotic posture), a tendency towards less scapulothoracic upward rotation and less posterior tilt during arm elevation, and at glenohumeral level, there was a significantly decreased internal rotation. Maximal humerothoracic elevation was also significantly lower in the GIRD group. These results show that it is important to look at the shoulder complex as a whole in rest and during movement. It makes sense that there was significantly less internal rotation in the GIRD group in contrast to the NO GIRD group as this outcome measure was the group classification item.

Overhead athletes without GIRD stood in a more upright trunk posture, as measured by the inclinometry assessment on the sternum. This finding has not been previously investigated in research. However, an increased thoracic forward posture is an important factor contributing to the alteration of scapulohumeral kinematics, the limitation of the glenohumeral range of motion (Kebaetse, McClure, & Pratt, 1999) and the development of shoulder pain (Borstad & Ludewig, 2006). A possible explanation for this more forward inclined position of the sternum in the GIRD group could be the shortening of the pectoral muscles (Wang, McClure, Pratt, & Nobilini, 1999). A valid and reliable measurement of the PMI would be of added value to confirm this hypothesis. Another possible explanation would be a muscular imbalance between the anterior and posterior chain of the scapulothoracic musculature. Due to the more slouched position, posterior scapular stabilising muscles could become elongated and weak (lower trapezius and serratus anterior) and the pectoral muscles on the anterior side shortened and hypertonic (Cools et al., 2014).

Cools et al. (2014) stated in their study that an appropriate intermuscular strength balance in the glenohumeral rotators must be attained in order to prevent that strength imbalance becomes a risk factor for the development of shoulder pathology. This article reports that in a population with overhead athletes, an external rotation (ER)/internal rotation (IR) ratio of 75% is advised. Therefore we used the strength measurements as described in the same article to assess this possible risk factor. No difference between groups was found on isometric strength measures for internal rotation (IR), external rotation (ER) and ratio

(ER/IR). However, we notice that the average strength ratio was 83% (SD= ±12,6%). This means that both participant groups achieved a score that was higher than the cut-off value advised in literature (75%) on their dominant side (Cools et al, 2014). An important reflection on these data is the fact that none of the participants reported shoulder pain before, during or after the tests. Struyf, Nijs, De Graeve, et al. (2011) stated that shoulder pain is an interfering factor during strength testing and will underestimate true shoulder strength. Neuromuscular strategies around the shoulder girdle will also change when a subject is experiencing shoulder pain (Struyf, Nijs, Baeyens, Mottram, & Meeusen, 2011). It is possible that results would be different between groups when overhead athletes with pain would be recruited. Thus, when shoulder pain is present in overhead athletes, we expect to see a decreased strength output independently from the presence or absence of GIRD.

With regard to scapular upward rotation and posterior tilt, the difference between groups increases with an increase in arm abduction. A significant reduced scapular upward rotation of 5.77° at 120° abduction and a tendency toward less posterior tilt is seen in the GIRD group. These slightly different scapular motion patterns between groups were also found in other scientific publications. Laudner, Moline, and Meister (2010), Borich et al. (2006) and Thomas et al. (2010) found, by means of 3D motion analysis techniques, an increased anterior tilt and decreased scapular upward rotation in overhead athletes with posterior shoulder tightness. Our clinical measurement techniques show the same trend and provide as such the opportunity to measure in a clinical setting. This makes it easy-to-use, inexpensive and increases the applicability. The tendency towards decreased posterior tilt and decreased scapular upward rotation could be due to the repetitive throwing actions on the dominant side (Cools et al., 2010; A. Tate et al., 2012), potentially leading to a shortened pectoralis minor (PM), and weakened lower trapezius (LT) and serratus anterior (SA). Based on this information, we would suspect a significant difference between groups for scapular dyskinesis. This was however not the case. Perhaps, we could argue that the altered motion seen in the inclinometry tests for the GIRD group simply represent a kinematic adaptation due to the repetitive throwing. This adaption seems furthermore successive since the athletes are pain free. When shoulder pain would be present, an aberrant kinetic pattern of the scapula would be more obvious (Struyf et al., 2009). Stretching of the pectoralis minor (PM) and restoring the strength ratio between upper trapezius (UT)/lower trapezius (LT) and

UT/serratus anterior (SA) are widely studied rehabilitation techniques to address scapular dyskinesis (winging – tipping of the scapula) and normalize the scapulohumeral rhythm (Cools et al., 2007). However, recently McQuade et al (2016) stated in their perspective on scapular stabilization that the scapulohumeral rhythm is very task-, context- and motion specific and that a dynamic equilibrium of muscle forces, and not equal forces is needed to prevent an aberrant scapular movement pattern. Given that our participants did not experienced pain, one might doubt to give preventive stretching and exercise therapy and potentially influence a dynamic equilibrium. However, learning to conscious control scapular position (perhaps with the use of visual biofeedback) remains a good method to address the scapulothoracic muscle activation, especially when a pathologic shoulder condition is present.

