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Mackenzie Tanya Anne
Salford University, Health, Sports and Rehabilitation Sciences, Manchester, United Kingdom, M5 4WT.

Bdaiwi Alya
Salford University, Health, Sports and Rehabilitation Sciences, Manchester, United Kingdom, M5 4WT.

Herrington Lee
Salford University, Health, Sports and Rehabilitation Sciences, Manchester, United Kingdom, M5 4WT.

Cools Ann
Ghent University Dept of Rehabilitation Science and Physiotherapy, Belgium.

Correspondence:
Bdaiwi Alya
Salford University, Health, Sports and Rehabilitation Sciences, Manchester, United Kingdom, M5 4WT.

The palpation meter (palm) is reliable for measuring scapular upward rotation in the coronal plane

Mackenzie Tanya Anne, Bdaiwi Alya, Herrington Lee, Cools Ann

Abstract
The objective of the study was to assess intra-session inter-rater reliability of the palpation meter (PALM) to assess scapular position in the coronal plane. Twenty shoulders of 10 asymptomatic participants (4 males, 6 females) were screened. The mean age of the participants was 29.86 years (STD = 7.8 years). PALM measurements were used to calculate the rotation angle of the scapula in the coronal plane. Intra- and inter-rater reliability intraclass correlation coefficients ($ICC_{3.1}$ and $ICC_{2.1}$) were calculated. Measurement error was evaluated via calculation of standard error of measure and minimal detectable change. $ICC_{2.1}$ scores ranged between 0.74 to 0.88 (SEM= 0.18cm-0.20cm, $MDC_{95\%}$=0.50cm-0.55cm) for inter-rater reliability for PALM measurements. It was concluded that the palmmeter was has excellent intra-reliability and good inter-rater reliability as a tool to measure horizontal distance of the scapula from the spine. These measures can be used to calculate scapular rotation. These methods developed to quantify scapular rotation could provide an objective measure of scapular rotation which is inexpensive, practical and easy to perform.

Keywords: glenohumeral joint, palpation meter (PALM), scapula

1. Introduction

Abnormalities in scapular kinematics, particularly decreased upward scapular rotation, have been associated with various shoulder pathologies in studies comparing healthy shoulders with those of patients with impingement syndrome and rotator cuff tendinopathy [1–6].

Underlying some of the fundamental principles in shoulder girdle rehabilitation are the following concepts: that upward rotation of the scapula is clinically important to prevent the humeral head from compressing and shearing against the under-surface of the acromion process during humeral elevation [4, 7]; that congruity of the glenoid and head of humerus, and centring of the axis of rotation and stability of the glenohumeral joint, are dependent on scapular position [8]; that control of length/tension relationships between the scapular and glenohumeral muscles is affected by scapular position [7, 9]; that abnormal scapular movement is associated with glenohumeral instability and subacromial impingement syndrome [7]. Consequently, observation and measurement of the static scapular position is considered essential in the clinical examination when investigating shoulder pathology.

Many studies [10–13] have used different techniques and tools to quantify scapular rotation. Three dimensional motion analysis [3, 5, 14–17] has been used, however, this is expensive, time consuming, and requires specialised software programs, hence it is not easily transferable to the clinical setting [18]. Other tools used include: inclinometer [7, 19–22], scoliometer [13, 23], callipers [13, 21], radiography [24], photography, tape measurement [10], and the palpation meter (PALM) [25, 26]. Previous reliability studies using these tools are summarised in Tables 1-2., the authors of these studies report that their methods are reliable and can be easily applied in the clinical setting, are cost, and practically effective. Despite authors reporting good reliability, the clinical value of scapular lateral displacement measurements or lateral scapular slide test (LSST) has been questioned. Previous authors [12, 11], report low sensitivity (28%-50%), and low specificity (35, 2%-58%) of these measures, finding no relationship between LSST and pain severity or the shoulder disability index. It is proposed that these measures would be more useful if used to calculate the rotation angle of the scapula.

The PALM (performance Attainment Associate, St. Paul, MN, USA), which has callipers and an analogue inclinometer, can be used to calculate the horizontal distance between the scapula position and the spine. The advantages of the PALM are that it is portable, quick to use, and inexpensive. Authors [25, 26] have established that the PALM, illustrated in Figure 1. Palpation Meter (PALM) (Performance Attainment Associate, St Paul, MN, USA), in is a reliable tool to measure scapular position in the scaption and coronal planes Table1.

