View metadata, citation and similar papers at core.ac.uk

brought to you by CORE

provided by SJSU ScholarWorks

San Jose State University
SJSU ScholarWorks

Master's Theses
Master's Theses and Graduate Research

2002

Examiner reliability of the load and shift test : a preliminary study

Patrick S. Jenkins
San Jose State University

Follow this and additional works at: https://scholarworks.sjsu.edu/etd_theses

Recommended Citation

Jenkins, Patrick S., "Examiner reliability of the load and shift test : a preliminary study" (2002). *Master's Theses*. 2360.
DOI: https://doi.org/10.31979/etd.hutz-ce4s
https://scholarworks.sjsu.edu/etd_theses/2360

This Thesis is brought to you for free and open access by the Master's Theses and Graduate Research at SJSU ScholarWorks. It has been accepted for inclusion in Master's Theses by an authorized administrator of SJSU ScholarWorks. For more information, please contact scholarworks@sjsu.edu.

INFORMATION TO USERS

This manuscript has been reproduced from the microfilm master. UMI films the text directly from the original or copy submitted. Thus, some thesis and dissertation copies are in typewriter face, while others may be from any type of computer printer.

The quality of this reproduction is dependent upon the quality of the copy submitted. Broken or indistinct print, colored or poor quality illustrations and photographs, print bleedthrough, substandard margins, and improper alignment can adversely affect reproduction.

In the unlikely event that the author did not send UMI a complete manuscript and there are missing pages, these will be noted. Also, if unauthorized copyright material had to be removed, a note will indicate the deletion.

Oversize materials (e.g., maps, drawings, charts) are reproduced by sectioning the original, beginning at the upper left-hand corner and continuing from left to right in equal sections with small overlaps.

ProQuest Information and Learning
300 North Zeeb Road, Ann Arbor, MI 48106-1346 USA
800-521-0600

UMI®

EXAMINER RELIABILITY OF THE LOAD AND SHIFT TEST: A PRELIMINARY STUDY

A Thesis

Presented to

The Faculty of the Department of Human Performance

San Jose State University

In Partial Fulfillment

Of the Requirements for the Degree

Master of Arts

By

Patrick S. Jenkins, ATC

December 2002

UMI Number: 1411613

Copyright 2002 by
Jenkins, Patrick Sean

All rights reserved.

UMI®

UMI Microform 1411613
Copyright 2003 by ProQuest Information and Learning Company.
All rights reserved. This microform edition is protected against
unauthorized copying under Title 17, United States Code.

ProQuest Information and Learning Company
300 North Zeeb Road
P.O. Box 1346
Ann Arbor, MI 48106-1346

© 2002

Patrick S. Jenkins

ALL RIGHTS RESERVED

APPROVED FOR THE DEPARTMENT OF HUMAN PERFORMANCE

Dr. Leamor Kahanov

Dr. V. Greg Payne

Jason Gauvin, MS, PT, ATC, Stanford University Sports Medicine

APPROVED FOR THE UNIVERSITY

ABSTRACT

EXAMINER RELIABILITY OF THE LOAD AND SHIFT TEST: A PRELIMINARY STUDY

By Patrick S. Jenkins

Preliminary studies with open magnetic resonance imaging scanners are promising for evaluating passive and active glenohumeral joint movements. However, no studies have addressed examiner reliability. This study sought to determine examiner reliability using the load and shift test when measuring anterior glenohumeral joint translation using an open magnetic resonance scanner to determine millimeters of translation. Four asymptomatic male subjects (8 shoulders) were evaluated using the load and shift stress test while seated upright in the open magnetic resonance scanner. Four examiners performed repeated posteroanterior stress tests on each shoulder. Repeated stress tests were performed one month later. Intraclass correlation found inter-examiner reliability to be (.76) and (.49) on dominant and non-dominant shoulders respectively. Intra-examiner reliability demonstrated a wider variance in statistical findings between the four different examiners, (-.04 to .72, and -.50 to.42) on dominant and non-dominant shoulders respectively. Results from this study suggest the Load and Shift test alone to be unreliable for assessing anterior glenohumeral translation.

ACKNOWLEDGEMENTS

I would like to thank all of those who helped me with the completion of this study, and with my experience over the past two years. Specifically I would like to thank Burnsy, Shy-dog, Mo, Ralphy, Snow, and Sully for the sacrifices you all made in your lives during our time at "The Farm." We made it. I would like to thank Dr. Kahanov, Dr. Payne, Jason Gauvin, and Dr. Beaulieu for their expertise and advice along the way. I would also like to thank Dr. Beaulieu for his generosity and contributions to this project. Kevin, Snow, Ralph, and Burnsy, Easter will never be the same without Half Moon Bay and the Old Princeton Landing! Roberts, where would I be without "Jensen"? Dale, Marc, Buck, Jimmy, P-Train, K.P., Rainbow, G.G., and Sammy J, your experience helped shaped mine, thank you. To Dava, your thoughts, knowledge, heart, mind, and desire are sorely missed on this Earth. To the rest of my SJSU class, good luck in life and whatever you do. Lastly, to my mom and dad, thank you for all of the time, love, support, and guidance in my life, without you I wouldn't have made it this far.

TABLE OF CONTENTS

TABLE OF FIGURES

Article for American Journal of Sports Medicine

EXAMINER RELIABILITY OF THE LOAD AND SHIFT TEST: A PRELIMINARY STUDY

EXAMINER RELIABILITY OF THE LOAD AND SHIFT TEST: A PRELIMINARY STUDY

Patrick S. Jenkins, ATC*!; Leamor Kahanov, EdD, ATC*, Chris Beaulieu, PhD, MD!#; Jason Gauvin, MS, PT, ATC$

*Department of Human Performance, San Jose State University, San Jose, CA 95192
!University of Washington Athletic Training Room, Seattle, WA 98195
Department of Radiology, Stanford University Medical Center, Stanford, CA 94305
$HealthSouth Rehabilitation Center, Stanford University Medical Center, Stanford, CA 94305

ABSTRACT

Preliminary studies with open magnetic resonance imaging scanners are promising for evaluating passive and active glenohumeral joint movements. However, examiner reliability has yet to be addressed. This study sought to determine examiner reliability using the load and shift test when measuring anterior glenohumeral joint translation using an open magnetic resonance scanner to determine millimeters of translation. Four asymptomatic male subjects (8 shoulders) were evaluated using the load and shift stress test while seated upright in the open magnetic resonance scanner. Four examiners performed repeated posteroanterior stress tests on each shoulder. Repeated stress tests were performed one month later. Intraclass correlation found inter-examiner reliability to be (.76) and (.49) on dominant and non-dominant shoulders respectively. Intra-examiner reliability demonstrated a wider variance in statistical findings between the four different examiners, (-.04 to .72, and -.50 to.42) on dominant and non-dominant shoulders respectively. Results from this study suggest the Load and Shift test alone, to be unreliable for assessing anterior glenohumeral translation.

INTRODUCTION

The glenohumeral joint has been described as the most mobile and potentially unstable joint in the body. [3, 6, 14, 24, 29] Normal glenohumeral joint mechanics require an intricate relationship between the rotator cuff muscles, glenohumeral joint capsule, and the capsule's associated ligaments to maintain stability of the joint when in motion. [4, 5, 7, 10, 15, 18, 22-25, 27, 29, 30] Due to the complex nature of normal glenohumeral mechanics, an accurate manual evaluation is often challenging, and has demonstrated poor reproducibility. [20] A subjective patient history, dynamic manual examination, and static radiographs are standard for clinical evaluation of the glenohumeral joint.[13] Manual laxity examination techniques targeting the capsuloligamentous structures of the glenohumeral joint require the examiner to recognize the amount of force applied on the joint, estimate the movement occurring at the joint, and consciously compare the expected joint response in a non-impaired shoulder. [17] This can be a difficult and misleading comparison since side-to-side differences have been demonstrated in healthy shoulders. [23]

The "load and shift" test is a standard manual special test used to evaluate glenohumeral translation. The load and shift test requires the examiner to stabilize the scapula and subjectively center the humeral head on the glenoid and apply anterior and posterior directed forces on the humeral head to evaluate the amount of translation. Due to the subjective amounts of force and perceived translation, this clinical test is potentially unreliable and susceptible to variations within and between examiners. [26] The ability to accurately assess translation may prove useful in assessment, approach, treatment, and/or operative procedure. [13] Therefore a quantitative measure of joint translation would be ideal for accurate and reliable assessment of glenohumeral translation.[12, 23, 28, 29]

Advances in diagnostic imaging have provided examiners the unique and increasingly valuable tools that may be applied to studies of joint anatomy and motion. Recent developments in magnetic resonance imaging include the development of open magnetic resonance imaging (OMRI), which enables examiners to perform stress testing on an array of joints while displayed in a cross-sectional manner with high quality imaging. Potentially the greatest advantage to using OMRI to evaluate an injury is the examiner's ability to be present and conduct a manual examination of the joint. OMRI allows for a more in depth joint evaluation, such as the glenohumeral joint because of the open configuration and real time image tracking.

