Shoulder anterior-posterior laxity measurement in a healthy population

PARVATHI NATHAN
Department of Mechanical and Aerospace Engineering
Nanyang Technological University
50 Nanyang Avenue
SINGAPORE 639798

SIAW MENG CHOU
Department of Mechanical and Aerospace Engineering
Nanyang Technological University
50 Nanyang Avenue
SINGAPORE 639798
MSMChou@ntu.edu.sg http://www.ntu.edu.sg/home/msmchou/

ANDY KHYE SOON YEW
Singapore General Hospital
20 College Road
SINGAPORE 169865
andy.yew.k.s@sgh.com.sg

DENNY TJIAUW TJOEN LIE
Singapore General Hospital
20 College Road
SINGAPORE 169865
denny.lie.t.t@singhealth.com.sg

Abstract: - The assessment of the shoulder anterior-posterior laxity has been performed using an instrumented mechanical device. The anterior-posterior translation measurement facilitates the generation of normative data of non-pathologic shoulders in a healthy population. The descriptive laboratory study has also investigated the impact of gender and exercise frequency on shoulder laxity. The glenohumeral anterior-posterior joint laxity was assessed in sixty-four subjects using an instrumented mechanical device. The tests were carried out on the left shoulder followed by the right and the duration of each test session was approximately thirty minutes. The sagittal plane translation measurement of the dominant and non-dominant shoulder was not statistically significant ($p > 0.05$) and varied from 17.0 to 24.8 mm with a mean of 20.7 ± 2.0 mm. On comparing the sagittal plane translation measurement of male (22.3 ± 0.9 mm) and female (19.0 ± 1.1 mm) subjects and active (21.3 ± 1.7 mm) and non-active (19.3 ± 1.7 mm) sports participants, a significantly higher variation was observed between them ($p < 0.05$). There was no significant variation ($p < 0.05$) between the overhead and non-overhead sports categories. The results indicate that being active in sports, irrespective of overhead/non-overhead sports and gender differences are likely to influence the shoulder anterior-posterior laxity. Objective measurements of glenohumeral joint laxity can be used as a reference for diagnosis of shoulder anterior-posterior laxity.

Key-Words: - Shoulder anterior-posterior laxity

1 Introduction

The shoulder mechanism is a complex musculoskeletal structure that permits the largest range of motion in the human body. Within this mechanism, there are a series of bones that connect the humerus to the trunk, permitting the shoulder to move freely [1,2,3,4,5]. The glenohumeral (GH) joint or shoulder joint is a very mobile joint which allows the shoulder to perform many overhead activities. Despite its exceptional range of motion, the GH joint is seen to be potentially unstable in the body where dislocations are most prevalent. Shoulder injuries are frequent in sports [2,4,6] and activities that involve arm to be moved at high velocity, under excessive load or repetitive overhead motion such as swimming, tennis, pitching and weightlifting. As the GH joint allows considerable amount of motion, its stability is usually compromised for mobility [4,7]. Normal shoulder functions involve the humeral head positioned relatively centered within the glenoid concavity during active motion. Excessive motion caused by damaging of soft tissue structure within the joint leads to the GH joint subluxation or dislocation.

Shoulder impairment is generally related to a decrease or increase in the translation of the humeral head on t he glenoid [4,6,8]. Such abnormal translational movement of the head on the glenoid compromises the shoulder function and comfort. Therefore, quantification of the humeral head translation or shoulder laxity is highly vital in clinical assessment. Shoulder laxity is defined as the passive translation ability of the humeral head [5]. It is particularly challenging to determine the GH joint laxity because of the complication of the combined motions of the glenohumeral and scapulothoraic articulation. Although recent studies have aided in detailed description of normal shoulder laxity [3,4,9], clinicians still face the problem of differentiating normal and pathologic laxity, especially in determination of the directions of instability of a patient's shoulder.

The ability of subluxating the shoulder over the glenoid rim posteriorly or anteriorly has been interpreted by various authors to be a sign of instability [3,4,8,9]. Hence, laxity testing of the shoulder in an anterior-posterior direction has been recommended as a tool for determining either non-operative or operative treatment. Shoulder laxity assessment is usually carried out using selected manual tests such as t he anterior-posterior drawer, load and shift and sulcus [5]. These tests are subjective in nature and reliant on the clinician's "gut feel" to determine the extent of the observed translation. Therefore, manual tests may not be an accurate assessment on the degree of shoulder dysfunction or injury.

Ultrasound and stress radiographs and have been used in an effort to standardize laxity testing and diagnose shoulder pathology quantitatively. However, it was found that patients with multi-directional instability and anterior instability exhibited overlapping and similar values, making it hard to evaluate [7].