The presence of the significant difference in favour of the NO GIRD group for maximal humerothoracic elevation may also be linked to the altered scapular movement pattern and the increased trunk inclination. However, the influence of the acromioclavicular joint (AC), the lumbar spine and external rotation in the glenohumeral joint must be considered as well to rule out compensations in other joints to cope with the motion deficit.

It is striking that the range of motion restriction seen in the scapulothoracic joint, i.e. less scapular upward rotation, in the GIRD group is not compensated in the glenohumeral joint, i.e. humerothoracic elevation (sum of glenohumeral and scapulothoracic motion) was also less in the GIRD group. This can possibly be an additional reason why the athletes in our study were pain free. Our sample of participants mainly consisted of recreational overhead athletes. Glenohumeral compensations for scapulothoracic limitations or visa versa, would probably be more present in elite athletes because they are being challenged daily to find their range of movement limits in order to gain an optimal performance. The fact that the ER/IR ratio was high, can furthermore explain the fact that pain was absent in this sample. It must be said that other joints, where compensation could take place, were not assessed in this study, i.e. the lumbar spine, acromioclavicular joint and glenohumeral external rotation. Future research definitely needs to integrate range of motion measurements in these regions.

Limitations

Since many included tests have to be carried out by two persons, they are not always easy to use in clinical practice. Furthermore, the large difference in number of subjects between the GIRD and NO GIRD group might have influenced results. Moreover, for an optimal study power, each study group should include 15 participants. Unfortunately, we could only include 11 overhead athletes with GIRD due to time limits. Finally, the shoulder range of motion is dose and exposure dependent, i.e. shoulder internal rotation reduces after years of throwing exposure, throughout the competitive season and acute after a throwing motion (Kibler et al, 2012; Reinold et al, 2008). In this sample size, seven participants were narrowly assigned to the NO GIRD group (12-14° deficit). When participants took part in overhead sporting activities the day preceding the measurements, this could have influenced the results of the glenohumeral internal rotation measurement in a positive or negative direction.

Strengths

We were able to set up a small study in a short period of time. The reliability study showed acceptable reliability for the protocol between a novice and experienced rater. In this way, the protocol demonstrates a high clinical applicability, i.e. a 4h training session is enough to make use the measurements in the CSMOP in a trustworthy manner. Measures which were insufficient reliable were removed from the CSMOP and therefore only test with a sufficient inter-rater and intra-rater reliability were used in the GIRD – NO GIRD comparative study.

Future perspectives

It is appropriate to develop alternative tests to assess the pectoralis minor length and the clavicular inclination, given the clinical importance of these measures. It would also be interesting to test the protocol in a larger sample, a more equal subdivision of subjects between groups or a subdivision of groups based on type of sport. This would give a better understanding of possible varying scapular movement patterns between types of sport measured in a clinical setting. Another interesting addition in future research would be the identification of cut-off values between normal and aberrant scapular movement patterns. Especially when subjects would be recruited with the presence of shoulder pain.

The CSMOP could be further optimized with the addition of range of motion measurements of the lumbar spine, the acromioclavicular joint and the glenohumeral external rotation.

CONCLUSION

An easy and clinically applicable protocol (CSMOP) was composed consisting of eleven tests to assess scapulothoracic motion and movement patterns. The reliability study showed a good inter-tester reliability for all included tests except for the PMI, clavicular inclination at rest, inclinometry of scapular upward rotation at 30° and the observation of trunk shift in resting position. The application of this CSMOP in the comparative study between overhead athletes with and without GIRD showed that the GIRD group had less glenohumeral internal rotation, an decreased upright trunk position (increased kyphosis), a trend towards less scapular upward rotation and less posterior tilt during arm elevation, and a decreased maximal humerothoracic elevation at the dominant arm side. It must be noticed that none of the athletes experienced shoulder pain. In this way, the adaptations of the body to move in a more rigid kinetic chain can possibly be a protecting reaction to prevent pain and overcompensation in other joints. Clearly, findings in this study demonstrate that in overhead athletes, attention must be paid in the assessment and rehabilitation, to the whole kinetic chain instead of an isolated glenohumeral view.