Currently minimal research exists pertaining to the use of OMRI in the assessment of anterior glenohumeral translation. Beaulieu et al.[2] performed preliminary studies regarding stress testing of the glenohumeral joint which identified that anteriorly directed forces on the humeral head resulted in as much 6-millimeters of anterior translation in asymptomatic subjects, demonstrating the ability to quantify glenohumeral translation in vivo.[2] In addition, glenohumeral alignment was assessed using OMRI examination under anesthesia. OMRI was found to accurately assess instability using the "load and shift" test in 6 of 11 shoulders.[14] While these separate studies are ground breaking in regards to the use of OMRI scanners to evaluate glenohumeral joints, further research is needed to establish reliability of the load and shift stress test using the OMRI. In order to generalize results to a broader group of examiners and subjects, an understanding of the variations in test results due to examiner differences is necessary.

Accordingly, the purpose of this study was to determine intra-examiner and inter-examiner reliability of the load and shift test using an OMRI scanner to measure millimeters of anterior translation.

MATERIALS AND METHODS

Data were collected on both dominant and non-dominant shoulders of four asymptomatic males (range 24-33 years old; *m* = 29 years) with no recent history of shoulder pain or evidence of glenohumeral instability. In total eight shoulders were examined. Subjects with previous shoulder injury requiring immobilization or surgery within the past 5 years were excluded from the study. The examiners were two physicians (Examiners 1 & 3), one physical therapist/athletic trainer (Examiner 4) and one athletic trainer (Examiner 3). All the examiners had previous experience with OMRI, but only examiners 1,2, and 3 had evaluation experience with the OMRI and glenohumeral joints prior to the study. Informed consent was obtained from all subjects prior to examination. The project was approved by the Human Subjects Review Board of associated universities/institutions prior to testing.

Subjects were examined in a seated upright position in a vertically-open configuration, 0.5T MR scanner (Signa SP, GE Medical Systems, Milwaukee, WI). A flexible transmit-receive RF coil (single loop large crown coil) was placed around the shoulder. Fast gradient-echo imaging sequences were used with the following parameters: TR 19.8 msec, TE 7.2 msec, flip angle 30-40 degrees, 256 x 128 matrix, FOV 24-30 cm, slice thickness 7-mm, 1 NEX. Sequential, transaxial, single slice images were acquired at a rate of approximately 2.5 seconds per image. Imaging parameters were selected to provide the fastest possible image acquisition, yielding images that produce consistent measurements.[14]

Subjects were examined in a seated upright position with the humerus slightly abducted and in neutral rotation using the load and shift test. The load and shift test requires the examiner to center the humeral head on the glenoid, and then apply an anteriorly directed force to the posterior aspect of the humeral head resulting in an anterior shift of the humeral head on the glenoid (Figure 2). Three separate posteroanterior stress tests were performed for each shoulder by each examiner, in random order. Images were taken at the point of maximal anterior translation, subjectively determined when the examiner could not elicit further glenohumeral translation. Examiners were instructed to hold the position of maximal excursion for at least one-second while images were taken. To provide a baseline for glenohumeral alignment, a neutral, non-stress, image was taken prior to measuring anterior glenohumeral translation with the load and shift test examination technique (Figure 1). The neutral image allowed examiners to view centering of the humeral head on the glenoid and assured the scanning plane included the labrum and the humeral head prior to producing maximal anterior translation. Once all four examiners evaluated the first shoulder, an identical seated upright position was used on the contralateral shoulder for examination using the exact same protocol. After one month had elapsed from initial testing, the same four examiners performed repeated testing on the same subjects, but in a different, random order.

A total of 24 images (12 images on days 1 and 2) were evaluated for both the dominant and non-dominant shoulders (8 shoulders total) on each of the four subjects.

Images for measurement consisted of the baseline (non-stress) image and images representing the maximum degree of glenohumeral translation for each of the stress tests. Since imaging was continuous, these images were selected from a set of approximately 20 images for each examiner, subject, and shoulder. Images at maximal passive translation in the anterior direction were used for assessment. Images were individually analyzed to assess millimeters of anterior translation. The center of the humeral head was determined by prescribing a circle around the humeral articular surface on the OMRI images. The center of the circle then defined the center of the humeral head.[2] Margins of the glenoid were used to construct a line parallel to the glenoid fossa. The geometric center of this line indicated the center of the glenoid fossa.[2] Once millimeters of translation were determined the results were analyzed using an intra-class correlation coefficient within SPSS 10.1 for Windows (SPSS Inc., Chicago, IL).

RESULTS

Inter-examiner reliability was calculated using an intra-class correlation (ICC). Examiners demonstrated good reliability (.76) on dominant shoulders, and fair reliability (.49) on non-dominant shoulders. Overall intra-examiner reliability for dominant shoulders was (.28) and (.36) for non-dominant shoulders (Table 1).

Dominant shoulder anterior translation mean values were 5.33mm and 7.39mm on days one and two respectively. Non-dominant shoulder anterior translation mean values were 2.64mm and 5.18mm on days one and two respectively. Examiner 4 demonstrated the largest translation values for dominant shoulders (15.48mm) and non-dominant shoulders (13.30mm) alike (Table 2). Tables 3 and 3.1 contain examiner means and standard deviations on dominant and non-dominant shoulders.

DISCUSSION

The importance of quantifying glenohumeral translation has been identified in previous studies as a measurement tool for test-to-test findings.[12,20, 23, 28, 29] Normal glenohumeral translation values have not been clearly defined, [16, 27] and manual exams have reported poor reproducibility.[20] Recent studies examining the use of OMRI to evaluate glenohumeral translation during active and passive range of motions, as well as glenohumeral joint stress testing, have expressed a need to further research the reliability of measurement, particularly with asymptomatic data. [2, 14] Normative data values would be advantageous in the determination of the extent of injury and whether surgical intervention is warranted.

Inconsistent with previous findings, which suggest greater amounts of translation in dominant shoulders, [2, 8, 13, 14, 16, 20, 26] subject 1 demonstrated greater amounts of glenohumeral translation on the non-dominant shoulder (4.37mm) as compared to the dominant shoulder (4.21mm). Inter examiner findings demonstrate good reliability on both dominant and non-dominant shoulders. An examination of Table 2 reveals similarities between mean amounts of translation from one examiner to another where dominant and non-dominant shoulders are concerned. However, there were increases in amounts of translation. On average dominant shoulders increased 2.06mm, and non-dominant shoulders increased 2.54mm, measured from exam day one to exam day two respectively. The average increase of 2.30mm between dominant shoulders and non-dominant shoulders from day one to day two could be a function of several factors, including an inability to standardize manually generated force amounts during stress testing, examiner and subject comfort levels within the OMRI scanner, glenoid fossa anteversion, and the practice effect from using the scanner on multiple occasions.

Pizzari, Remedios, and Kolt, [26] and Sauers et al [29] were able to measure exact amounts of force in vivo during glenohumeral examination. In the present study manual examiner forces when performing the load and shift test were not measured on the glenohumeral joint. A lack of accurate force measurements, and having to rely on examiner sensitivity for force production with each test, could potentially increase the variability between examiner translation values. Pizzari, Remedios, and Kolt[26] used 67N (15lbs), and Sauers et al [29] used 67N, 89N, 111N, and 134N when performing anterior-to-posterior, and posterior-to-anterior stress evaluations on the glenohumeral joint with a KT-1000 knee joint arthrometer. Wuelker, Korell, and Thren[30] identified in a dynamic shoulder model that 27.8 +/- 11.9N is necessary to sublux the humeral head half the distance across the glenoid diameter. The capability to consistently produce exact amount of force in an otherwise subjective stress test evaluation would allow for more reliable test-to-test comparisons. In vivo assessment is theoretically an optimal setting for evaluation, since asymptomatic shoulders examined under anesthesia may demonstrate "perceived" hyper-translation. Anesthesia may present large amounts of glenohumeral translation that would clinically be determined as asymptomatic instability. Test-to-test differences in amounts of force may explain the variability within examiners and the differences from day one to day two in millimeters of anterior translation. In a daily clinical practice it is highly likely that varying amounts of force exist when performing the load and shift test, from examiner to examiner and from test to test, similar to the present study. Determining manually applied force amounts would provide greater accuracy of the current results.

Another potential factor with regards to variability may have been subject and examiner comfort level with the OMRI unit and the load and shift test within the unit. For many of the examiners this was their first and second exposures to performing stress tests inside the OMRI scanner. Being comfortable with positioning of the subject, hand placement, and force application could have influenced the outcome of results in this study. Intra examiner reliability results demonstrate a wider variance in both dominant and non-dominant shoulders, which supports the comfort of examination in the OMRI unit.

The glenoid is described as facing superiorly, anteriorly, and laterally.[32] However, the glenoid fossa is not always situated in a perpendicular plane with the scapular body, this structural arrangement is referred to as version.[32] This structural variation would mean manual forces being applied to the joint must be in the same plane as the glenoid fossa to ensure accurate force angles, something that cannot be determined without aid of radiographic investigation. Due to this fact and that the current study did not account for this structural possibility, some of the manual forces may have been "misdirected," resulting in inaccurate findings of anterior translation. Without a baseline radiograph to predetermine what degree of anteversion the subject has, every manual shoulder test may demonstrate inaccurate findings.

Several methods have been used to quantify glenohumeral translation, [2, 8, 9, 11, 13, 14, 16, 20, 26, 29] which use subjective rating scales, [9, 20] two groups used knee arthrometers, [16, 26] one group used a modified chair with force applicator, [29] where the others use a post evaluation quantification similar to this study. [2, 8, 11, 13, 14] The shoulder has a wide range of motion that an evaluation device should accommodate this range of motion. The ability to provide simultaneously visual feedback with a manual examination being can potentially aid in an accurate diagnosis and course of treatment. The development of OMRI technology allows a superior level of examination for multidirectional joints such as the shoulder. Enhancing a standard glenohumeral stress test with OMRI technology could provide more conclusive results and information with regards to glenohumeral injuries.

While manual examination of the glenohumeral joint has been the standard clinical test of glenohumeral instability, and is clearly going to remain the primary evaluation technique, the interpreted results are subjective and difficult to quantify, yet important for assessing internal injury. Manual examination techniques need to be established as reliable or unreliable in order to assure accuracy of exams within the clinical setting.

Based on current findings, OMRI technology allows examiners to account for soft tissue depths and movements which can not be seen via plain X-ray films, OMRI also provides accurate measurements of passive humeral head translation on the glenoid. OMRI provides examination of glenohumeral stability and integrity in detail in a non-invasive manner. Using an objective measuring device to assess results from a subjective manual exam will help determine the reliability of the manual exam, and therefore that exam's clinical relevance.

Assessing anterior glenohumeral translation with OMRI can provide objective information regarding the extent of a subject's shoulder injury. Past studies have attempted to examine anterior and posterior glenohumeral translation, [8, 9, 11, 13, 14, 16, 26] and more recently, dynamic evaluation of glenohumeral movements have been performed using an OMRI.[2, 11, 14] Until this study, current research had yet to investigate the reliability of manual anterior glenohumeral translation examination while using OMRI to objectify millimeters of translation. Several studies have assessed the load and shift stress test, [9, 13, 20] two of which used subjective measurement values (grades 0-3) of anterior translation,[9, 20] where the other study used stress radiographs to evaluate anterior glenohumeral translation.[13] However, none of the measurement techniques share the in vivo, real time capabilities of the OMRI scanner. Hawkins et al, [13] found patients with clinical anterior instability translated anteriorly 29% further than normal patients. Faber, Homa, and Hawkins [9] used a subjective grading scale for anterior glenohumeral translation and demonstrated significantly reliable values on the affected shoulder under anesthesia and while awake when compared to the unaffected shoulder. Levy et al, [20] evaluated intraobserver and interobserver reliability using a subjective rating scale and found intraobserver reproducibility ranged from 33-46% for anterior translation, where interobserver reproducibility ranged from 43-47%. [20] In the same study, when the evaluation grades 0 and 1 were equalized (grouped together) overall intraobserver reliability went up to 54-78%, and interobserver reliability went up to 65-67%.[20] By demonstrating less than desirable reliability results these studies help to demonstrate the need for a more reliable and quantifiable method to assess anterior glenohumeral translation.

The complexity of the glenohumeral joint and its synchronous movements are necessary for normal shoulder activities to occur. The large range of motion inherent to the shoulder creates an environment that exposes the joint to possible laxity, instability, and secondary injuries. Glenohumeral instability is a common cause for shoulder pain and dysfunction [1, 18, 22]. The ability to evaluate a shoulder throughout a large range of motion, and in painful positions that target structures of interest is important. Until the development of OMRI, manual glenohumeral assessment was the initial observation, followed by a static image of the shoulder, and potentially surgical examination and repair. The ability to evaluate the glenohumeral joint in any position and obtain quantifiable MRI-like images, make the OMRI unit appealing for evaluative purposes. However, manual examination will remain the initial and most cost effective means to evaluate glenohumeral injuries. Therefore it is important to establish routinely used manual exam techniques as reliable, and to establish normative translation values. Quantifying glenohumeral translation values will help establish normative data for asymptomatic subjects and provide a basis for comparison in the future. The ability to quantify translation values allows a basis for measurement from which reliability can be determined. Determining the reliability of the load and shift test as a manual exam is necessary to justify its use in the clinical setting.

CONCLUSION

This study demonstrated moderate amounts of inter examiner reliability (.76 for dominant shoulders & .49 for non-dominant shoulders), and poor amounts of intra examiner reliability (.28 for dominant shoulders & .36 for non-dominant shoulders) when measuring anterior glenohumeral translation using the load and shift test in asymptomatic shoulders. OMRI is on the forefront of diagnostic evaluation technology, and using such an objective measuring device to evaluate a manual stress test is important to ensure manual exam accuracy. Further research with manual exams and OMRI should include a larger sample of shoulders, heterogenous populations, symptomatic shoulders, and more repetitions of exam trials on each glenohumeral joint to more accurately assess reliability of the load and shift using OMRI. A means to measure standardized amounts of manually applied forces needs to be developed to provide more quantifiable assessment of glenohumeral translation. Future studies need to be conducted to help further develop confidence in examiner reliability and comfort if OMRI to be used in conjunction with manual glenohumeral evaluation. Overall, the load and shift test using OMRI demonstrated modest reliability when measuring anterior glenohumeral translation, and should be considered as a less than reliable method for glenohumeral evaluation. Authors from this study would suggest multiple glenohumeral examination techniques for a more accurate interpretation of glenohumeral instability when assessing anterior glenohumeral translation.

Acknowledgements

The authors would like to thank Dr. Kim Butts for her technical expertise, and Dr. Gary Gold, Marc Guillet, MS, PT, ATC, Jeff Roberts, MS, ATC, Sam Johnson, MS, ATC, Mike Burns, ATC, and Chris Reed, MS, PT for their generous time contributions to make this study possible.

References

1. Baker CL, & Merkley MS: Clinical evaluation of the athlete's shoulder. *J Athl Train 35*:256-260,2000
2. Beaulieu CF, Hodge DK, Bergman AG, et al.: Glenohumeral relationships during physiologic shoulder motion and stress testing: Initial experience with open MR imaging and active imaging-plane registration. *Radiology 212*:699-705,1999
3. Branch TP, Avilla O, London L, et al.: Correlation of medial/lateral rotation of the humerus with glenohumeral translation. *Br J Sports Med 33*:347-351,1999
4. Branch TP, Lawton RL, Iobst CA, et al.: The role of glenohumeral capsular ligaments in internal and external rotation of the humerus. *Am J Sports Med 23*:632-637,1995
5. Cain PR, Mutschler TA, Fu FH, et al.: Anterior stability of the glenohumeral joint: A dynamic model. *Am J Sports Med 15*:144-148,1987
6. Chan KM, Maffulli N, Nobuhara M, et al.: Shoulder instability in athletes: the Asian perspective. *Clin Orthop 323*:106-112,1996
7. Chen SK, Simonian, PT, Wickiewicz TL, et al.: Radiographic evaluation of glenohumeral kinematics: A muscle fatigue model. *J Shoulder Elbow Surg 8*:49-52,1999
8. Ellenbecker TS, Mattalino AJ, Elam E, et al.: Quantification of anterior translation of the humeral head in the throwing shoulder. *Am J Sports Med 28*:161-167,2000
9. Faber KJ, Homa K, & Hawkins RJ: Translation of the glenohumeral joint in patients with anterior instability: Awake examination versus examination with the patient under anesthesia. *J Shoulder Elbow Surg 8*:320-323,1999

10. Gohlke F, Essigkrug B, & Schmitz F: The pattern of the collagen fibers of the capsule of the glenohumeral joint. *J Shoulder Elbow Surg 3*:111-128,1994

11. Graichen H, Stammberger T, Bonel H, et al.: Glenohumeral translation during active and passive elevation of the shouler-a 3D open-MRI study. *J Biomech 33*:609-613,2000

12. Harryman DT, Sidles JA, Harris SL, et al.: Laxity of the normal glenohumeral joint: a quantitative in vivo assessment. *J Shoulder Elbow Surg 2*:66-76,1992

13. Hawkins RJ, Schutte JP, Janda DH, et al.: Translation of the glenohumeral joint with the patient under anesthesia. *J Shoulder Elbow Surg 5*:286-292,1996

14. Hodge DK, Beaulieu CF, Thabit GH, et al.: Dynamic MR imaging and stress testing in glenohumeral instability: Comparison with normal shoulders and clinical/surgical findings. *J Mag Res Imaging 13*:748-756,2001

15. Howell SM, & Kraft TA: The role of the supraspinatus and infraspinatus muscles in glenohumeral kinematics of anterior shoulder instability. *Clin Orthop 262*:128-134,1991

16. Jorgensen U, & Bak K: Shoulder instability: Assessment of anterior-posterior translation with a knee laxity tester. *Acta Orthop Scand 66*:398-400,1995

17. Keating J, Matyas TA, & Bach TM: The effect of training on physical therapists' ability to apply specified forces of palpation. *Phys Ther 73*:38-46,1993

18. Kvitne RS, & Jobe FW: The diagnosis and treatment of anterior instability in the throwing athlete. *Clin Orthop 291*:107-123,1993

19. Kwak AM, Brown RR, Trudell D, et al.: Glenohumeral joint: comparison of shoulder positions at MR arthrography. *Radiology 208*:375-380,1998

20. Levy AS, Lintner S, Kenter K, et al.: Intra-and interobserver reproducibility of the shoulder laxity examination. *Am J Sports Med 27*:460-463,1999
21. Matsen FA, Harryman DT, & Sidles JA: Mechanics of glenohumeral instability. *Clin Sports Med: Basic Science and Clinical Application in the Athlete's Shoulder 10*:783-805,1991
22. McCluskey GM, Getz BA: Pathophysiology of anterior shoulder instability. *J Athl Train 35*:268-272,2000
23. McFarland EG, Torpey BM, & Curl LA: Evaluation of shoulder laxity. *Sports Med 22*:264-272,1996
24. O'Brien SJ, Pagnani MJ, Panariello RA, et al.: Anterior Instability of the Shoulder in Andrews JR., & Wilk KE (eds): *The Athlete's Shoulder.* New York, Churchill Livingstone, 1994, pp 177-201
25. O'Brien SJ, Schwartz RS, Warren RF, et al.: Capsular restraints to anterior-posterior motion of the abducted shoulder: a biomechanical study. *J Shoulder Elbow Surg 4*:298-308,1995
26. Peat, M., & Culham, E. (1994). Functional Anatomy of the shoulder complex. The Athlete's Shoulder, Wilk, K.E., Andrews, J.R. New York, Churchill Livingstone.
27. 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 29*:602-608,1999
28. Rodkey WG, Noble JS, & Hintermeister RA: Laboratory methods of evaluating the shoulder: strength, range of motion, and stability, in Matsen FA, Fu FH, & Hawkins

RJ (eds): *The Shoulder: A Balance of Mobility and Stability*. Rosemont, IL, American Academy of Orthopaedic Surgeons, 1993, pp 551-582,

29. Sauers EL, Borsa PA, Herling DE, et al.: Instrumented measurement of glenohumeral joint laxity and its relationship to passive range of motion and generalized joint laxity. *Am J Sports Med 29*:143-150,2001
30. Terry GC, & Chopp TM: Functional anatomy of the shoulder. *J Athl Train 35*:248-255,2000
31. Vellet AD, Munk PL, & Marks P: Imaging techniques of the shoulder: Present perspectives. *Clin Sports Med: Basic Science and Clinical Application in the Athlete's Shoulder 10*:721-756,1991
32. Wilk KE, Arrigo CA, & Andrews JR: Current concepts: The stabilizing structures of the glenohumeral joint. *J Orthop Sports Phys Ther 26*:364-379,1997
33. Wuelker N, Korell M, & Thren K: Dynamic glenohumeral joint stability. *J Shoulder Elbow Surg 7*:43-52,1998

Footnotes

No author or related institution has received any financial benefit from research in this study.

The address for correspondence is:
Patrick Jenkins, ATC
Graves Building
Box 354070
Seattle, WA 98195

The address for reprints is:
Leamor Kahanov, EdD, ATC
Program Director Graduate Athletic Training
Department of Human Performance
One Washington Square
San Jose, CA 95192-0054

Table1. Intra tester reliability scores for dominant and non-dominant shoulders (n=48) (p=.05).

Examiner #	Dominant Shoulder	Non-Dominant Shoulder
Examiner 1	-.04	.24
Examiner 2	.72	-.50
Examiner 3	.41	.29
Examiner 4	-.04	.42

Table 2. Mean and standard deviation values (mm) for subject's dominant (D) and non-dominant (ND) shoulders.

Subject #/ Shoulder	Mean	Standard Deviation
1 Dominant	4.21	2.12
1 Non-Dominant	4.37	2.30
2 Dominant	7.41	3.35
2 Non-Dominant	3.85	2.64
3 Dominant	8.62	2.42
3 Non-Dominant	3.29	2.28
4 Dominant	5.08	2.70
4 Non-Dominant	4.11	2.91
Overall Dominant (n=96)	6.33	3.18
Overall Non-Dominant (n-96)	3.91	2.54

Table 3. Examiner means and standard deviations with regards to Dominant and Non-dominant shoulders (n=48).

Examiner Number & Shoulder Examined	**Mean**	**Standard Deviation**
Examiner 1/Dominant	6.75mm	2.40mm
Examiner 1/Non-Dominant	3.72mm	2.32mm
Examiner 2/Dominant	6.46mm	3.74mm
Examiner 2/Non-Dominant	4.11mm	2.16mm
Examiner 3/Dominant	5.81mm	2.97mm
Examiner 3/Non-Dominant	3.72mm	2.37mm
Examiner 4/Dominant	6.43mm	3.58mm
Examiner 4/Non-Dominant	4.10mm	3.29mm

Table 3.1: Examiner Translation Amounts in millimeters for Dominant (n=48) and Non-Dominant (n=48) Shoulders

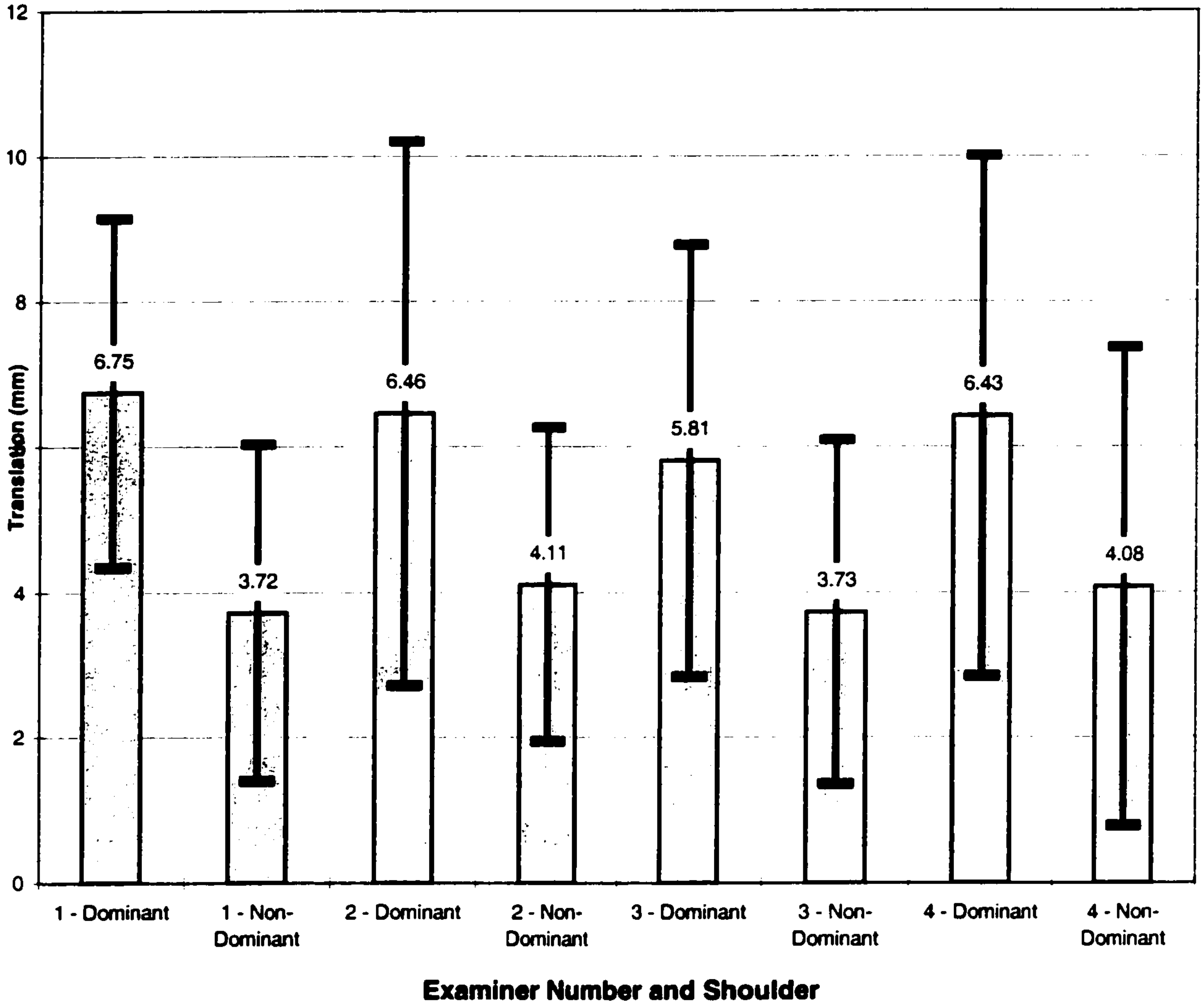
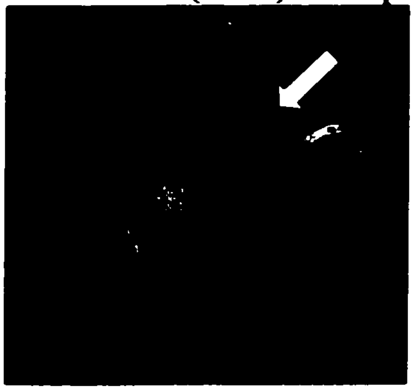


Figure 1. Neutral image demonstrating humeral head centering on the glenoid prior to the load and shift.

Figure 2. Anterior shift image, notice examiner's thumb and evidence of posterior-to-anterior force (arrow) on the posterior musculature.



EXTENDED SUPPORT MATERIAL

PROJECT PROPOSAL

Chapter 1

INTRODUCTION

The glenohumeral joint has been described as the most mobile and potentially unstable joint in the body (Chan, Maffulli, Nobuhara, & Wu, 1996; Kwak, Brown, Trudell, & Resnick, 1998). The wide range of motion characteristic to the shoulder, and its dependence on the rotator cuff muscles for dynamic stability, exposes the joint to both unidirectional and multidirectional instability. Instability can be defined as unwanted translation of the humeral head on the glenoid fossa causing pain, functional disability, and potential long term injury (Matsen, Harryman, & Sidles, 1991). Laxity is another term frequently used to describe shoulder stability characteristics. Glenohumeral laxity is defined as the ability of the humeral head to passively translate on the glenoid fossa (Matsen, Harryman, & Sidles, 1991). Laxity is the objective component of interest to clinicians when examining the integrity of glenohumeral ligaments. The clinician determines the extent of injury to the shoulder using subjective history gathering and partially objective manual examination techniques. While this method of evaluating shoulders has sufficed in the past, and remains standard procedure across the board, manual examination is subjective in nature since the amount of shoulder movement detected is often not highly discriminating (Pizzari, Kolt, & Remedios, 1999). Thorough evaluation of glenohumeral joint injuries requires an easily applicable and reproducible method for objective assessment of shoulder instability (Jorgensen & Bak, 1995).

Pizzari, Kolt and Remedios (1999) stated that "the measurement of shoulder laxity is subjective and unreliable....and that standard manual examination techniques, while adequate for assessing general instability ideas, are clearly not practical for quantifying glenohumeral laxity in a clinical environment" (p. 602-603). Pizzari, Kolt, and Remedios (1999) modified a KT-1000 (MedMetric Corporation, San Diego, CA) knee ligament tester in an effort to objectively measure anterior and posterior glenohumeral translation, where they had "good" and "moderate" test-retest reliability using the KT-1000. Jorgensen and Bak (1995) reported highly reproducible results testing anterior glenohumeral translation using the DonJoy Knee Laxity Tester, however deltoid thickness and subcutaneous tissue movement which are potential limitations, were not considered (Jorgensen & Bak, 1995). Another considerable limitation to the research of Pizzari, Kolt, and Remedios (1999), and Jorgensen and Bak (1995) is that knee ligament arthrometers were designed for knee ligament testing. Glenohumeral ligaments have been proven to have diminished tensile strength when compared to knee ligaments (Bigliani, Pollock, Soslowsky, Flatow, Pawluk, & Mow, 1992), thus the use of the KT-1000, DonJoy Knee Laxity Tester, or similar arthrometers on shoulder laxity may be an inaccurate assessment of shoulder joint stability. While Pizzari, Kolt, and Remedios (1999), and Jorgensen and Bak (1995) search for an external glenohumeral arthrometer, or the adaptation of a pre-existing knee ligament arthrometer, to measure shoulder instability, a newly developed method of magnetic resonance imaging (MRI), open magnectic resonance (OMR) imaging may prove to be the method of choice for assessing glenohumeral laxity. OMR technology accounts for soft tissue depths and allows accurate, if not exact measurements of active and passive humeral head translation on the glenoid.

The ability to visualize internal derangement and movement within a joint has become increasingly more accurate and available as recent technology, like open magnetic resonance (OMR) imaging, has been developed. Image evaluation of the glenohumeral joint should include images of the rotator cuff muscles, glenoid labrum, glenohumeral capsular ligament mechanism, long head of the biceps, articular cartilage, and bony shoulder girdle structures (Vellet, Munk, & Marks, 1991). OMR makes viewing the aforementioned anatomic structures possible, and provides examination of glenohumeral stability in detail using a non-invasive manner. It also allows sequential images to be taken simultaneously as the subject performs active movements and as the examiner applies clinical stress tests to the subject. As stress testing is being performed, the clinician's subjective shoulder evaluation of glenohumeral translation can be compared against objective OMR images making a more concise and objective determination of injury. OMR is a relatively new diagnostic tool. Reliability of this new evaluation technique in providing accurate anatomic information while stress testing and examining the glenohumeral joint has yet to be assessed. Beaulieu, Hodge, Bergman, Butts, Daniel, Napper, Darrow, Dumoulin, and Herfkens (1999) have conducted preliminary OMR studies on range of motion (ROM) and stress testing of the glenohumeral joint depicting humeral head centering on the glenoid through most movements and quantitative amounts of humeral head translation in uninjured shoulders. Recently, Hodge, Beaulieu, Thabit, Gold, Bergman, Butts, Dillingham, and Herfkens (in press) have compared OMR imaging versus examination under anesthesia (EUA) to determine glenohumeral stability, and expressed a need to further study the reliability of OMR in glenohumeral examination to determine shoulder assessment accuracy.

In an anatomically unstable joint such as the shoulder adapting a uni-planar arthrometer such as the KT-1000 or DonJoy Knee Ligament Tester may be difficult, because the device was originally designed to evaluate the unidirectional knee, to accurately measure multi-planar glenohumeral joint translation. The shoulder has such a wide range of motion that an evaluation device should accommodate this ROM while simultaneously providing visual feedback regarding all possible lesions and excessive joint movement to make accurate decisions for rehabilitation and/or operative intervention. The advent of open magnetic resonance (OMR) technology allows a level and method of examination for multidirectional joints such as the shoulder which include visualization of soft tissue structures as well as the bony anatomy involved while clinical manual examinations are being performed.

Purpose of this Project

The purpose of this project is to examine the reliability of open magnetic resonance (OMR) imaging in measuring anterior glenohumeral translation in normal shoulders. Intratester and intertester reliability examining anterior glenohumeral translation will be measured using OMR images for objective accuracy.

Significance of the Study

Recent studies (Beaulieu et al., 1999; Hodge et al., in press) have suggested the need to further investigate the reliability of OMR imaging for measuring glenohumeral translation. Results may establish OMR imaging as a valuable and reliable non-invasive evaluation device to assess levels of glenohumeral translation which will aid in diagnosing glenohumeral instability. This study may also lead to further investigation to determine normal glenohumeral movement compared to abnormal glenohumeral movement studies.

Delimitations

This study is delimited by the number of subjects (5), the age (18 to 35) of the subjects, the exclusion of injured shoulders, the number of testers, the evaluation tool (open magnetic resonance tracking device, GE Systems), and the manual examination stress test (load and shift).

Limitations

A major limitation of this study was the number of subjects that could be tested in the amount of time available in the open magnetic resonance imaging unit. This study is also limited by the number of testers utilized. The small number of subjects and testers may limit the generalizability of the outcome but may establish president for future evaluation of this technique.

Statement of Hypothesis

The hypothesis of this study is that open magnetic resonance imaging technology will prove to be reliable when measuring anterior glenohumeral translation, and that using one manual examination stress test, testers will have good reproducibility of measurements.

Definition of Terms

Accessory movement: Movements within a joint that cannot be voluntarily performed by the individual such as glides and joint mobilizations.

Dynamic stabilizers: The four muscles, supraspinatus, subscapularis, teres minor, and infraspinatus, that are responsible for holding the humeral head centered on the glenoid fossa during active movements.

Glenohumeral joint: The articulation between the glenoid fossa of the scapula and the head of the humerus.

Internal derangement: Disruption of the normal structures within a joint that causes injury.

Laxity: The ability of the humeral head to passively translate on the glenoid fossa (Matsen, Harryman, & Sidles, 1991)

Load and shift test: A joint stress test where the examiner places one hand over the clavicle and scapula to stabilize the scapula while the other hand with the thumb located posteriorly on the humeral head and the index and middle fingers on the anterior aspect of the humeral head. The head of the humerus is then centered ("load") on the glenoid fossa. From here an anterior or posterior force is applied and translation is graded on a scale of zero to three ("shift") (Magee, 1997).

Open magnetic resonance imaging: Open configuration MRI unit that allows image tracking while range of motion and stress tests are performed on joints.

Static stabilizers: The glenohumeral joint capsule, comprised of the superior, middle, and inferior glenohumeral ligaments which are thickenings of the joint capsule (Anderson & Hall, 1995).

Translation: Gliding of the head of the humerus on the glenoid fossa.

Summary

Assessing anterior glenohumeral translation with OMR can provide objective information regarding the extent of a subject's shoulder injury, since manual examination of anterior glenohumeral translation is purely subjective (Pizzari, Kolt, & Remedios, 1999). Past studies have attempted to examine anterior and posterior glenohumeral translation (Ellenbecker, Mattalino, Elam, & Caplinger, 2000; Faber, Homa, & Hawkins, 1999; Hawkins, Schutte, Janda, & Huckell, 1996; Jorgensen & Bak, 1995; Pizzari, Kolt, & Remedios, 1999), and more recently, dynamic evaluation of glenohumeral movements have been performed using open magnetic resonance imaging (Beaulieu et al., 1999; Graichen, Stammberger, Bonel, Englmeier, Reiser, & Eckstein, 2000; Hodge et al., in press). Currently research has yet to investigate the reliability of open magnetic resonance (OMR) imaging in the evaluation of anterior glenohumeral translation. The purpose of this study is to determine whether OMR imaging demonstrates intratester and intertester reliability in evaluating anterior glenohumeral translation. Data from this study will be compiled into a journal article for *The American Journal of Sports Medicine*, and written according to the author's notes see (Appendix A).

Chapter 2

REVIEW OF LITERATURE

The purpose of this study is to examine the reliability of open magnetic resonance (OMR) imaging in measuring anterior glenohumeral translation. Intratester and intertester reliability of objective OMR images examining anterior glenohumeral translation will be assessed for accuracy. The review of literature will be divided into the following four sections: 1) glenohumeral joint musculoskeletal anatomy, 2) static stabilizer mechanics, 3) dynamic stabilizer mechanics, and 4) glenohumeral examination techniques.

Glenohumeral Joint Musculoskeletal Anatomy

To accurately assess a joint, such as the glenohumeral joint, an understanding of the involved anatomy is imperative. The glenohumeral joint is composed of bony, soft tissue, and connective tissue structures which play an integral role in the dynamic and static stability of the shoulder.

The underlying anatomy of the glenohumeral joint begins with the bony structures of the scapula and humerus, in particular the glenoid fossa of the scapula and the head of the humerus. The glenoid fossa is the concave surface on the most lateral portion of the scapula or shoulder blade, and the humeral head is the most proximal and superior aspect of the humerus or upper arm bone. (See Figure 1). The medial aspect of the humeral head articulates with the glenoid fossa to form the multi-axial ball-and-socket joint the shoulder is described as. However, the glenohumeral joint is not a classic ball-and-socket joint. At any one time the humeral head, which has approximately 3 to 4 times the surface area as the glenoid, has no more than 25 to 30 percent of its surface area in contact with the glenoid (Peat & Culham, 1994). This lack of bony contact allows the shoulder its large range of motion. Since only a portion of the humeral head in contact with the glenoid fossa during movements, the glenohumeral joint relies heavily upon ligaments and muscles (rotator cuff) to provide stability to the joint. Thus, due to minimal bony support, the shoulder is considered the most unstable joint in the body.

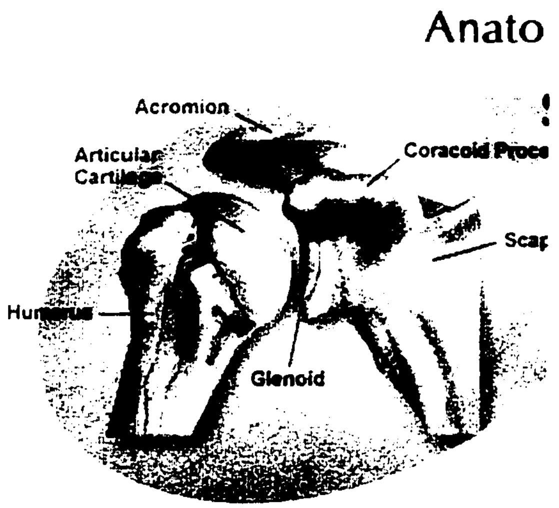


Figure 1. Bony Shoulder Anatomy
Note: (http://www.scoi.com/sholanat.htm), public domain.

The glenohumeral joint is unstable from a bony standpoint, thus the static and dynamic stabilizers of the joint play an integral role in maintaining stability through all movements. The static stabilizers are comprised of the glenoid labrum, and the glenohumeral joint capsule and its integrated ligaments, which are considered thickened parts of the joint capsule (Chen, Simonian, Wickiewicz, Otis, & Warren, 1999; Peat & Culham, 1994; Vellet, Munk, &Marks, 1991). (See Figure 2). The dynamic stabilizers are the rotator cuff muscles; the supraspinatus, infraspinatus, teres minor, and subscapularis muscles (Chen et al., 1999; Peat & Culham, 1994; Vellet, Munk, & Marks, 1991). (See Figure 3). Soft tissue structures allow for movements to occur at the glenohumeral joint, including deleterious movements that may cause injury, such as excessive joint translation in any direction which over time detracts from the joint capsule's elasticity. Additional deleterious movements include the range of motion in an action like overhand throwing where large amounts of external rotation are needed. With high volumes of external rotation added stability expectations are placed on the anterior stabilizing ligaments of the shoulder. During these types of motions unwanted amounts of stress are placed on the soft tissue structures, causing an eventual failure of the structures, which can lead to symptomatic joint instability. Instability of the glenohumeral joint corresponds with accessory injuries such as secondary impingement which occurs when the static stabilizers exhibit laxity forcing the dynamic stabilizers into a compensatory role to maintain glenohumeral stability .

Static Stabilizer Mechanics

The glenoid labrum is a meniscal type piece of connective tissue composed of fibrocartilage and fibrous tissue residing around the outer edge of the glenoid fossa and deepens the glenoid cavity, to provide increased stability to the glenohumeral joint by increasing the depth of socket the humeral head rests in (Peat & Culham, 1994). The glenoid labrum provides a site for attachment for the long head of the biceps brachii and triceps brachii muscles, as well as the glenohumeral ligaments (Peat & Culham, 1994).

The glenohumeral joint capsule can be divided into several separate thickenings known as glenohumeral ligaments: the superior glenohumeral ligament, middle glenohumeral ligament, inferior glenohumeral ligament complex (O'Brien, Pagnani, Panariello, O'Flynn, & Fealy, 1994; Peat & Culham, 1994). These ligaments provide stability only when taut in the extreme ends of glenohumeral range of motion (Matsen, Harryman, & Sidles, 1991). For example, when the humerus is abducted and externally rotated the joint capsule twists, or winds up, centering the head of the humerus on the glenoid (Terry & Chopp, 2000). The superior glenohumeral ligament traverses laterally from the superior glenoid tubercle, upper glenoid labrum, and the base of the coracoid process to the humerus between the lesser tuberosity and the anatomic neck (Peat & Culham, 1994). Together with the superior joint capsule and rotator cuff muscles, the superior glenohumeral ligament assists in preventing inferior translation of the humeral head (Peat & Culham, 1994).

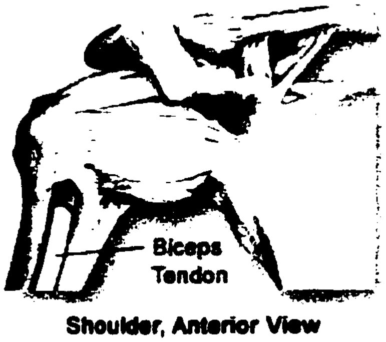


Figure 2. Joint Capsule and Glenohumeral Ligaments
Note: (http://www.scoi.com/sholanat.htm), public domain.

The middle glenohumeral ligament is much broader than the superior glenohumeral ligament and attaches similarly at the anterior glenoid fossa down to the middle third of the glenoid rim (1994). Laterally the middle glenohumeral ligament attaches to the anterior margin of the anatomic neck of the humerus and the lesser tuberosity of the humerus (Peat & Culham, 1994). This particular ligament, along with the subscapularis tendon, which it is attached to and lies beneath this structure, is responsible for limiting lateral rotation of the humerus in lower ranges of abduction (Peat & Culham, 1994).

The inferior glenohumeral ligament complex consists of three different parts: the anterior band, axillary pouch, and posterior band (Peat & Culham, 1994). The inferior glenohumeral ligament complex arises from either the glenoid labrum or the glenoid neck and inserts on the anatomic neck of the humerus (O'Brien, Pagnani, Panariello, O'Flynn, & Fealy, 1994). The anterior inferior ligament has been described as the thickest and strongest portion of the capsule due to the dense configuration of collagen fibers (Gohlke, Essigkrug, & Schmitz, 1994). The anterior band of the inferior glenohumeral ligament complex is the prime stabilizer against anterior humeral translation on the glenoid, particularly in abduction and external rotation (Branch, Lawton, Iobst, Hutton, 1995; Cain, Mutschler, Fu, & Lee, 1987; Ellenbecker, Mattalino, Elam, & Caplinger, 2000; Kvitne & Jobe, 1993; Kwak, Brown, Trudell, & Resnick, 1998; O'Brien, Pagnani, Panariello, O'Flynn, & Fealy, 1994; Peat & Culham, 1994; Wilk, Arrigo, & Andrews, 1997). Tension in the inferior glenohumeral ligament is produced when rotation of the humerus is present, creating a winding of the anterior joint capsule and a compressive force that centers the humeral head on the glenoid (Goehlke, Essigkrug, & Schmitz, 1994). This mechanical centering of the humeral head makes the anterior band of the inferior glenohumeral ligament complex the most important stabilizing structure of the shoulder in the overhead athlete (Peat & Culham, 1994). Knowledge of glenohumeral ligamentous support prompts utilization of a more specific stress test for the inferior glenohumeral ligament complex in assessing anterior glenohumeral laxity. Use of OMR technology may provide objective measurements that display the integrity of static stabilizers and quantify the amount of glenohumeral translation. The ligamentous components of glenohumeral stability are necessary for proper function, yet the role of the dynamic stabilizers is also a critical component for shoulder movement.

Dynamic Stabilizer Mechanics

The rotator cuff, comprised of the supraspinatus, infraspinatus, teres minor, and subscapularis, are considered to be the dynamic stabilizers of the glenohumeral joint, and originate from the scapula and insert on the humeral head at the greater and lesser tuberosities (Kvitne & Jobe, 1993). (See Figure 3). The main function of the rotator cuff muscles is to depress the humeral head to clear the acromion and to dynamically rotate the humerus, as well as provide dynamic stability to the glenohumeral joint (Howell, & Kraft, 1991; Starkey, & Ryan, 1996). Other muscles that contribute to glenohumeral stability include the long head of the biceps, deltoid, teres major, latissimus dorsi, and pectoralis muscles (Wilk, Arrigo, & Andrews, 1997). A combined contraction of these muscles during active arm movements provides dynamic

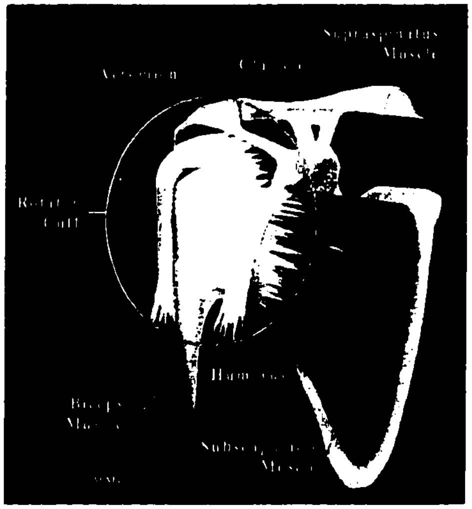


Figure 3. Rotator Cuff Muscles
Note: (http://sechrest.com/mmg/shoulder/graphics/rotcuf.jpg), public domain.

stability and centering of the humeral head on the glenoid fossa (Wilk, Arrigo, & Andrews, 1997).

Anterior glenohumeral stability is influenced by the muscles of the rotator cuff, mainly the infraspinatus and teres minor. Cain et al (1987) demonstrated that the infraspinatus and teres minor are important during the cocking phase of a throwing motion by reducing the amount of external rotation of the humerus. Reducing the amount of external rotation of the humerus reduces the amount of strain on the inferior glenohumeral ligament thus reducing the potential for laxity. Normal glenohumeral motion is affected if any of the rotator cuff muscles become fatigued transferring increased amounts of rotational stress on the glenohumeral ligamentous structures. At this point static stabilizers accept forces that would normally be controlled by dynamic stabilizers, the glenohumeral joint experiences accessory movements and subsequent injury (Chen et al., 1999; McCluskey & Getz, 2000; Wilk, Arrigo, & Andrews, 1997). Abduction, external rotation, and extension (late cocking phase of throwing motion) of the humerus places the joint in the most susceptible position for dislocation and subluxation (Branch, Avilla, London, & Hutton, 1995). Posterior humeral head translation occurs during the late cocking stages of a throwing motion in an asymptomatic shoulder, demonstrating good rotator cuff control (Cain et al., 1987; Kvitne & Jobe, 1993; Wilk, Arrigo, & Andrews, 1997). In contrast, a symptomatic shoulder with anterior instability will not experience normal posterior translation (Cain et al., 1987; Kvitne & Jobe, 1993; Wilk, Arrigo, & Andrews, 1997). Instead, the dynamic stabilizers become fatigued by accommodating for the laxity in the static stabilizers, and in an effort to hold the humeral head centered on the glenoid, excess translation then occurs, (Cain et al., 1987; Kvitne & Jobe, 1993; Wilk, Arrigo, & Andrews, 1997) which may lead to secondary impingement.

Proper function of the dynamic and static stabilizers of the glenohumeral joint is necessary to provide joint stability. The function of the dynamic stabilizers serves to safeguard the integrity of the static stabilizers (Cain et al., 1987). The glenohumeral joint becomes unstable and experiences abnormal, unwanted movements without the integrity of the static stabilizers and dynamic stability provided by the rotator cuff.

A multitude of injuries can occur due to inadequate glenohumeral joint stability. These injuries may occur to any of the static stabilizers secondary to the dynamic stabilizers lack of function. For example, if the infraspinatus and teres minor do not function to prevent the humeral head from externally rotating into a range where the anterior static stabilizers are unable to stabilize, the anterior static stabilizers may become stretched and expose the joint to injury. When the static stabilizers do not function properly to contain the humeral head within the glenoid fossa, the dynamic stabilizers are required to work harder to compensate for the lack of static stability leading to secondary impingement. Understanding the importance of the soft tissue structures that contribute to glenohumeral joint stability provides necessary knowledge for evaluating and assessing the glenohumeral joint. A thorough evaluation of glenohumeral injuries and laxity will expedite the correct treatment plan and necessary rehabilitation to minimize time loss.

Glenohumeral Examination Techniques

Examination of the glenohumeral joint ranges from subjective manual examination, examination under anesthesia (EUA), to objective kinematic X-ray, KT-1000 arthrometer measurements, magnetic resonance (MR) arthrography and magnetic resonance imaging (MRI). The manual examination remains the standard examination practice. The purpose of manual examination is to determine if abnormalities are suspected, and request a more visually detailed investigation for accurate diagnosis. Manual laxity examination techniques of the capsule and ligaments of the glenohumeral joint require the examiner to recognize the amount of force applied on the joint, estimate the movement occurring at the joint, and consciously compare the response of the joint that would be expected in a non-impaired shoulder (Keating, Matyas, & Bach, 1993). The "load and shift" test requires that the examiner subjectively center the humeral head on the glenoid and apply subjective amounts of anteriorly and posteriorly directed forces on the humeral head and evaluate the amount of translation present. The subjective nature of this process makes it potentially unreliable and susceptible to error within and between examiners (Pizzari, Kolt, & Remedios, 1999). Therefore quantitative measures of joint translation are necessary for accurate and reliable assessment of glenohumeral joint laxity (Harryman, Sidles, Harris, & Matsen, 1992).

The availability and clarity of radiographic devices such as X-ray and more recently MRI, and MR arthrography, has allowed for more in depth and accurate results in glenohumeral examination. Until OMR became available, all radiographic examinations of the glenohumeral joint were in a static position or in static progressions throughout a typical range of motion. OMR imaging enables examiners to perform stress tests on the glenohumeral joint while providing MRI quality films of the movement present or damaged structures within the joint. The closest comparison to open MR imaging is MR arthrography. MR arthrography involves injecting the glenohumeral joint with gadolinium to distend the joint for greater description and contrast of the internal structures during MRI evaluation in a classic stationary position (Vellet, Munk, & Marks, 1991). The advantages of OMR over conventional examination techniques include the facts that X-ray aids in the evaluation of bone. Standard MRI films allow static examination only and is often uncomfortable for subjects. Kinematic MRI allows for images in range of motion intervals, and examination under anesthesia requires life support and anesthetic medication and an anesthesiologist for supervision. These techniques do not provide the comfort and ability of OMR. OMR allows active and passive ranges of motion to be examined, permits the examiner to apply stress tests (See Figure 4), directly to the subject, and provides the same distinct quality inherent to MRI (Beaulieu et al., 1999). With the ability to manipulate the subject passively or actively, OMR imaging allows a more in depth evaluation of the glenohumeral joint because of the open configuration of the unit where a subject and examiner can be present during the examination.

Figure 4. OMR Stress Test (Arrow indicates direction of force and examiner's thumb) Note: (http://radiology.rsnajnls.org/cgi/content/full/212/3/699), public domain.

Currently little research exists pertaining to the use of open magnetic resonance imaging and anterior glenohumeral translation. Beaulieu et al (1999) examined normal glenohumeral relationships during physiologic ranges of motion and also performed preliminary investigation on stress testing of the glenohumeral joint. Beaulieu et al (1999) found that in the five subjects and ten shoulders, the humeral head remained centered on the glenoid fossa during active movement via the combined contractions of the dynamic stabilizers. Beaulieu et al (1999) also examined anteriorly directed forces on the humeral head resulting in as much as 6-millimeters of anterior translation (1999). This finding suggests OMR is useful in objectively evaluating anterior glenohumeral translation in asymptomatic subjects.

In a follow up study Hodge et al (2001) investigated glenohumeral alignment in asymptomatic and symptomatic shoulders using OMR and examination under anesthesia. Open MR imaging was found to accurately assess instability using the "load and shift" test in 6 of 11 shoulders, but underestimated the degree of instability in the remaining five shoulders (Hodge et al, 2001). The load and shift test requires the examiner to subjectively place the head of the humerus centered in the glenoid and then provide anteriorly and posteriorly directed forces to subjectively determine the amount of translation. Overall, OMR underestimated glenohumeral instability when compared to examination under anesthesia in 7 of 10 post surgical shoulders (Hodge et al, 2001). In theory, examination under anesthesia provides more conclusive results than open magnetic resonance imaging. The inactivity of the dynamic stabilizers, which results from general or local anesthesia, presumably provides more accurate results. Anesthetizing an asymptomatic subject may demonstrate large amounts of laxity in an otherwise normal shoulder, thus the stability of the glenohumeral joint should be examined in an awake state to accurately assess the integrity of all contributing factors, including the integrity of supporting musculature.

Humeral head positioning is crucial during glenohumeral examination. A seated load and shift test in 45 to 90 degrees of abduction and external rotation should be performed to assess anterior capsular structures. The anterior band of the inferior glenohumeral ligement complex is taut and provides the most stability against anterior translation in 45 to 90 degrees of abduction (Baker & Merkley, 2000). Examination in a position of abduction, external rotation, and extension is imperative. In this position the anterior stabilizers are maximally stretched, compressing and centering the head of the humerus on the glenoid. An examination in any other humeral position would not assess all the involved structures in the position of optimal contribution to anterior glenohumeral stability. Conventional MRI units do not allow this necessary abduction and external rotation examination position to occur, but OMR imaging allows this position to be applied and directed by the examiner while images are recorded. With OMR imaging used to evaluate a dynamic joint such as the shoulder, choosing a test position relative to the structures of interest is important. Evaluating a joint for ligamentous stability in a position where the ligament is not providing support is not valid or advantageous to injury assessment. Therefore, evaluation of anterior stability of the glenohumeral joint should take place in the abducted and externally rotated position using an objective device that allows for this range of motion. The OMR can accommodate the necessary range of motion to evaluate a glenohumeral joint, however the reliability of the machine has yet to be determined for assessing glenohumeral translation.

Summary

The complexity of the glenohumeral joint and its synchronous movements are necessary for normal shoulder activities to occur. The large range of motion inherent to the shoulder creates an environment that exposes the joint to possible laxity, instability, and secondary injuries. Understanding glenohumeral anatomy and functions of the joint structures necessary to support the shoulder at rest and during activity provides the clinician with a knowledgeable approach to evaluation. A myriad of injuries can occur at this joint. Some shoulder injuries are undetectable by manual examination alone, necessitating further means of evaluation, i.e. OMR. The clarity and definition of OMR images provide optimal non-invasive evaluation techniques of anatomic structures. Combine the fact that active and passive ranges of motion, and manual stress tests may be applied to the glenohumeral joint while MR images are taken, and OMR imaging becomes more attractive. Considering the detail OMR imaging provides, this method of examination should be the choice for glenohumeral evaluation when manual examination needs to be augmented. The use for this technology to assist in dynamic examination procedures is visible, but the reliability of the equipment has yet to be proven experimentally. This project will attempt to determine the reliability of anterior glenohumeral translation using open MR imaging.

Chapter 3

METHODS and PROCEDURES

The purpose of this study is to determine intratester and intertester reliability using OMR in conjunction with manual glenohumeral stress testing while examining anterior glenohumeral translation. This section will be divided into the following six sections: subjects, open magnetic resonance configuration, testing procedures, data collection, data analysis, and pilot study.

Subjects

Participants four volunteer male subjects (8 shoulders) with no previous history of recent shoulder pathology. Shoulder pathology, i.e. shoulder pain or instability, were determined by subjective reporting on a survey to be completed prior to examination. Subjects were excluded if they report previous shoulder injury requiring immobilization or surgery within the past 5 years. The participants varied in age from 24 to 33 years of age. Informed consent was obtained from all participants prior to examination. The project was approved by the Human Subjects Review board of San Jose State University and Stanford University prior to testing. There were four testers, one athletic trainer, one physical therapist, and two physicians, all with more than 5 years experience.

Open Magnetic Resonance Imaging Configuration

Subjects were examined in a seated upright position in a vertically-open configuration, 0.5T MR scanner (Signa SP, GE Medical Systems, Milwaukee, WI). A flexible transmit-receive RF coil (single loop large crown coil) was placed around the shoulder. Fast gradient-echo imaging sequences were used under the following parameters: TR 19.8 msec, TE 7.2 msec, flip angle 30-40 degrees, 256 x 128 matrix, FOV 24-30 cm, slice thickness 7-mm, 1 NEX. Sequential, single slice images were acquired at a rate of approximately 1 image per second. The imaging parameters as listed were chosen to provide the fastest possible image acquisition providing images of diagnostic quality (Hodge et al., 2001).

Testing Procedures

The open magnetic resonance unit was calibrated prior to each subject evaluation. Subjects were examined in the seated upright position with the scapula stabilized by the examiner's hand. The order in which subject's shoulders were examined was previously determined prior to examination. Three images were taken on each shoulder at the point of maximal anterior translation by each examiner. To ensure accuracy, a neutral image was taken prior to measuring anterior glenohumeral translation with the load and shift examination technique. The "load and shift" test requires the examiner to center the humeral head on the glenoid, then apply an anteriorly directed force on the posterior aspect of the humeral head. After the first shoulder was examined by each tester, the same seated upright position was used on the second shoulder for examination using the exact same protocol. Once all the images were complete, a computer analysis of the images was produced. The testing procedures were reproduced one month after the initial OMR examination for intratester realiability determination. Several authors have performed test retest evaluations at intervals of 2 to 8 days after initial evaluation (Brandy & McLaughlin, 1993; Cross, Johnson, & Agre, 1991; Feiring, Ellenbecker, & Deischeid, 1990; Francis & Hoobler, 1987; Gross, Huffman, Phillips, Wray, 1991).

Data Collection

The center of the humeral head was determined by prescribing a circle around the humeral articular surface on the images produced after all images have been collected. The center of the circle was then be defined as the center of the humeral head (Beaulieu et al., 1999). Margins of the glenoid were used to construct a line along and parallel to the glenoid fossa. The geometric center of this line determined the center of the glenoid fossa (1999). Centering of the humeral head will be determined by constructing a perpendicular line from the humeral head center to the glenoid line (1999). Using this method, the position of the humeral head was accurately determined in any shoulder position by applying the prescribed circle, parallel and perpendicular lines to the humeral head in comparison to the glenoid. Millimeters of translation were then be calculated and serve as the determining measure of laxity.

Data Analysis

The data collected was analyzed using SPSS (Statistical Package for Social Sciences). Intraclass correlation (ICC) was used to determine reliability within and between examiners.

Pilot Study

A pilot study was performed to determine the most accurate and clinically valuable test position of the subject in the OMR scanner. One male subject was examined by two testers using the methods described above in the scanner and using the seated upright test position in conjunction with the load and shift test. The testers were one athletic trainer with 5 years experience and one physician with 15 years experience.

References

Anderson, M.K., & Hall, S.J. (1995). *Sports Injury Management.* Baltimore, MD: Williams & Wilkins.

Baker, C.L., & Merkley, M.S. (2000). Clinical evaluation of the athlete's shoulder. *Journal of Athletic Training, 35*(3), 256-260.

Bandy, W.D., & McLauglin, S. (1993). