

Ultrasound comparison of the effects of prehabilitation exercises and the scapular assistance test on the acromiohumeral distance.

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ABSTRACT

Background: Prolonged participation in overhead sports creates shoulder muscle imbalances that eventually alter the efficacy of the shoulder stabilizer muscles and heighten injury risk such as subacromial impingement syndrome.

Objectives: The aim of this study was to determine if ultrasound is effective to measure the acromiohumeral distance (AHD) to compare the effect of the scapular assistance test (SAT) on the AHD with a prehabilitative exercise intervention program in asymptomatic cricket players.

Method: Baseline testing on cricket players from the North-West University cricket squad (N=47) included AHD measurements performed by a sonographer at 0°, 30° and 60° humeral abduction angles, with and without the SAT application. Players were then randomly assigned to an intervention and control group. The control group continued with their normal in-season programme whereas the intervention group additionally performed shoulder stability exercises for six weeks.

Results: The exercise intervention had a similar effect as SAT on the AHD at 0° abduction in the intervention group. The AHD measurements in the intervention group indicated widening at all abduction angles after the six-week intervention period, whereas the AHD

measurements in the control group were equal or smaller than baseline measurements without SAT at 30° and 60°.

Conclusion: Exercise intervention has a similar effect on the AHD of asymptomatic cricket players as SAT – especially in 0° of humeral abduction. Ultrasound can, therefore, be utilized to assist in identifying the risk of developing SIS in asymptomatic overhead athletes by measuring the AHD at different angles of humeral abduction, without and with SAT application.

INTRODUCTION

Subacromial Impingement Syndrome (SIS) is commonly encountered in overhead athletes. Although a complete throwing motion only lasts a few seconds, repetitive overhead motion creates significant stress on the shoulder, resulting in muscle imbalances which heighten the risk of developing SIS.¹ Prolonged muscle imbalances lead to narrowing of the acromiohumeral distance (AHD) and painful compression of the soft tissue structures which pass through the subacromial space (SAS) during dynamic humeral abduction.^{2,3} A late diagnosis of SIS may lead to decreased sport performance while valuable training and competition time is lost due to long periods of rehabilitation.⁴

The scapular assistance test (SAT) is used to identify abnormal scapular motion before late stage winging is present. The examiner manually corrects the dyskinesia and stabilizes the scapula on the bony thorax, by rotating the scapula upward and outwards while simultaneously pushing the scapula to increase the posterior tilt during humeral elevation.^{5,6}

The SAT maneuver relieves compression on soft tissue structures responsible for SIS by increasing the AHD. The test is therefore positive when the athlete's symptoms reduce with abduction of the humerus while SAT is applied.^{5,6,7} If pain reduces with SAT, it may be

assumed that strengthening of the scapular stabilizers will result in widening of the AHD and lessening of the clinical effects of SIS. However, in the sporting world it would be ideal to determine whether prehabilitation of the shoulder girdle is needed before the onset of impingement symptoms. Determining the AHD before and after SAT application at different angles of humeral abduction in the dominant and non-dominant shoulders of unilateral overhead athletes could provide valuable insight and contribute to mitigate soft tissue injury.

There is currently no proven imaging or clinical method to identify the risk of future SIS in asymptomatic overhead athletes. Ultrasound is a non-invasive, comfortable and dynamic examination which provides extensive diagnostic information of the shoulder muscles as well as the AHD variation during abduction of the humerus.⁸ Ultrasound is, furthermore, proved to be accurate in measuring the AHD, however, there is paucity in the literature if ultrasound can be utilized to predict SIS in overhead athletes by measuring the AHD at different humeral abduction angles.⁸ The purpose of this article is thus to describe the use of ultrasound AHD measurements to compare the effect of SAT on the AHD with that of a prehabilitative exercise intervention in asymptomatic cricket players.