REFERENCES

Almeida, G. P., Silveira, P. F., Rosseto, N. P., Barbosa, G., Ejnisman, B., & Cohen, M. (2013). Glenohumeral range of motion in handball players with and without throwing-related shoulder pain. *J Shoulder Elbow Surg, 22*(5), 602-607. doi: 10.1016/j.jse.2012.08.027

Amin, N. H., Ryan, J., Fening, S. D., Soloff, L., Schickendantz, M. S., & Jones, M. (2015). The Relationship Between Glenohumeral Internal Rotational Deficits, Total Range of Motion, and Shoulder Strength in Professional Baseball Pitchers. *J Am Acad Orthop Surg, 23*(12), 789-796. doi: 10.5435/JAAOS-D-15-00292

Bigliani, L. U., Codd, T. P., Connor, P. M., Levine, W. N., Littlefield, M. A., & Hershon, S. J. (1997). Shoulder motion and laxity in the professional baseball player. *Am J Sports Med, 25*(5), 609-613.

Borich, M. R., Bright, J. M., Lorello, D. J., Cieminski, C. J., Buisman, T., & Ludewig, P. M. (2006). Scapular angular positioning at end range internal rotation in cases of glenohumeral internal rotation deficit. *J Orthop Sports Phys Ther, 36*(12), 926-934. doi: 10.2519/jospt.2006.2241

Borstad, J. D., & Ludewig, P. M. (2005). The effect of long versus short pectoralis minor resting length on scapular kinematics in healthy individuals. *J Orthop Sports Phys Ther, 35*(4), 227-238. doi: 10.2519/jospt.2005.35.4.227

Borstad, J. D., & Ludewig, P. M. (2006). Comparison of three stretches for the pectoralis minor muscle. *J Shoulder Elbow Surg, 15*(3), 324-330. doi: 10.1016/j.jse.2005.08.011

Burkhart, S. S., Morgan, C. D., & Kibler, W. B. (2003a). The disabled throwing shoulder: spectrum of pathology Part I: pathoanatomy and biomechanics. *Arthroscopy, 19*(4), 404-420. doi: 10.1053/jars.2003.50128

Burkhart, S. S., Morgan, C. D., & Kibler, W. B. (2003b). The disabled throwing shoulder: spectrum of pathology Part III: The SICK scapula, scapular dyskinesis, the kinetic chain, and rehabilitation. *Arthroscopy, 19*(6), 641-661.

Burkhart, S. S., Morgan, C. D., & Kibler, W. B. (2003c). The disabled throwing shoulder: spectrum of pathology. Part II: evaluation and treatment of SLAP lesions in throwers. *Arthroscopy, 19*(5), 531-539. doi: 10.1053/jars.2003.50139

Cools, A. M., De Wilde, L., Van Tongel, A., Ceyssens, C., Ryckewaert, R., & Cambier, D. C. (2014). Measuring shoulder external and internal rotation strength and range of motion: comprehensive intra-rater and inter-rater reliability study of several testing protocols. *J Shoulder Elbow Surg, 23*(10), 1454-1461. doi: 10.1016/j.jse.2014.01.006

Cools, A. M., Dewitte, V., Lanszweert, F., Notebaert, D., Roets, A., Soetens, B., . . . Witvrouw, E. E. (2007). Rehabilitation of scapular muscle balance: which exercises to prescribe? *Am J Sports Med, 35*(10), 1744-1751. doi: 10.1177/0363546507303560

Cools, A. M., Johansson, F. R., Borms, D., & Maenhout, A. (2015). Prevention of shoulder injuries in overhead athletes: a science-based approach. *Braz J Phys Ther*, 0. doi: 10.1590/bjpt-rbf.2014.0109

Cools, A. M., Johansson, F. R., Cambier, D. C., Velde, A. V., Palmans, T., & Witvrouw, E. E. (2010). Descriptive profile of scapulothoracic position, strength and flexibility variables in adolescent elite tennis players. *Br J Sports Med, 44*(9), 678-684. doi: 10.1136/bjsm.2009.070128

Cools, A. M., Vanderstukken, F., Vereecken, F., Duprez, M., Heyman, K., Goethals, N., & Johansson, F. (2015). Eccentric and isometric shoulder rotator cuff strength testing using a hand-held dynamometer: reference values for overhead athletes. *Knee Surg Sports Traumatol Arthrosc*. doi: 10.1007/s00167-015-3755-9

Couppe, C., Thorborg, K., Hansen, M., Fahlstrom, M., Bjordal, J. M., Nielsen, D., . . . Magnusson, S. P. (2014). Shoulder rotational profiles in young healthy elite female and male badminton players. *Scand J Med Sci Sports, 24*(1), 122-128. doi: 10.1111/j.1600-0838.2012.01480.x