To date, there have been a few instrumented devices used in measuring glenohumeral translation. These instrumented devices includes KT-1000 or KT-2000 arthrometer (MEDmetric Corporation, San Diego, CA, USA) used to measure translation in the knee [4] and computerized stress device (LigMaster) used for comparing the GH joint laxity between the throwing and non-throwing shoulders of high school baseball pitchers [3]. However, these attempts at measuring humeral head translations could not conclude on the translation distance that could be used as a standard to facilitate the diagnosis of shoulder instability. Additional research on instrumented devices for measuring GH translation is needed before the evaluation of patients with possible instability can be accomplished.

2 Methods

2.1 Experimentation

The purpose of this series of tests is to provide normative data in healthy shoulder of a young population using an instrumented mechanical device. The significance of the following factors was also examined: non-dominant shoulder versus dominant shoulder, male versus female shoulder. Results for active sport participants versus non-sport participants and overhead versus non-overhead sport participants have also been studied.

2.2 Participants

Sixty-four subjects (32 male, 32 female, age = 22.3 ± 1.5 yr, mass = 57.8 ± 10.4 kg, ht. = 166.9 ± 8.8 cm) with no previous history of dominant or non-dominant shoulder pathology were recruited for this investigation (Table 1). The dominant shoulder is defined as the preferred arm for throwing ball. Subjects with a history of injury, including subluxation or dislocation to their shoulder, were excluded from this study. All subjects read and signed an informed consent form that explained the risks and procedures of taking part in the study and indicating their willingness to participate. The institution review board of the university approved the experimental protocol.

Table 1. Demographic information of study subjects

	Min (mm)	Max (mm)	Mean (mm)	SD (mm)
Weight (kg)	40	85	57.8	10.4
Age (yrs)	19	26	22.3	1.5
Height (cm)	151	188	166.9	8.8

2.3 Instrumentation
A shoulder mechanical device was developed and used to measure the GH translation. All measurements were taken by the same person, who undertook approximately 8 man hours of instruction and trial practices with the shoulder mechanical device prior to data collection.
A posture correction vest (instead of a scapula support assembly) was used to ensure subjects had a relaxed, upright seating posture with their scapula supported during the test. The measuring instrument consisted of an arm support that was wrapped around the subject's arm. This was then connected to a sliding block positioned on the shoulder (with a pointer), allowing measurement to be taken. By determining the distance from each of the proximal and distal end of the translation in relation to a zeroed starting position, the amount of displacement in mm during the translation was measured.

3 Procedure
The participants were asked to perform some relaxation exercises for approximately one minute on both shoulders before the test. This included rotating the arm forward and backward. These exercises were selected for their ability to loosen the muscles around the shoulder joint, thus enhancing the GH joint mobility and flexibility [5]. The subjects wore the posture correction vest and sat upright on a stool. The device was placed on the shoulder with the arm support strapped to the participant's arm. Once the device was set-up on the shoulder, the examiner checked that the spirit level on the device was balanced at the centre before proceeding with the measurement.

The test was first carried out on the left shoulder followed by the right. A total of five readings were taken from each shoulder and each laxity measurement was averaged. The duration of each test session was less than 30 minutes.

4 Results
The overall GH joint translation measurements (including male and female, dominant and non-dominant shoulders) ranged from 17.0 to 24.8 mm with a mean of 20.7 ± 2.0 mm (Table 2).

Table 2. Shoulder anterior-posterior translation of study subjects

	Min (mm)	Max (mm)	Mean (mm)	SD (mm)
Overall (n = 64)	17.0	24.8	20.7	2.0
Male (n = 32)	20.4	24.8	22.3	0.9
Female (n = 32)	17.0	21.3	19.0	1.1

4.1 Reproducibility
To assess the reproducibility of the measurements, a test-retest series was performed on the same 64 subjects. After performing the test, the device was removed, repositioned and a retest was made. Reproducibility between the mean values of test and retest was evaluated with the intraclass correlation coefficient (ICC). The reliability was excellent and showed high reproducibility (Intraclass coefficient $r = 0.919$).

4.2 Comparison between dominant and non-dominant shoulder
Measurements taken from both left and right shoulder (n = 64). In order to avoid bias, it was ensured that the same researcher obtained all the measurements. Fig.1 shows the comparison between the dominant shoulder versus non-dominant shoulder. The data showed no statistically difference (unpaired t-test) between both shoulders ($p > 0.05$). Hence, for subsequent analysis, data will be taken from the average of both the left and right shoulder from both the male and female subjects.