METHODS

Research design and participants

Male cricket players (N=51) from the NWU cricket squad were recruited to voluntarily participate in this randomized control trial during the 2013 cricket season. Ethical approval was obtained from the Faculty of Health Science Ethics Committee of the NWU (NWU-00026-12-A1) and the University of Johannesburg (AEC12-01-2013). Players and coaches were thoroughly informed regarding the testing procedures and exercise intervention and written informed consent was obtained from all participating players prior to baseline testing.

Only players' ≥ 17 and ≤ 25 years, who did not suffer from any current orthopaedic condition or injury or who did not rehabilitate from any orthopaedic injury at commencement of the study were eligible for inclusion. Four of the recruited players were excluded prior to baseline testing – two were above the age limit of 25 years and asymptomatic shoulder injuries were detected via the pre-test ultrasound in another 2 players. Therefore, the final sample of the study comprised of 47 male cricket players. The study population was randomly allocated to the exercise intervention and control groups by one of the investigators who blindly draw participant numbers from a box after the baseline testing. Thirty-four participants completed the post-test procedures (intervention group, n=16 and control group, n=18).

Research methods and instruments

Ultrasound measurements

Ultrasound examination was performed on all cricketers with an Aloka F75 ultrasound unit equipped with a 7MHz – 14MHz linear broadband transducer. The AHD of both shoulders were measured at 0°, 30° and 60° humeral abduction angles in the scapular plane, with and without application of the SAT. The degrees of humeral abduction were measured with a goniometer, placed on the posterior aspect of the shoulder along the long axis of the humerus to measure exact humeral abduction angles.^{3,6,9} AHD measurements of more than 60° humeral abduction are not possible due to constraint in imaging technique.⁹

The transducer was positioned in a sagittal plane along the long axis of the supraspinatus tendon and humerus (Figure 1a). The AHD on the frozen image can then be defined as the shortest linear distance between the antero-inferior tip of the acromion and the greater tubercle of the humeral head (Figure b).¹⁰

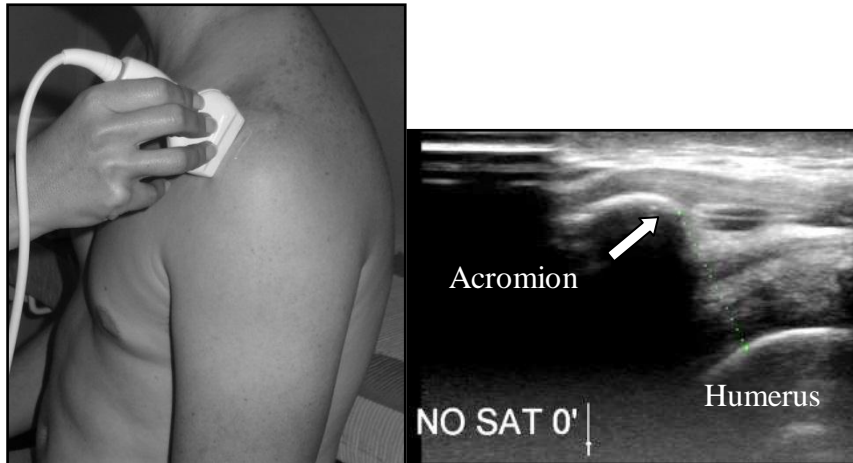


FIGURE1(a-b): AHD measurement at 0° humeral abduction (Author’s private collection).

The SAT was then applied by a registered biokineticist who manually rotated the scapula in an upward rotation and posterior tilt during humeral abduction to manually stabilize the scapula on the bony thorax.^{5,6} The AHD was re-measured at the same 0°, 30° and 60° humeral abduction angles.