The main aim of the present study was to establish the intra- and inter-rater reliability of using the PALM to capture the horizontal distance of the scapula from the thoracic spine, and to propose at new method using these measures to calculate rotation of the scapula in the coronal plane

2. Materials and Methods

2.1 Participants

In the present study 10 participants volunteered (4 females, 6 males) with a mean age of 29.86 (STD7.8) years. Side to side difference in measurements taken with the PALM within this group were analysed with paired t-tests. There were no significant side to side differences with all p values exceeding 0.05. This enabled data collected on a total of 20 shoulders to be used in reliability analysis. Participants included in the study were of full musculoskeletal development and had healthy shoulders. Participants were excluded from the study if they had: cervical, shoulder, or elbow pain within six months before testing; previous fracture, surgery, or dislocation of the upper limb; scoliosis; or a rheumatologic condition. Each participant was asked to read and sign a consent form approved of by the University of **** Research Ethics Committee.

2.2 Instrumentation

The horizontal distance of the scapular from the thoracic spine was measured using the PALM (Performance Attainment Associate, St. Paul, MN, USA).

2.3 Procedure

Participants were seated with their shoulders exposed, on a customized chair with a short back support. Hips and knees were positioned at 90 degrees of flexion. The participant was asked to adopt a relaxed posture that felt comfortable to them. In order to evaluate normal habitual scapular posture no attempt was made to make the participant conform to a single standardised posture. The seated posture eliminated the effect of possible leg length discrepancies and reduced the chance of syncopal episode in the participants. Measurements of scapular position were taken in 2 arm positions, one, shoulder neutral, and two, 60 degrees of active abduction in the coronal plane. For the neutral position, participants placed their hands palm down on their same side thigh with the elbow left unsupported to ensure that the shoulder girdle was not elevated. For the 60 degrees of arm abduction position, the arm was abducted to 60 degrees of abduction by the examiner as determined by a goniometer (Baseline plastic 360 ISOM Goniometer 12") and the participant was then asked to maintain this position actively. Once 60 degrees of abduction was determined for each participant, in order to assist the participant in maintaining the correct angle of arm abduction, a marker tape was placed on an adjacent wall at the level of the participant's finger tips. The examiner could then ensure that the correct angle was being maintained by the participant while measuring. Between each measurement the participant rested the arm by the side to avoid the effects of fatigue.

The following anatomical landmarks were repeatedly palpated by the examiner: the inferior angle of the scapula (IAS) (Figure 1.), the root of the spine of the scapula (RSS) (Figure 2.), and the spinous process of the thoracic spine (Sp) (Figures 1. and 2), before taking of each measurement. The participant's skin was not marked by the examiners ensuring that markings could not introduce bias between examiners during repeated palpation and locating of the anatomical landmarks. The PALM callipers were used to measure the distances and horizontal distance was ensured by the analogue inclinometer on the PALM. The following distances were measured: the distance between the inferior angle of the scapula to the closest horizontal spinous process of the thoracic spine (IAS-Sp) Figure 1; the root of spine of the scapula to the closest horizontal spinous process of the thoracic spine (RSS-Sp) Figure 2.; and the distance from the inferior angle of the scapula to the root of the spine of the scapula (RSS-IAS), Figure 3.

Before commencing data collection, the PALM inclinometer was checked to be centred at 0 in the vertically aligned position. All participants were measured by two examiners. Three consecutive measurements were taken by each examiner. The examiners were separated by a room divide from each other and blinded to each other's results during collection of measurements

2.4 Calculation of scapular rotation

The distances IAS-Sp, RSS-Sp, and IAS-RSS were used to calculate the scapula rotation angle. As shown in Figure 4, if a perpendicular line is dropped down from the root of the spine of the scapula (RSS) to intersect the horizontal line between the inferior angle of the scapula and the closest spinous process of the thoracic spine (IAS-Sp), a right angle triangle is created. The hypotenuse is the distance IAS to RSS. The side opposite the angle θ (θ was defined as the angle between the hypotenuse and the vertical) and the vertical is the distance IAS-Sp minus the distance RSS-Sp. To calculate the angle one can apply

$$\sin \theta = \frac{opposite}{hypotenuse}$$

A positive result indicates the degree of upward scapular rotation and a negative result indicates the degree of downward scapular rotation.