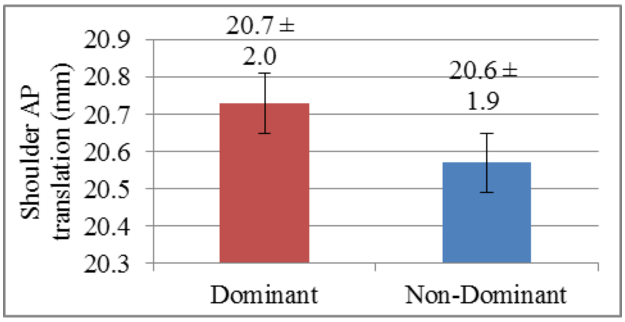

Fig.1 Shoulder AP translation - Dominant versus non-dominant shoulder (n = 64)

4.3 Comparison between genders
Fig.2 shows the translation between male and female groups. The translations for the male and female subjects were 22.3 ± 0.9 mm and 19.0 ± 1.1 mm respectively. An independent t-test showed that translation for male subjects were significantly higher than female ($p < 0.05$).

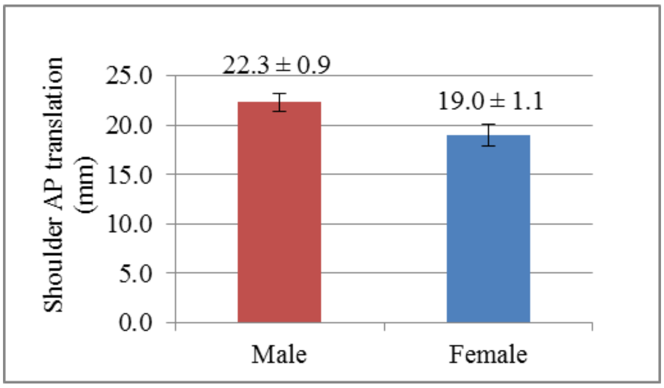

Fig.2 Shoulder AP translation- Male versus Female (n = 32)

4.4 Comparison between Active and Non-Active Sports participants

The pie chart in Fig.3 shows the exercise frequency of all the participants. Sports (non-overhead) includes activities that involve less utilization of hands like soccer, jogging and running while sports (overhead) includes activities that involve greater utilization of the hands like swimming, badminton, softball and basketball. Frequent exercise (daily/weekly) were categorized as "Active" while others were categorised as "Non-Active" (monthly or no exercise).

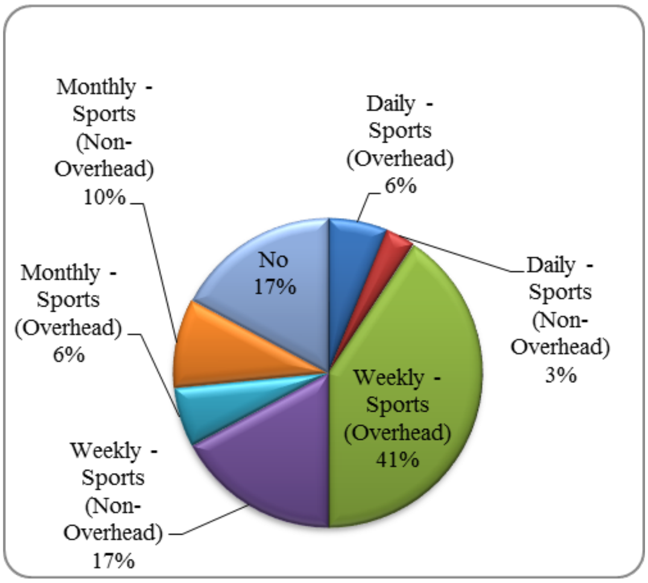

Fig.3 Exercising frequency of the participants (n = 64)

In this study, 42 pa rticipants belonged to the "Active" category while the remaining 22 participants belonged to the "Non-Active". Independent t-test showed that participants who were active in sports had significantly higher ($p < 0.05$) translation (21.3 ± 1.7 mm) compared to non-active participants (19.3 ± 1.7 mm) (see Fig.4).