Crockett, H. C., Gross, L. B., Wilk, K. E., Schwartz, M. L., Reed, J., O'Mara, J., . . . Andrews, J. R. (2002). Osseous adaptation and range of motion at the glenohumeral joint in professional baseball pitchers. *Am J Sports Med, 30*(1), 20-26.
De Baets, L., Jaspers, E., & Van Deun, S. (2016). Scapulohumeral control after stroke: A preliminary study of the test-retest reliability and discriminative validity of a clinical scapular protocol (ClinScaP). *NeuroRehabilitation*. doi: 10.3233/NRE-161327
Ellenbecker, T. S., Kibler, W. B., Bailie, D. S., Caplinger, R., Davies, G. J., & Riemann, B. L. (2012). Reliability of scapular classification in examination of professional baseball players. *Clin Orthop Relat Res, 470*(6), 1540-1544. doi: 10.1007/s11999-011-2216-0
Ellenbecker, T. S., Roetert, E. P., Bailie, D. S., Davies, G. J., & Brown, S. W. (2002). Glenohumeral joint total rotation range of motion in elite tennis players and baseball pitchers. *Med Sci Sports Exerc, 34*(12), 2052-2056. doi: 10.1249/01.MSS.0000039301.69917.0C
Harryman, D. T., 2nd, Sidles, J. A., Clark, J. M., McQuade, K. J., Gibb, T. D., & Matsen, F. A., 3rd. (1990). Translation of the humeral head on the glenoid with passive glenohumeral motion. *J Bone Joint Surg Am, 72*(9), 1334-1343.
Johnson, M. P., McClure, P. W., & Karduna, A. R. (2001). New method to assess scapular upward rotation in subjects with shoulder pathology. *J Orthop Sports Phys Ther, 31*(2), 81-89. doi: 10.2519/jospt.2001.31.2.81
Kebaetse, M., McClure, P., & Pratt, N. A. (1999). Thoracic position effect on shoulder range of motion, strength, and three-dimensional scapular kinematics. *Arch Phys Med Rehabil, 80*(8), 945-950.
Kibler, W. B., Kuhn, J. E., Wilk, K., Sciascia, A., Moore, S., Laudner, K., . . . Uhl, T. (2013). The disabled throwing shoulder: spectrum of pathology-10-year update. *Arthroscopy, 29*(1), 141-161 e126. doi: 10.1016/j.arthro.2012.10.009
Kibler, W. B., Ludewig, P. M., McClure, P. W., Michener, L. A., Bak, K., & Sciascia, A. D. (2013). Clinical implications of scapular dyskinesis in shoulder injury: the 2013 consensus statement from the 'Scapular Summit'. *Br J Sports Med, 47*(14), 877-885. doi: 10.1136/bjsports-2013-092425
Kibler, W. B., Uhl, T. L., Maddux, J. W., Brooks, P. V., Zeller, B., & McMullen, J. (2002). Qualitative clinical evaluation of scapular dysfunction: a reliability study. *J Shoulder Elbow Surg, 11*(6), 550-556. doi: 10.1067/mse.2002.126766
Kinsella, S. D., Thomas, S. J., Huffman, G. R., & Kelly, J. D. t. (2014). The thrower's shoulder. *Orthop Clin North Am, 45*(3), 387-401. doi: 10.1016/j.ocl.2014.04.003
Laudner, K. G., Moline, M. T., & Meister, K. (2010). The relationship between forward scapular posture and posterior shoulder tightness among baseball players. *Am J Sports Med, 38*(10), 2106-2112. doi: 10.1177/0363546510370291
Ludewig, P. M., Phadke, V., Braman, J. P., Hassett, D. R., Cieminski, C. J., & LaPrade, R. F. (2009). Motion of the shoulder complex during multiplanar humeral elevation. *J Bone Joint Surg Am, 91*(2), 378-389. doi: 10.2106/JBJS.G.01483
Maenhout, A., Van Eessel, V., Van Dyck, L., Vanraes, A., & Cools, A. (2012). Quantifying acromiohumeral distance in overhead athletes with glenohumeral internal rotation loss and the influence of a stretching program. *Am J Sports Med, 40*(9), 2105-2112. doi: 10.1177/0363546512454530
McClure, P., Tate, A. R., Kareha, S., Irwin, D., & Zlupko, E. (2009). A clinical method for identifying scapular dyskinesis, part 1: reliability. *J Athl Train, 44*(2), 160-164. doi: 10.4085/1062-6050-44.2.160
McQuade, K. J., Borstad, J., & de Oliveira, A. S. (2016). Critical and Theoretical Perspective on Scapular Stabilization: What Does It Really Mean, and Are We on the Right Track? *Phys Ther*. doi: 10.2522/ptj.20140230
Meister, K. (2000). Injuries to the shoulder in the throwing athlete. Part one: Biomechanics/pathophysiology/classification of injury. *Am J Sports Med, 28*(2), 265-275.

Mohseni-Bandpei, M. A., Keshavarz, R., Minoonejhad, H., Mohsenifar, H., & Shakeri, H. (2012). Shoulder pain in Iranian elite athletes: the prevalence and risk factors. *J Manipulative Physiol Ther, 35*(7), 541-548. doi: 10.1016/j.jmpt.2012.07.011

Myers, J. B., Laudner, K. G., Pasquale, M. R., Bradley, J. P., & Lephart, S. M. (2006). Glenohumeral range of motion deficits and posterior shoulder tightness in throwers with pathologic internal impingement. *Am J Sports Med, 34*(3), 385-391. doi: 10.1177/0363546505281804

Nijs, J., Roussel, N., Struyf, F., Mottram, S., & Meeusen, R. (2007). Clinical assessment of scapular positioning in patients with shoulder pain: state of the art. *J Manipulative Physiol Ther, 30*(1), 69-75. doi: 10.1016/j.jmpt.2006.11.012

Nijs, J., Roussel, N., Vermeulen, K., & Souvereyns, G. (2005). Scapular positioning in patients with shoulder pain: a study examining the reliability and clinical importance of 3 clinical tests. *Arch Phys Med Rehabil, 86*(7), 1349-1355.

Noonan, T. J., Shanley, E., Bailey, L. B., Wyland, D. J., Kissenberth, M. J., Hawkins, R. J., & Thigpen, C. A. (2015). Professional Pitchers With Glenohumeral Internal Rotation Deficit (GIRD) Display Greater Humeral Retrotorsion Than Pitchers Without GIRD. *Am J Sports Med, 43*(6), 1448-1454. doi: 10.1177/0363546515575020

Park, J. Y., Hwang, J. T., Oh, K. S., Kim, S. J., Kim, N. R., & Cha, M. J. (2014). Revisit to scapular dyskinesis: three-dimensional wing computed tomography in prone position. *J Shoulder Elbow Surg, 23*(6), 821-828. doi: 10.1016/j.jse.2013.08.016

Reagan, K. M., Meister, K., Horodyski, M. B., Werner, D. W., Carruthers, C., & Wilk, K. (2002). Humeral retroversion and its relationship to glenohumeral rotation in the shoulder of college baseball players. *Am J Sports Med, 30*(3), 354-360.

Scibek, J. S., & Carcia, C. R. (2013). Validation and repeatability of a shoulder biomechanics data collection methodology and instrumentation. *J Appl Biomech, 29*(5), 609-615.

Scibek, J. S., & Carcia, C. R. (2014). Validation of a new method for assessing scapular anterior-posterior tilt. *Int J Sports Phys Ther, 9*(5), 644-656.

Struyf, F., Meeus, M., Fransen, E., Roussel, N., Jansen, N., Truijen, S., & Nijs, J. (2014). Interrater and intrarater reliability of the pectoralis minor muscle length measurement in subjects with and without shoulder impingement symptoms. *Man Ther, 19*(4), 294-298. doi: 10.1016/j.math.2014.04.005

Struyf, F., Nijs, J., Baeyens, J. P., Mottram, S., & Meeusen, R. (2011). Scapular positioning and movement in unimpaired shoulders, shoulder impingement syndrome, and glenohumeral instability. *Scand J Med Sci Sports, 21*(3), 352-358. doi: 10.1111/j.1600-0838.2010.01274.x

Struyf, F., Nijs, J., De Coninck, K., Giunta, M., Mottram, S., & Meeusen, R. (2009). Clinical assessment of scapular positioning in musicians: an intertester reliability study. *J Athl Train, 44*(5), 519-526. doi: 10.4085/1062-6050-44.5.519

Struyf, F., Nijs, J., De Graeve, J., Mottram, S., & Meeusen, R. (2011). Scapular positioning in overhead athletes with and without shoulder pain: a case-control study. *Scand J Med Sci Sports, 21*(6), 809-818. doi: 10.1111/j.1600-0838.2010.01115.x

Suzuki, Y., Kawai, H., Kojima, M., Shiba, Y., Yoshida, H., Hirano, H., . . . Obuchi, S. (2015). Construct validity of posture as a measure of physical function in elderly individuals: Use of a digitalized inclinometer to assess trunk inclination. *Geriatr Gerontol Int*. doi: 10.1111/ggi.12600

Tate, A., Turner, G. N., Knab, S. E., Jorgensen, C., Strittmatter, A., & Michener, L. A. (2012). Risk factors associated with shoulder pain and disability across the lifespan of competitive swimmers. *J Athl Train, 47*(2), 149-158.

Tate, A. R., McClure, P., Kareha, S., Irwin, D., & Barbe, M. F. (2009). A clinical method for identifying scapular dyskinesis, part 2: validity. *J Athl Train, 44*(2), 165-173. doi: 10.4085/1062-6050-44.2.165

Thomas, S. J., Swanik, K. A., Swanik, C., Huxel, K. C., & Kelly, J. D. t. (2010). Change in glenohumeral rotation and scapular position after competitive high school baseball. *J Sport Rehabil, 19*(2), 125-135.

Tyler, T. F., Nicholas, S. J., Roy, T., & Gleim, G. W. (2000). Quantification of posterior capsule tightness and motion loss in patients with shoulder impingement. *Am J Sports Med, 28*(5), 668-673.

Uhl, T. L., Kibler, W. B., Gecewich, B., & Tripp, B. L. (2009). Evaluation of clinical assessment methods for scapular dyskinesis. *Arthroscopy, 25*(11), 1240-1248. doi: 10.1016/j.arthro.2009.06.007

Wang, C. H., McClure, P., Pratt, N. E., & Nobilini, R. (1999). Stretching and strengthening exercises: their effect on three-dimensional scapular kinematics. *Arch Phys Med Rehabil, 80*(8), 923-929.

Watson, L., Balster, S. M., Finch, C., & Dalziel, R. (2005). Measurement of scapula upward rotation: a reliable clinical procedure. *Br J Sports Med, 39*(9), 599-603. doi: 10.1136/bjsm.2004.013243

Whiteley, R., & Oceguera, M. (2016). GIRD, TRROM, and humeral torsion-based classification of shoulder risk in throwing athletes are not in agreement and should not be used interchangeably. *J Sci Med Sport*. doi: 10.1016/j.jsams.2015.12.519

APPENDIX A: Illustrations of included tests in the CSMOP

Figure 1: Test 1: Glenohomeral internal rotation

Figure 2: Test 2: Acromial index (AI)

Figure 3 – 4: Test 3: Pectoralis minor index (PMI)

Figure 5 – 6: Test 4: Internal rotation strength

External rotation strength

Figure 7 – 8: Test 5: Forward trunk inclination at rest

Clavicula inclination at rest

Figure 9 – 10: Test 6: Scapular upward rotation

Figure 11 – 12: Test 7: Anterior-Posterior (AP) scapular tilt

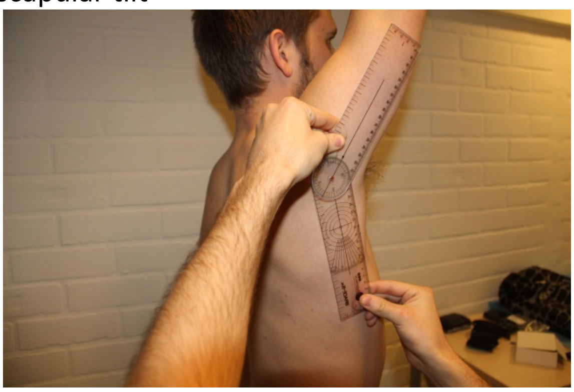

Figure 13: Test 8: Maximal humerothoracic elevation

Figure 14: Test 9: Observation of trunk and scapular dyskinesis at rest position

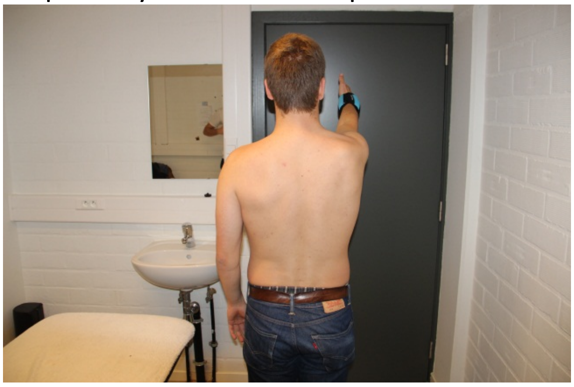

Figure 15: Test 10: Obersvation of trunk and scapular dyskinesis during unilateral arm movement

Figure 16: Test 11: Observation of trunk and scapular dyskinesis during bilateral arm movement

APPENDIX B

- Appendix Table 1: Descriptive statistics retrieved for the reliability study (normative data)
- Appendix Table 2: Descriptive statistics retrieved for the reliability study (ordinal data)
- Appendix Table 3: Descriptive statistics of the CSMOP for the GIRD and NO GIRD group (normative data)
- Appendix Table 4: Descriptive statistics of the CSMOP for the GIRD and NO GIRD group (ordinal data)

Appendix Table 1: Descriptive statistics retrieved for the reliability study (normative data)