2.5Data analysis

Estimated sample size was based on guidance from by Walter *et al.* 1998 [27], who suggest that with 2 raters, a significance level of 0.05, and a power of 80%, to determine an ICC score of 0.7 (to interpret reliability indicative of a true p0, versus an alternative ICC score of 0.9 indicating a p1), that 19 samples are required. Statistical Package for Student Statistics for Windows version 20.0 (SPS Sinc, Chicago, IL), was used for statistical analysis. The interclass correlation coefficients ($ICC_{3.1}$) model was used for within-day intra-rater reliability, a two-way fixed effects model (examiner is fixed effect and participants are randomised effects), with absolute agreement for each single measure. $ICC_{2.1}$ model was used for within-day inter-rater reliability, a two-way random effects model, (examiners and participants are both treated as random effects), with absolute agreement for each single measure. SEM based on the calculation SEM = SD x √ (1-ICC) [28] and $MDC_{95\%}$ based on the calculation $MDC_{95\%}$ = 1.96 x √2 x SEM[29] were calculated to establish random error. The following criterion was used to interpret ICC: poor = less than 0.4, fair = 0.4-0.7, good = 0.7-0.90, and excellent = >0.90[30]

3. Results

Means, standard deviations, standard error of measure, minimal detectible change, ICC, and 95% confidence intervals for the lateral scapular displacement measurements are summarised in Table 3. $ICC_{3.1}$ varied from 0.90 to 0.99 for intra-rater reliability, and $ICC_{2.1}$ scores ranged between 0.74 to 0.88 for inter-rater reliability. The SEM ranged from 0.18cm to 0.20cm, and $MDC_{95\%}$ ranged between 0.50cm to 0.55cm. The SEM and $MDC_{95\%}$ was for all measurements were less than the calculated means.

4. Discussion

The principal aim of this study was to assess intra- and inter-rater reliability of using the PALM to measure lateral distance of the scapula from the spine and use these measures in the sin rule to calculate scapula rotation. As seen in Table 3., the current study found an excellent degree ($ICC_{3.1}$ = 0.90 to 0.99) of intra-rater reliability and a good degree ($ICC_{2.1}$ = 0.74 to 0.88) of inter-rater reliability for within-day measurements of lateral scapular displacement from the spine using the PALM device with 2 examiners in arm neutral and 60 degrees of abduction. Additionally, the ICC values for three trials measuring the distances RSS-IAS indicated substantial reliability (Table 3.), confirming that this measure could be reproduced in the same participants by two examiners during one day using the PALM device. For the neutral arm position, these results are in an agreement with the results obtained by previous researchers [25, 26] using the PALM (Table 1), despite differences in methodology between the studies in patient position. The intra-class correlation coefficient of measuring scapular position has been provided by a number of authors (see Table 2.) using simple clinical approaches with other tools such as tape measures, string and callipers [10–13, 18, 31–35]. In the present study an additional measure was taken, namely the RSS to the IAS, to date no other researcher has reported taking this measure. Sobush *et al*. 1996 [13], who also used geometry to calculate the degree of scapula rotation, used a vertical distance between spinous process, measured off x-ray, giving the adjacent triangle side to the calculated angle, in contrast to this study which used the RSS-IAS measure as the hypotenuse of the created triangle (Figure 4). The advantages of using the PALM rather than x-ray are numerous.

The random error associated with a measure can be reduced if the experimenter's measures are consistent. The Standard Error of Measurement [SEM] was calculated to provide a range from the experimental score within which the true score of a measure is likely to lie [36]. Some investigators have mentioned the SEM as being able to distinguish whether changes seen between tests are real or due to measurement error. It has been reported that only 68% of all test scores fall within one SEM of the true score, rather than the 95% criterion commonly used. The minimal detectable change ($MDC_{95\%}$) has been calculated to allow determination of the change needed to indicate statistical significance. In addition to the excellent intra-and inter-tester reliability scores demonstrated associated SEM and $MDC_{95\%}$ values were low, suggesting that that there is minimal contribution of experimenter error to the overall error of the measure and that error is due to systematic bias or other within-participant variation. Therefore, we can be confident that the measure is stable between different examiners.

The rationale of using the 60 degrees abducted arm position while evaluating scapular position is worthy of debate. Previous authors have used various degrees of arm elevation in the scaption and coronal planes [7, 19, 20, 22, 25, 35, 37], others have used the three Kibler positions, namely arm in neutral with the thumb pointing forward, hand on hip with the thumb pointing posteriorly, and 90 degrees arm abduction with the thumb pointing forwards [11, 12, 31–35]. Reliability of surface palpation of the IAS and the RSS has been proven to be poor when the arm is elevated above 90 degrees [24, 32, 33].

The clinical value of scapular lateral displacement measurements is questionable; previous authors [12, 11], report low sensitivity (28%-50%), and low specificity (35, 2%-58%) of these measures, finding no relationship between LSST and pain severity or the shoulder disability index. It is proposed that these measures would be more useful if used to calculate the rotation angle of the scapula, which would have more clinical relevance. One author, Sobush *et al*. 1996 [13], used the method of calculating scapular rotation from lateral displacement measurements similar to those used in the present study. To add to the debate, opinion is divided about whether the medial scapular border should be parallel to the spine as originally proposed by Sahrmann [38], and supported by authors who propose an ideal mean distance for lateral displacement of the scapula from the spine [13]. Recent research has shown that asymmetry exists between sides in sportsman [39, 40]. The commonly used LSST as proposed by Kibler is based on bilateral assessment of sides, but authors have proposed that this comparison is not appropriate [41]. Furthermore, McClure *et al*. 2004 [5], report that in subacromial impingement patients, scapular position did not change after six weeks of exercise intervention, although their symptoms improved [5]. There is an absence of objective data on what constitutes normal scapular position in varying populations, but despite this Physiotherapy evaluation emphasises the importance of postural evaluation, specifically head and shoulder posture in patients with spinal and upper extremity dysfunction [38]. This is often subjectively assessed. A clinical test to quantify scapular position and to document normal positional data for systematic investigation is imperative [13]. Only then can the influence of exercise, and therapeutic intervention, and postural effects on scapular position be evaluated objectively.

Although the results of this study are useful, the current study has limitations that should be borne in mind when interpreting the results and addressed in future studies. Firstly, measurement sequence on the participants was not randomised when using the PALM. Secondly, the study was conducted on asymptomatic participants and reliability of both the PALM for measuring scapular rotation needs to be established on symptomatic participants. Thirdly, scapular movement includes movement over three axes in three planes, and this method at present only evaluates the movement of the scapula in the frontal plane.

5. Conclusion

The palm meter was found to have excellent intra-reliability and good inter-rater reliability as a tool to measure horizontal distance of the scapula from the spine. These measures can be used to calculate scapular rotation. This method that has been developed to quantify scapular rotation provides an objective measure of scapular rotation at rest and in the abducted arm position, which is inexpensive, practical and easy to perform in healthy individuals.

Ethical approval: University of Salford Institutional Review Board approval the study. Study number: HSCR12/71.

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Three potential reviewers:
Ian Horsley: Ian.Horsley@eis2win.co.uk
Stuart Porter: stuartbporter@aol.com
Julia Walton: julia.walton@wwl.nhs.uk

Table 1: Studies Reporting Reliability of Measuring Horizontal Distance of the of Scapula from the Spine with the Palm

author	population	methodology	GHJ position	Position	measurement	intra ICC (SEM cm) in GHJ neutral	inter ICC (SEM cm) in GHJ neutral
Costa *et al*. 2010	n=30 AS	3 raters 2 sessions a week apart	Neutral 90 scaption Full scaption	Standing	IAS-Sp RSS-Sp	0.89(0.56) 0.81(0.63)	0.89(0.59) 0.77(0.69)
Rondeau 2007	n=18 AS	1 rater 1 session	neutral 90 abduction	Standing	IAS-T8 RSS-T3	0.96(0.30) 0.98(0.20)	NT

Abbreviations: AS=asymptomatic; GHJ=glenohumeral joint; IAS-Sp=inferior angle of the scapula to spinous process; RSS-Sp=root of spine of scapula to spinous process; ICC=intraclass correlation coefficient; SEM=standard error of measure; NT=not tested; cm=centimetres

Table 2: Studies Reporting Reliability of Measuring Horizontal Distance of the of Scapula From The Spine With Tape, String, And Callipers.

author	tool	N	methodology	GHJ position	position	measurement	intra ICC (SEM cm) in neutral	Inter ICC (SEM cm) in neutral
Gibson *et al*. 1995	string	n=32 AS	2 raters 1 session	Kibler 1 to 3	ST	IAS-Sp RSS-Sp	0.81-0.94(0.49-0.59) NT	0.91-0.92(0.60-0.65) NT
T'Jonk *et al*. 1996	tape	n=17 AS	2 raters 1 session	Kibler 1 to 3	SIT	IAS-Sp RSS-Sp	0.80-0.96(0.18-0.62) 0.57-0.99(0.12-0.60)	0.72-0.90(0.47-0.72) 0.52-0.87(0.45-0.77)
Mckenna *et al*. 2004	tape	n=15 AS	3 raters 2 repeated measures	Kibler 1 to 2	ST	IAS-Sp RSS-Sp	NR NR	0.87(0.53) 0.74(0.59)
Odom *et al*. 2001	string	n=46 AS&S	5 raters Mean of 2 measures	Neutral 45 abd 90 abd	ST	IAS-Sp RSS-Sp	0.75(0.61) NT	0.67(0.79) NT
Struf *et al*. 2009	tape	n=30 AS	2 raters 1session	Kibler 1 to 3	ST	IAS-Sp RSS-Sp	NR NT	0.63(1.85) NT
Lewis *et al*. 2008	tape	n=90 AS&S	1 rater 2 sessions 30 min apart	neutral	ST	IAS-Sp RSS-Sp	0.90-0.98(0.83-0.99) 0.79-0.93(0.66-0.97)	NT NT
Nijs *et al*. 2005	tape	n=29 AS&S	2 raters 1 session	Kibler 1 to 3	ST	IAS-Sp RSS-Sp	NR NT	0.70(0.31) NT
Sobush *et al*. 1996	calliper	n=15 AS	3 raters 1 session	Kibler 1	ST	IAS-Sp RSS-Sp	NR NR	0.77(NR) 0.80(NR)
Thomas *et al*. 2010	calliper	N=36 AS	1 rater 2 sessions 3-5 days apart	Kibler 1-3	ST	IAS-Sp RSS-Sp	0.94(0.33) NT	Not tested NT

Abbreviations: AS=asymptomatic; A=symptomatic; Kibler 1-3 = neutral shoulder thumb forward, hand on hip thumb posterior, and arm at 90 degrees abduction thumb down; Abd=abduction; GHJ=glenohumeral joint; ST = participant standing; SIT=participant sitting; IAS-Sp=inferior angle of the scapula to spinous process; RSS-Sp=root of spine of scapula to spinous process; ICC=intraclass correlation coefficient; SEM=standard error of measure; NT=not tested; NR=not reported; cm= centimetres

Table 3: Mean, 95% confidence intervals, standard error of measure, minimal detectible change, and intraclass correlation coefficient values for horizontal distance of the scapula from the spine measured with the PALM.

Measurement	combined Mean of 2 examiners cm	SEM cm	STD cm	$MDC_{95\%}$ cm	Inter-rater 95% CI	Inter-rater $ICC_{2.1}$	Intra-rater $ICC_{3.1}$ for rater one	Intra-rater $ICC_{3.1}$ for rater two
RSS-Sp in neutral	7.52	0.20	0.91	0.55	0.69-0.92	0.83	0.98	0.95
IAS-Sp in neutral	8.36	0.18	0.82	0.50	0.71-0.93	0.85	0.97	0.96
RSS-IAS	11.69	0.18	0.80	0.50	0.78-0.95	0.88	0.90	0.94
RSS-Sp in 60° abd	7.16	0.20	0.88	0.55	0.52-0.89	0.74	0.98	0.99
IAS-Sp in 60° abd	8.55	0.18	0.80	0.50	0.63-0.91	0.80	0.98	0.97

Abbreviations: IAS-Sp=inferior angle of the scapula to spinous process; RSS-Sp=root of spine of scapula to spinous process; RSS-IAS= root of spine of scapula to inferior angle of scapula; ICC=intraclass correlation coefficient; SEM=standard error of measure; 95% CI=95% confidence interval; STD=standard deviation; $MDC_{95\%}$=minimal detectable differences with 95% confidence; cm=centimetres

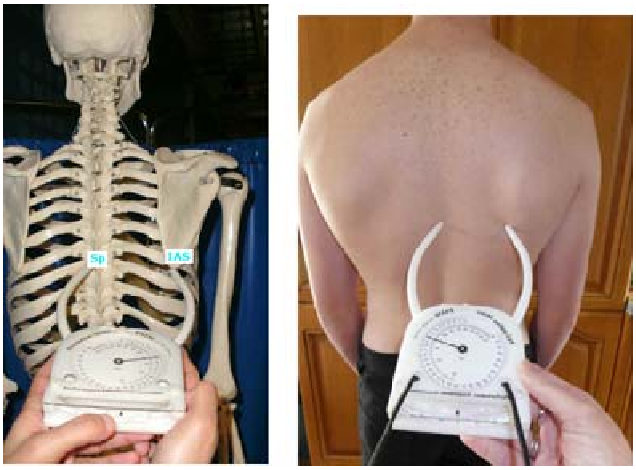

Fig 1: Measurement of the distance between the inferior angle of the scapula (IAS) and the closest horizontal spinous process (Sp) of the thoracic spine (IAS-Sp).

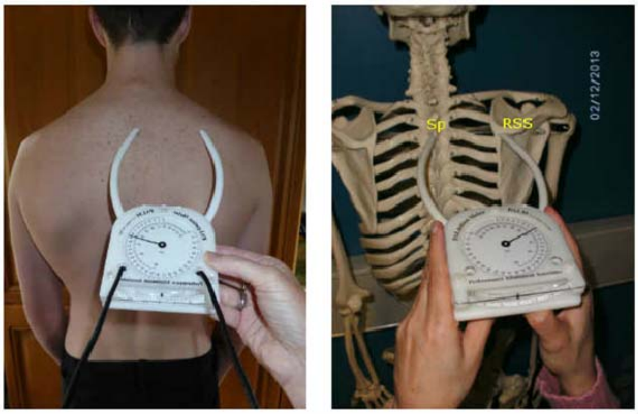

Fig 2: Measurement of the distance between the root of the spine of the scapula (RSS) and the closest horizontal spinous process (Sp) of the thoracic spine (RSS-Sp).

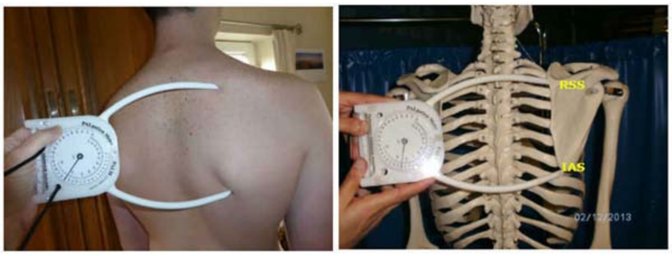

Fig 3: Measurement of the distance from the inferior angle of the scapula (IAS) to the root of the spine of the scapula (RSS-IAS)

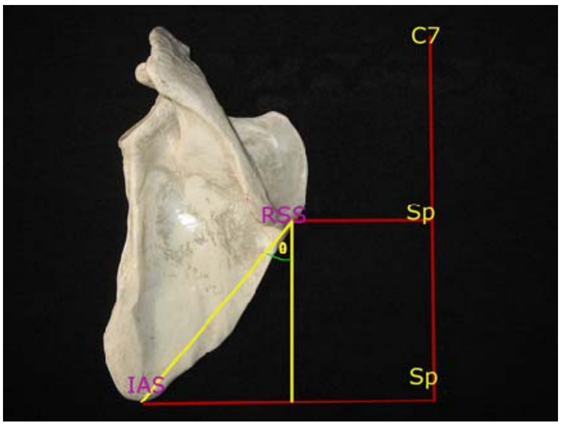

Fig 4: Calculation of the scapular rotation angle. Abbreviations: RSS=root of spine of scapula; IAS inferior angle of scapula; C7 = cervical vertebra 7; Sp=spine of scapula.

6. References

1. Endo K, Ikata T, Katoh S, Takeda Y. Radiographic assessment of scapular rotational tilt in chronic shoulder impingement syndrome. Journal of Orthopaedic Science. 2001; 6(1):3-10.
2. Graichen H, Bonel H, Stammberger T, Englmeier K-H, Reiser M, Eckstein F. Subacromial space width changes during abduction and rotation -a 3-D MR imaging study. Surgical and Radiologic Anatomy 1999; 21(1):59-64.
3. Hebert LJ, Moffet H, McFadyen BJ, Dionne CE. Scapular behavior in shoulder impingement syndrome. Archives of Physical Medicine and Rehabilitation 2002; 83(1):60-9.
4. Ludewig PM, Cook TM. Alterations in shoulder kinematics and associated muscle activity in people with symptoms of shoulder impingement. Physical Therapy 2000; 80(3):276-91.
5. McClure PW, Bialker J, Neff N, Williams G, Karduna A. Shoulder Function and 3-Dimensional Kinematics in People With Shoulder Impingement Syndrome Before and After a 6-Week Exercise Program. Physical Therapy 2004; 84(9):832-48.
6. Warner W, Micheli LI, Arslanian LE, Kennedy J, Kennedy R. Scapulothoracic motion in normal shoulders and shoulders with glenohumeral instability and impingement syndrome. A study using Moire topographic analysis. Clinical orthopaedics and related research 1992; 285:191.
7. Borsa PA, Timmons MK, Sauers EL. Scapular-Positioning Patterns during Humeral Elevation in Unimpaired Shoulders. J Athl Train. 2003; 38(1):12-7.
8. Brody LT, Hall CM. Therapeutic Exercise: Moving Toward Function. Wolters Kluwer/Lippincott Williams & Wilkins Health, 2010, 779.
9. Smith. ScienceDirect.com - Archives of Physical Medicine and Rehabilitation - Rhomboid muscle electromyography activity during 3 different manual muscle tests [Internet]. 2004 [cited 2012 Aug 6]. Available from: http://www.sciencedirect.com/science/article/pii/S00039993030 0618X
10. Lewis J, Green A, Reichard Z, Wright C. Scapular position: the validity of skin surface palpation. Manual Therapy 2002; 7(1):26-30.
11. Nijs J, Roussel N, Vermeulen K, Souvereyns G. Scapular Positioning in Patients With Shoulder Pain: A Study Examining the Reliability and Clinical Importance of 3 Clinical Tests. Archives of Physical Medicine and Rehabilitation 2005; 86(7):1349-55.
12. Odom CJ, Taylor AB, Hurd CE, Denegar CR. Measurement of scapular asymmetry and assessment of shoulder dysfunction using the Lateral Scapular Slide Test: a reliability and validity study. Physical Therapy 2001; 81(2):799-809.
13. Sobush DC, Simoneau GG, Dietz KEP, Levene JAM, Grossman RE, Smith WB. The Lennie Test for Measuring Scapular Position in Healthy Young Adult Females: A Reliability and Validity Study. [Miscellaneous Article]. Journal of Orthopaedic. 1996; 23(1):39-50.
14. Borstad JD, Ludewig PM. Comparison of scapular kinematics between elevation and lowering of the arm in the scapular plane. Clinical Biomechanics 2002; 17(9-10):650-9.
15. Kawasaki T, Yamakawa J, Kaketa T, Kobayashi H, Kaneko K. Does scapular dyskinesis affect top rugby players during a game season? Journal of Shoulder and Elbow Surgery. 2012, 1-6.
16. Ludewig PM, Cook TM, Nawoczenski DA. Three-Dimensional Scapular Orientation and Muscle Activity at Selected Positions of Humeral Elevation. [Miscellaneous Article]. Journal of Orthopaedic. 1996; 24(2):57-65.
17. Roy J-S, Moffet H, Hébert LJ, St-Vincent G, McFadyen BJ. The reliability of three-dimensional scapular attitudes in healthy people and people with shoulder impingement syndrome. BMC Musculoskeletal Disorders 2007; 8(1):49.
18. Lewis JS, Valentine RE. Intraobserver Reliability of Angular and Linear Measurements of Scapular Position in Subjects with and Without Symptoms. Archives of Physical Medicine and Rehabilitation 2008; 89(9):1795-802.
19. Laudner KG, Stanek JM, Meister K. Differences in Scapular Upward Rotation between Baseball Pitchers and Position Players. Am J Sports Med. 2007; 35(12):2091-5.

20. Tucker WS, Ingrim RL. Reliability and validity of measuring scapular upward rotation using an electrical inclinometer. Journal of Electromyography and Kinesiology. 2012; 22(3):419-23.
21. Thomas SJ, Swanik KA, Swanik C, Huxel KC. Glenohumeral Rotation and Scapular Position Adaptations after a Single High School Female Sports Season. J Athl Train. 2009; 44(3):230-7.
22. Watson L, Balster SM, Finch C, Dalziel R. Measurement of Scapula Upward Rotation: A Reliable Clinical Procedure. Br J Sports Med. 2005; 39(9):599-603.
23. Curtis T, Roush JR. The Lateral Scapular Slide Test: A Reliability Study of Males with and without Shoulder Pathology. N Am J Sports Phys Ther. 2006; 1(3):140-6.
24. Daniels TP. Evaluation of the lateral scapular slide test using radiographic imaging : a validity and reliability study [Internet]. 2001 [cited 2014 Nov 21]. Available from: http://ir.library.oregonstate.edu/xmlui/handle/1957/32104
25. Da Costa BR, Armijo-Olivo S, Gadotti I, Warren S, Reid DC, Magee DJ. Reliability of scapular positioning measurement procedure using the Palpation Meter (PALM). Physiotherapy 2010; 96:59-67.
26. Rondeau MW, Padua DA, Thigpen CA, Harrington SE. Precision and Validity of a Clinical Method for Pectoral Minor Length Assessment in Overhead-Throwing Athletes. Athletic Training & Sports Health Care: The Journal for the Practicing Clinician. 2012; 4(2):67-72.
27. SD Walter, Eliasziw M, Donner A. Sample size and optimal designs for reliability studies. Statistics in Medicine 1998; 17(1):101-10.
28. Bruton A, Conway JH, Holgate ST. Reliability: What is it, and how is it measured? Physiotherapy 2000; 86(2):94-9.
29. Eliasziw M, Young SL, Woodbury MG, Fryday-Field K. Statistical Methodology for the Concurrent Assessment of Interrater and Intrarater Reliability: Using Goniometric Measurements as an Example. Phys Ther. 1994; 74(8):777-88.
30. Coppieters M, Stappaerts K, Janssens K, Jull G. Reliability of detecting onset of pain and submaximal pain during neural provocation testing of the upper quadrant. Physiotherapy Research International 2002; 7(3):146-56.
31. Gibson MH, Goebel GV, Jordan TM, Kegerreis S, Worrell TW. A reliability study of measurement techniques to determine static scapular position. J Orthop Sports Phys Ther. 1995; 21(2):100-6.
32. T' Jonck L, Lysens R, Grasse G. Measurements of scapular position and rotation: a reliability study. Physiotherapy Research International 2006; 1(3):148-58.
33. McKenna L, Cunningham J, Straker L. Inter-tester reliability of scapular position in junior elite swimmers. Physical Therapy in Sport 2004; 5(3):146-55.
34. Struyf F, Nijs J, De Coninck K, Giunta M, Mottram S, Meeusen R. Clinical Assessment of Scapular Positioning in Musicians: An Intertester Reliability Study. J Athl Train. 2009; 44(5):519-26.
35. Thomas SJ, Swanik C Buz, Higginson JS, Kaminski TW, Swanik KA, Bartolozzi AR, *et al*. A bilateral comparison of posterior capsule thickness and its correlation with glenohumeral range of motion and scapular upward rotation in collegiate baseball players. Journal of Shoulder and Elbow Surgery. 2011; 20(5):708-16.
36. Salkind NJ. Salkind. (2000) Statistics for people who (think they) hate statistics. London: Sage Publications, 2007.
37. Johnson GR, Stuart PR, Mitchell S. A method for the measurement of three-dimensional scapular movement. Clinical Biomechanics 1993; 8(5):269-73.
38. Sahrmann SA. Does Postural Assessment Contribute to Patient Care? Journal of Orthopaedic & Sports Physical Therapy 2002; 32(8):376-9.
39. Downar JM, Sauers EL. Clinical Measures of Shoulder Mobility in the Professional Baseball Player J Athl Train. 2005; 40(1):23-9.
40. Oyama S, Myers JB, Wassinger CA, Daniel Ricci R, Lephart SM. Asymmetric Resting Scapular Posture in Healthy Overhead Athletes. J Athl Train. 2008; 43(6):565-70.
41. Ozunlu N, Tekeli H, Baltaci G. Lateral Scapular Slide Test and Scapular Mobility in Volleyball Players. Journal of Athletic Training. 2011; 46(4):438-44.