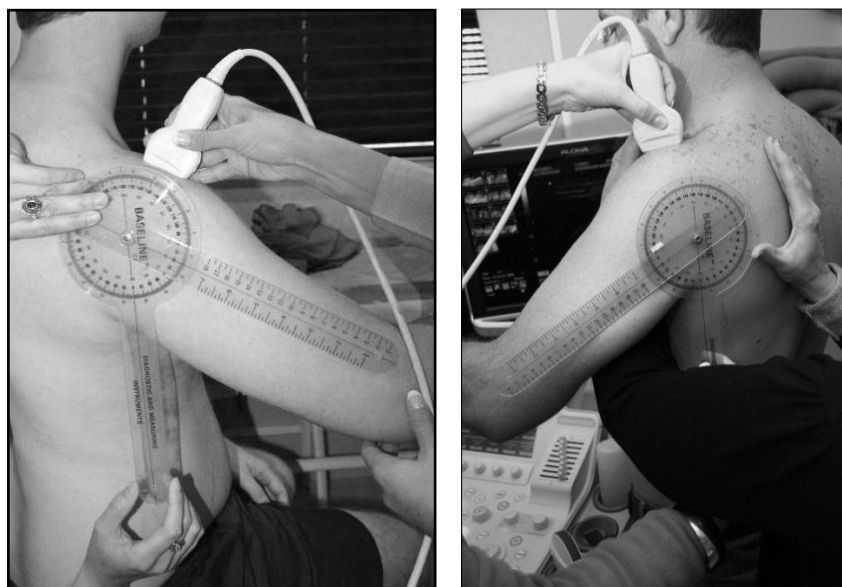


FIGURE 2(a-b): AHD measurement at 60° humeral abduction without and with the application of the SAT (Author’s private collection).

The AHD of both shoulders was re-measured at humeral abduction angles of 0°, 30° and 60° after a six week prehabilitative exercise intervention program by using the same technique as during baseline measurements, but without the application of the SAT. These measurements served as comparative information of the increase in AHD measurement achieved both with SAT application, as well as after prehabilitation exercises.

An independent radiologist, with experience in MSK ultrasound, reviewed all the ultrasound images to verify that the correct technique had been used consistently in obtaining the required images and in measuring the AHD. This practice ensured internal validity.

Exercise intervention

A six-week controlled exercise intervention program (in addition to normal conditioning regimes) was followed after completion of the baseline tests under supervision of a Biokineticist. The exercise intervention program focused on releasing the pectoralis minor, pectoralis major, latissimus dorsi and posterior capsule, as well as strengthening the scapular and core stabilizer muscles and humeral lateral rotators. Emphasis was placed on maintaining postural control during execution of all exercises. Four exercise sessions, forty to fifty minutes in duration, was supervised per week and it was expected of all players in the intervention group to attend two of these session. A register was kept to log each session a player attended to ensure that all players attended the required two sessions per week. The exercise program was also progressed every two weeks. The comparison of the follow-up AHD measurements without SAT, after intervention to the initial AHD measurements with SAT, will therefore support or refute the hypothesis that strengthening of the stabilizers of the scapula act in the same manner as the SAT application.

Statistical analysis

The statistical analyses were performed using the Statistica 12 programme (StatSoft inc., 2014). Departure from normality for all variables was evaluated using the Shapiro-Wilk test and Quantile-Quantile plots, justifying the use of parametrical statistical methods. Independent T-tests were performed to determine if the intervention and control group differed in basic participant characteristics. Dependent T-Test were performed to indicate the difference in AHD at 0° and 30°, as well as 0° and 60° of humeral abduction for both the dominant and non-dominant shoulders. Lastly, Dependent T-tests were performed separately in both the intervention and control groups to establish how the AHD at different humeral abduction angles differed without and with the application of SAT. Also to indicate whether the effect of the SAT and exercise intervention differed. Statistical significance was set at $p \leq 0.05$ and Cohen's effect sizes (d-values) were calculated to determine practical significance ($d \leq 0.2$ indicating a small practical significance, $d \geq 0.5$ $d \geq 0.8$ indicating a large practical significance).

RESULTS

The biographical and anthropometrical characteristics of the sample are summarized in Table 1.

TABLE 1. Comparison of biographical characteristics between intervention and control groups (N=34)

Variables	Mean±SD Intervention (n=16)	Mean±SD Control (n=18)	P-value (p≤0.05) Independent t test
Age (Years)	20.70	20.90	0.826
Height (m)	1.81	1.79	0.202
Body mass (kg)	81.36	77.49	0.315
BMI (kg/m ²)	24.70	24.00	0.786
Number of Years Participating	n(%)	n(%)	P-value (p≤0.05)
< 4 years	1(6.3%)	1(5.6%)	0.957
≥ 4 years	15(93.8%)	17(94.4%)	
Participating Level	n(%)	n(%)	P-value (p≤0.05)
University squad	12(75%)	15(83.3%)	0.163
Provincial level	4(25%)	3(16.7%)	
Average Training Hours per Week	n(%)	n(%)	P-value (p≤0.05)
< 6 hours	4(25%)	7(38.9%)	0.586
≥ 6 hours	12(75%)	11(61.1%)	
History of Resistance Training	n(%)	n(%)	P-value (p≤0.05)
< 3 years	10(62.5%)	7(38.9%)	0.182
≥ 3 years	6(37.5%)	11(61.1%)	

Independent T-Tests were used to describe and compare the basic characteristics of the two groups (Table 1). No statistical significant differences (p≤0.05) were recorded with regards to age, body mass, height, BMI, years participating in the sport, participating level, hours per week training or the history of resistance training, rendering the groups suitable for comparison.

In Table 2 the change in the AHD at baseline, without SAT at 0°, 30° and 60° humeral abduction angles is indicated for both the dominant and non-dominant shoulders of the group in total and also the intervention and control groups separately.

TABLE 2. Comparison of baseline AHD measurements at 0°, 30° and 60° humeral abduction without SAT

	Mean AHD 0° Humeral abduction	Mean AHD 30° Humeral abduction	Mean AHD 60° Humeral abduction	P-value Δ 0° - 60°	P-value Δ 30° - 60°
Dependent T-test					
Total group (N=34)					
Dominant	1.14±0.15	1.08±0.17*	0.94±0.22 ^{†‡}	≤0.001	≤0.001
Non-dominant	1.13±0.16	1.08±0.17*	0.97±0.19 ^{†‡}	≤0.001	≤0.001
Intervention group (n=16)					
Dominant	1.09±0.15	1.03±0.16	0.90±0.23 ^{†‡}	0.001	0.005
Non-dominant	1.06±0.12	1.02±0.15	0.90±0.12 ^{†‡}	0.001	0.009
Control group (n=18)					
Dominant	1.19±0.14	1.12±0.17*	0.97±0.22 ^{†‡}	≤0.001	≤0.001
Non-dominant	1.20±0.17	1.14±0.17*	1.02±0.22 ^{†‡}	≤0.001	0.011

* Statistical significant difference ($p \leq 0.05$) between baseline AHD at 0° and 30° humeral abduction

† Statistical significant difference ($p \leq 0.05$) between baseline AHD at 0° and 60° humeral abduction

‡ Statistical significant difference ($p \leq 0.05$) between baseline AHD at 30° and 60° humeral abduction

The mean AHD of the dominant shoulders of both groups significantly narrowed during 0° to 60° and 30° to 60° humeral abduction. When measured separately the AHD of both shoulders of the intervention and control showed a similar narrowing trend during 0° to 30° humeral abduction.

TABLE 3. Comparison of baseline AHD with and without SAT and after intervention without SAT at 0°, 30° and 60° humeral abduction

	AHD at Baseline (without SAT)	AHD at Baseline (with SAT)	AHD after Intervention (without SAT)	P-value (SAT vs Intervention) Dependent T- test	d-value
Intervention group (n=16)					
0° Humeral abduction					
Dominant	1.09±0.15	1.16±0.15*	1.15±0.13 [†]	0.538	0.40
Non-dominant	1.06±0.12	1.13±0.13*	1.14±0.12 [†]	0.673	0.67
30° Humeral abduction					
Dominant	1.03±0.16	1.10±0.14*	1.08±0.13	0.396	0.31
Non-dominant	1.02±0.15	1.06±0.13	1.09±0.13	0.556	0.47
60° Humeral abduction					
Dominant	0.90±0.23	1.07±0.18*	0.94±0.20 [‡]	0.001	0.17
Non-dominant	0.90±0.12	0.98±0.14	0.91±0.18	0.198	0.08
Control group (n=18)					
0° Humeral abduction					
Dominant	1.19±0.14	1.28±0.17*	1.21±0.16 [‡]	0.015	0.14
Non-dominant	1.20±0.17	1.28±0.17*	1.22±0.16	0.119	0.12
30° Humeral abduction					
Dominant	1.12±0.17	1.19±0.12*	1.11±0.15 [‡]	0.010	0.05
Non-dominant	1.14±0.17	1.18±0.16	1.12±0.21	0.152	0.12
60° Humeral abduction					
Dominant	0.97±0.22	1.15±0.19*	0.96±0.21 [‡]	0.001	0.05
Non-dominant	1.02±0.22	1.12±0.18*	0.92±0.23 ^{†‡}	≤0.001	0.46

* Statistical significant difference ($p \leq 0.05$) between baseline AHD with and without SAT

[†] Statistical significant difference ($p \leq 0.05$) between AHD without SAT at baseline and AHD after exercise intervention (without SAT)

[‡] Statistical significant difference ($p \leq 0.05$) between baseline AHD with SAT and AHD after exercise intervention (without SAT)

Baseline AHD for both shoulders, with and without SAT, was compared to each other as well as after a six-week intervention period (Table 3). Both the application of the SAT, as well as the exercise intervention resulted in significant widening of the AHD (both dominant and non-dominant) at 0° humeral abduction. The AHD widening was of medium practical

significance (d-values) at 0° and 30° abduction in the intervention, whereas only very small practical significance was detected in the control group. Also, dependent T-tests showed no significant difference between the effect of the SAT and the exercise intervention on the AHD at 0° and 30° of humeral abduction. In other words, the exercise intervention had the same effect as the SAT on the AHD at 0° of humeral abduction. The AHD in the control group's dominant side was significantly less than the AHD after SAT application in all measured degrees of humeral abduction. In other words, normal practice regimes did not translate into AHD widening in the control group. Also note how all the AHD measurements in the intervention group indicated widening (although not always significant), whereas the mean AHD in the control group was either equal to or smaller than the baseline measurement without SAT at 30° and 60° abduction angles after the six-week period.

DISCUSSION

The study aimed to test the hypothesis that prehabilitative exercises would correct upper body postural adaptations and shoulder muscle imbalances in a similar way as the SAT manually alters the orientation of the scapula to increase the AHD. This was achieved by comparing the effect of SAT on the AHD to the initial baseline measurements *without SAT* at 0°, 30° and 60° humeral abduction angles and also to the effect of a six week biokinetics prehabilitation intervention program on AHD measurements *without SAT*.

The baseline AHD measurements of the dominant and non-dominant shoulders were found to be almost identical in both groups before the SAT was applied. The assumption that the application of SAT would increase the AHD in both groups at baseline was proved correct. The greatest effect of the SAT was, however, observed in the dominant shoulder of overhead athletes. Weakness of the serratus anterior and upper or lower trapezius muscles, as well

tightness of the posterior capsule, result in anterior tipping of the scapula with subsequent SIS.^{11,12} The SAT is believed to alter the scapular position through manual upward rotation and posterior tipping to increase the AHD, thus limiting compression of the rotator cuff and subacromial subdeltoid bursa in the same way that prehabilitation exercises would strengthen the scapular stabilizer muscles and reposition the scapula to prevent SIS.^{2,3,5,13,14}

When the mean AHD with SAT was compared to the AHD without SAT, after completion of the six-week prehabilitation program, widening of the AHD after prehabilitation was evident in the intervention group at all abduction angles – significant at 0° of humeral abduction. This finding implies that prehabilitation mitigated the muscle imbalances associated with a repeated overhead motion, with a smaller chance of developing SIS.

The same general trend was not observed in the control group. With AHD distances almost equal to or smaller than the initial baseline measurements without SAT, it can be deduced that normal training had no positive effect on the AHD. On the contrary, it seems as if the reduced AHD in both shoulders at 30° and 60° abduction suggest scapular imbalances which may result in SIS over time. A study by Silva, *et al.*⁴ similarly reported that asymptomatic tennis players with postural adaptations presented with a smaller AHD than control non-playing participants, as well as tennis players without shoulder dyskinesia which highlights the importance of preventative exercises to limit the condition.

The results of this study thus practically confirm that AHD measurements of the intervention groups *without SAT* application after a six-week intervention period are wider than baseline AHD measurements *without SAT* at all angles of humeral abduction, and almost similar to

AHD measurements *with SAT* at baseline. These measurements, therefore, confirm that scapular stabilization prehabilitation exercises indeed acts in a similar manner as SAT.

As a non-invasive, non-radiating and dynamic examination ultrasound provides extensive diagnostic information of the shoulder muscles as well as the variation in the acromiohumeral distance (AHD) during abduction of the humerus.⁸ Although mostly utilized for the diagnosis of rotator cuff disease and SIS¹⁵, ultrasound has also been proved to provide accurate measurements of the AHD between 0° and 60° angles of humeral abduction. Measurements over 60° can unfortunately not be provided due to constrains in imaging technique.^{8,9,10,15} Furthermore, musculoskeletal ultrasound examinations are operator dependent which may render less accurate results and may be considered as a limitation.

CONCLUSION

This research aimed to describe the use of ultrasound AHD measurements to compare the effect of SAT on the AHD with that of a prehabilitative exercise intervention in asymptomatic cricket players. As proved through AHD measurements made during ultrasound imaging, the results of our study indicate that exercise intervention has a similar effect on the AHD of asymptomatic cricket players as SAT – especially in 0° of humeral abduction. Ultrasound can, therefore, be utilized to assist in identifying the risk of developing SIS in asymptomatic overhead athletes by measuring the AHD at different angles of humeral abduction, without and with SAT application. With the SAT having a more pronounced effect on the dominant shoulder as compared to the non-dominant shoulder, it can be expected that the athlete may develop SIS in future as a result of postural adaptations and scapular muscle imbalances already present in the athlete.

The findings of this study propose the employment of a standardized ultrasound protocol for the evaluation of the shoulder in unilateral overhead athletes. A multidisciplinary approach for injury prevention is also encouraged which is currently only seen in rehabilitation of already symptomatic athletes. Biokineticists, sport scientists and coaches working with unilateral overhead athletes are urged to work in conjunction with sonographers and use high frequency sound imaging as an additional screening tool to detect if SAT has a more pronounced effect on the dominant shoulder of overhead athletes. Implementation of such a multidisciplinary approach can result in the early identification of athletes at risk and timely correction of muscle imbalances to prevent decreased sport performance and loss of training and competition time due to injury.

KEY POINTS

Findings:

A controlled 6-week exercise intervention, that focused on correcting upper body postural and biomechanical adaptations usually observed in athletes with prolonged participation in overhead sports, resulted in similar widening of the AHD at 0° of humeral abduction than the application of the SAT.

Implications:

Ultrasound is therefore useful to detect if the AHD in especially the dominant side of overhead athletes significantly widens with the applications of the SAT and whether pre- or rehabilitative exercise prescriptions resulted in widening of the AHD to decrease the risk of SIS.

Caution:

The sonographer should be skilled in the application of the SAT and ensure the correct humeral abduction angles in the scapular plane is used. If not, assistance from a biokineticist should be obtained whilst the sonographer performs the ultrasound measurements.

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