	Test name			Mean	SD
Test 1:	Internal rotation (°)		Rater 1	52.42	10.45
			Rater 2	52.17	12.01
Test 2:	Acromial index/length (cm)		Rater 1	3.98	1.36
			Rater 2	3.94	1.38
Test 3:	Pectoralis minor /length (cm)		Rater 1	8.94	0.66
			Rater 2	8.51	0.87
Test 4:	Strength (kg)	Internal rotation	Rater 1	14.80	4.88
			Rater 2	14.95	4.26
		External rotation	Rater 1	11.48	4.18
			Rater 2	11.95	3.96
		Ratio ER/IR	Rater 1	0.79	0.16
			Rater 2	0.80	0.15
Test 5:	Inclinometry (rest) (°)	Trunk	Rater 1	16.83	4.76
			Rater 2	17.58	4.58
		Clavicula	Rater 1	8.67	3.70
			Rater 2	8.42	3.00
Test 6:	Inclinometry scapular upward rotation (°)	Rest	Rater 1	-4	2.95
			Rater 2	-4.67	4.01
		30°	Rater 1	-0.67	3.77
			Rater 2	-0.42	3.68
		45°	Rater 1	3.42	4.64
			Rater 2	4	4.43
		60°	Rater 1	9.25	5.01
			Rater 2	9.00	5.04
		90°	Rater 1	20.25	5.61
			Rater 2	18.91	5.33
		120°	Rater 1	33.58	5.23
			Rater 2	32.58	5.88

continued

***Continued* Appendix Table 1: Descriptive statistics retrieved for the reliability study (normative data)**

Test name				**Mean**	**SD**
Test 7:	Inclinometry scapular A-P tilt (°)	Rest	Rater 1	15.33	5.55
			Rater 2	15.25	7.35
		30°	Rater 1	10.92	5.03
			Rater 2	12.58	5.88
		45°	Rater 1	7.67	4.90
			Rater 2	9.08	6.20
		60°	Rater 1	4.67	4.87
			Rater 2	6.17	7.52
		90°	Rater 1	0.33	6.58
			Rater 2	-0.42	7.37
		120°	Rater 1	-6.08	6.80
			Rater 2	-5.33	9.08
Test 8:	Maximal humerothoracic elevation (°)		Rater 1	147.17	6.06
			Rater 2	148.75	10.29

Abbreviations: ER= glenohumeral external rotation; IR= glenohumeral internal rotation; A-P= anterior-posterior; LF= lateral flexion

Appendix Table 2: Descriptive statistics retrieved for the reliability study (ordinal data)

	Test name			Score (in %)				
				1a	2	3	0	1b
Test 9	Observation in rest position	Trunk LF	Rater 1	72.7	18.2	9.1		
			Rater 2	72.7	18.2	9.1		
		Trunk rotation	Rater 1	27.3	0	72.7		
			Rater 2	36.4	0	63.6		
		Trunk shift	Rater 1	72.7	0	27.3		
			Rater 2	72.7	9.1	18.2		
		Scapular dyskinesis	Rater 1				58.3	41.7
			Rater 2				58.3	41.7
Test 10	Observation in unilateral arm movement	Trunk LF	Rater 1	100	0	0		
			Rater 2	100	0	0		
		Trunk rotation	Rater 1	100	0	0		
			Rater 2	100	0	0		
		Trunk shift	Rater 1	100	0	0		
			Rater 2	90.9	0	9.1		
		Scapular dyskinesis	Rater 1				81.8	18.2
			Rater 2				72.7	27.3
Test 11	Observation bilateral arm movement	Scapular dyskinesis	Rater 1				72.7	27.3
			Rater 2				72.7	27.3

Abbreviations: 1a= no deviation; 2= deviation left; 3= deviation right; 0= dyskinesis absent; 1b= dyskinesis present; LF= lateral flexion

Appendix Table 3: Descriptive statistics of the CSMOP for the GIRD and NO GIRD group (normative data)

				Mean	SD
Test 1:	Internal rotation (°)		GIRD	46.81	10.48
			NO GIRD	58.57	7.48
Test 2:	Acromial index/length (cm)		GIRD	4.33	0.71
			NO GIRD	4.60	0.83
Test 3:	Pectoralis minor /length (cm)		GIRD	8.98	0.83
			NO GIRD	9.05	0.77
Test 4:	Strength (kg)	Internal rotation	GIRD	14.44	3.02
			NO GIRD	14.35	3.85
		External rotation	GIRD	11.64	2.66
			NO GIRD	11.96	3.26
		Ratio ER/IR	GIRD	0.81	0.13
			NO GIRD	0.84	0.13
Test 5:	Inclinometry (rest) (°)	Trunk	GIRD	16.09	2.02
			NO GIRD	19.73	5.27
		Clavicula	GIRD	5.36	6.17
			NO GIRD	9.85	4.81
Test 6:	Inclinometry scapular upward rotation (°)	Rest	GIRD	-3.09	4.66
			NO GIRD	-1.65	5.20
		30°	GIRD	-0.54	5.50
			NO GIRD	0.9	6.50
		45°	GIRD	3.72	4.69
			NO GIRD	5.53	6.82
		60°	GIRD	8.09	5.56
			NO GIRD	11.70	7.07
		90°	GIRD	20.27	5.35
			NO GIRD	24.93	9.15
		120°	GIRD	35.27	6.63
			NO GIRD	41.5	9.47

continued

***Continued* Appendix A Table 3: Descriptive statistics of the CSMOP for the GIRD and NO GIRD group (normative data)**

				Mean	**SD**
Test 7:	Inclinometry	Rest	GIRD	15.27	3.32
	Scapular A-P		NO GIRD	15.43	5.01
	tilt (°)	30°	GIRD	11.45	4.32
			NO GIRD	11.90	5.30
		45°	GIRD	8.27	4.26
			NO GIRD	9.55	5.37
		60°	GIRD	4.81	4.81
			NO GIRD	6.33	5.20
		90°	GIRD	0.63	4.27
			NO GIRD	2.65	5.35
		120°	GIRD	-4.09	3.44
			NO GIRD	-1.63	6.05
Test 8:	Maximal humerothoracic elevation (°)		GIRD	143.09	4.32
			NO GIRD	149.10	9.09

Abbreviations: ER= glenohumeral external rotation; IR= glenohumeral internal rotation; A-P= anterior-posterior; LF= lateral flexion

Appendix Table 4: Descriptive statistics of the CSMOP for the GIRD and NO GIRD group (ordinal data)

				Score in %				
				1a	2	3	0	1b
Test 9:	Observation rest position	Trunk LF	GIRD	90.9	0	9.1		
			NO GIRD	87.5	5	7.5		
		Trunk rotation	GIRD	63.6	0	36.4		
			NO GIRD	62.5	0	37.5		
		Trunk shift	GIRD	81.8	0	18.2		
			NO GIRD	87.5	2.5	10		
		Scapular dyskinesis	GIRD				54.5	45.5
			NO GIRD				52.5	47.5
Test 10:	Observation unilateral arm movement	Trunk LF	GIRD	100	0	0		
			NO GIRD	97.5	0	2.5		
		Trunk rotation	GIRD	100	0	0		
			NO GIRD	100	0	0		
		Trunk shift	GIRD	100	0	0		
			NO GIRD	100	0	0		
		Scapular dyskinesis	GIRD				54.5	45.5
			NO GIRD				62.5	37.5
Test 11:	Observation bilateral arm movement	Scapular dyskinesis	GIRD				45.5	54.5
			NO GIRD				57.5	42.5

Abbreviations: 1a= no deviation; 2= deviation left; 3= deviation right; 0= dyskinesis absent; 1b= dyskinesis present; LF= lateral flexion

Auteursrechtelijke overeenkomst

Ik/wij verlenen het wereldwijde auteursrecht voor de ingediende eindverhandeling:
Evaluation of scapulothoracic kinematics in overhead athletes with and without GIRD based on a clinical measurement protocol: a reliability and cross-sectional study

Richting: **master in de revalidatiewetenschappen en de kinesitherapie-revalidatiewetenschappen en kinesitherapie bij musculoskeletale aandoeningen**
Jaar: **2016**

in alle mogelijke mediaformaten, - bestaande en in de toekomst te ontwikkelen - , aan de Universiteit Hasselt.

Niet tegenstaand deze toekenning van het auteursrecht aan de Universiteit Hasselt behoud ik als auteur het recht om de eindverhandeling, - in zijn geheel of gedeeltelijk -, vrij te reproduceren, (her)publiceren of distribueren zonder de toelating te moeten verkrijgen van de Universiteit Hasselt.

Ik bevestig dat de eindverhandeling mijn origineel werk is, en dat ik het recht heb om de rechten te verlenen die in deze overeenkomst worden beschreven. Ik verklaar tevens dat de eindverhandeling, naar mijn weten, het auteursrecht van anderen niet overtreedt.

Ik verklaar tevens dat ik voor het materiaal in de eindverhandeling dat beschermd wordt door het auteursrecht, de nodige toelatingen heb verkregen zodat ik deze ook aan de Universiteit Hasselt kan overdragen en dat dit duidelijk in de tekst en inhoud van de eindverhandeling werd genotificeerd.

Universiteit Hasselt zal mij als auteur(s) van de eindverhandeling identificeren en zal geen wijzigingen aanbrengen aan de eindverhandeling, uitgezonderd deze toegelaten door deze overeenkomst.

Voor akkoord,

Didden, Matthias **Vanhees, Bram**