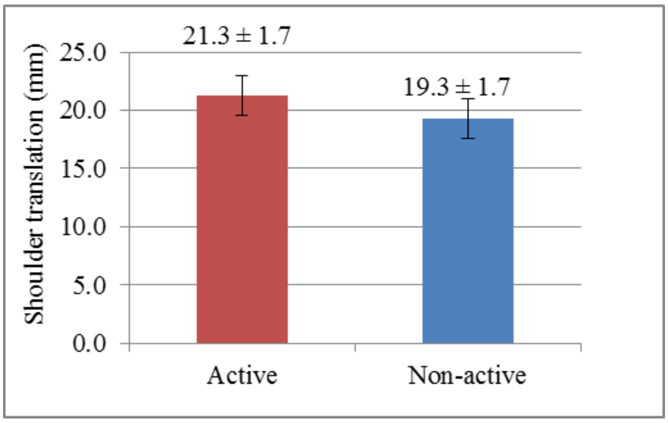

Fig.4 Comparing AP translation in active (n = 42) and non-active sports participants (n = 22)

4.5 Comparison between Overhead Sports and Non-Overhead Sports participants

The "Active" sports participants were further categorised into two groups; overhead sports and non-overhead sports. It was observed that the shoulder translation participants involved in overhead and non-overhead sports was 21.5 ± 1.9 mm and 21.0 ± 1.4 mm respectively (Fig.5). Independent t-tests performed between "Overhead" and "Non-Overhead" disclosed no significant difference between them ($p > 0.05$).

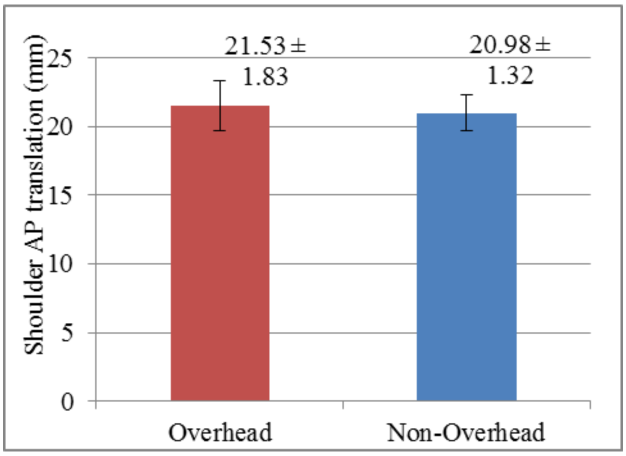

Fig.5 AP translation in overhead sports (n = 29) and non-overhead (n = 13) sports in active participants

The results were further analysed based on gender (Fig.6). It was observed that both male subjects who played overhead sports demonstrated significantly greater ($p < 0.05$) shoulder translation (22.7 ± 0.9 mm) compared to their peers (21.8 ± 0.7 mm). The shoulder translation in female subjects showed no significant difference ($p > 0.05$).

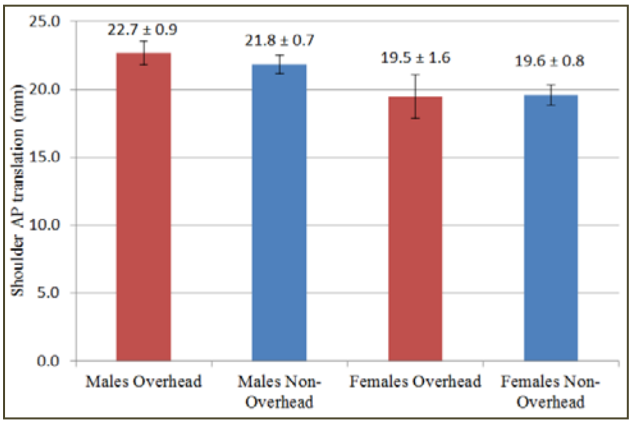

Fig.6 Gender-based comparison between overhead versus non-overhead sports

5 Discussion

Reliable quantification of GH translation, and correlating shoulder laxity and pathology for improving shoulder instability assessment has always been a challenge. Clinical studies of shoulder laxity have shown that the range of shoulder laxity in normal subjects varies widely [3,4,7]. Instrumented arthrometry involves the measurement of joint translation in a non-invasive, inexpensive and objective manner using specialised instrumentation [3,4,9]. Determining the reliability of a test instrument is important and has practical significance. The ability to document instrument reliability and measurement error helps to validate research findings and demonstrate the accuracy of the instrument. A test-retest assessment was used showing high reproducibility with ICC = 0.919.

The unpaired t-test revealed no significant difference in translation between the dominant and non-dominant shoulders. The findings were consistent with other similar research studies [8]. Crawford and Sauers [3] used a commercially available computerized stress device (LigMaster, Sports Tech, Charlottesville, VA) to quantify the anterior-posterior (AP) translations. In their study, 22 asymptomatic high school baseball pitchers were assessed for laxity using a 1 50 N displacement force. Their mean AP translation values for both dominant and non-dominant shoulders were 24.6 ± 3.7 mm and 24.9 ± 3.1 mm respectively. Pizarri et al. [10] used a co mmercial knee arthrometer to quantify AP translations. Their reported AP laxity range of 28 h ealthy subjects was 20.9 ± 4.9 m m (dominant 20.2 ± 5.0 mm, non-dominant 21.5 ± 4.8 mm) using a force of 67 N. The magnitudes of translation by Crawford and Sauers [3] and Pizarri et al. [10] were similar to the recorded measurements in our study.

Besides the paired t-test, the independent t-test performed between males and females showed no significant difference between genders ($p < 0.05$). Our study observed that male subjects have generally greater GH displacement as co mpared to female subjects (Table 2). To date, no previous studies have reported shoulder laxity between genders in general. Jansson et al. [2] provided evidence that shoulder laxity in male swimmers (age - 9 years) was generally higher than a female swimmers of (age - 12 years). However, Lintner et al. [11] concluded that there was no statistical difference between genders in passive range of motion (GH elevation, internal and external rotation at 0° and 90° of abduction).

In this study, significant difference between active and non-active sport participants ($p < 0.05$) was observed. It should be noted that we did not incorporate a s tandardised force application as compared to other studies using instrumented device [3,4]. From our observations, different subjects will require different amount of force application to translate the humeral head to reach its capsular end-point. This inconsistency could be due to the difference in bulk tissues surrounding the humeral head due to different physique of each individual.

Borsa et al. [2] has attempted to establish the amount of force required to reach capsular end-point. They estimated that in order to reach capsular end-point in subjects with healthy shoulders, it would require 203.1 ± 13.1 N of anteriorly directed force. However, most studies with instrumented devices, [3, 5, 9, 10] had applied a force of not more than 150 N to the joint. This force may not be sufficient for accurate measurements. In addition, the physical bone structure of different shoulders is likely to influence the maximum displacement measured between subjects.

6 Conclusion

This study has objectively measured the glenohumeral joint translations in healthy shoulders. The results indicate that dominant or non-dominant shoulders are not contributing factors in the shoulder AP laxity while the difference in gender and active in sports are likely to influence the same. Further study is needed to investigate laxity pattern variation between genders and documented shoulder pathologies. This information will lead to greater understanding of normal and abnormal glenohumeral joint laxity potentially aiding injury prevention, diagnosis, and possible treatments.

References:

[1] Guanche CA, Hale JE. Shoulder Arthometer. US Patent 6,390,994. May 21, 2002.

[2] Jansson A, Saartok T, Werner S, Renstrom, P. Evaluation of general joint laxity, shoulder laxity and mobility in competitive swimmers during growth and in normal controls. Scand J Med Sci Sports. 2005;15(3):169-176.

[3] Crawford SD, Sauers EL. Glenohumeral Joint Laxity and Stiffness in the Functional Throwing Position of High School Baseball Pitchers. J Athl Train. 2006;41(1): 52-59.

[4] Hatzel B, Horodyski M., Kaminski TW, Meister K, Powers M, Brunt D. Measurement of glenohumeral joint laxity using the KT-2000 knee ligament arthrometer: Reliability analysis. Phys Ther Sport. 2006;7:137-143.

[5] Bahk M, Keyurapan E, Tasaki A, Sauers EL, McFarland EG. Laxity Testing of the Shoulder – A Review. Am J Sports Med. 2007; 35(1): 131-144.

[6] Hawkins RJ, Schutte JP, Janda DH, Huckell GH. Translation of the glenohumeral joint with the patient under anaesthesia. J Shoulder Elbow Surg. 1996;5(4):286-292.

[7] Borsa PA, Jacobson JA, Scibek JS, Dover GC. Comparison of dynamic sonography to stress radiography for assessing glenohumeral laxity in asymptomatic shoulders. Am J Sports Med. 2005; 33:734-741.

[8] Jobe FW, Kvitne RS, Giangarra CE. Shoulder pain in the overhand or throwing athlete: the relationship of anterior instability and rotator cuff impingement. Orthop Rev. 1989;18(9): 963-975.

[9] Jorgensen U, Bak K. Shoulder instability: assessment of anterior-posterior translation with a knee laxity tester. Acta Orthop Scand. 1995;66(5):398-400.

[10] Pizzari T, Kolt GS, Remedios L. Measurement of anterior-to-posterior translation of the glenohumeral joint using the KT-1000. J Orthop Sports Phys Ther. 1999;29(10): 602-608.

[11] Lintner SA, Levy A, Kenter K, Speer KP. Glenohumeral translation in the asymptomatic athlete's shoulder and its relationship to other clinically measurable anthropometric variables. Am J Sports Med. 1996;24(6): 716-720.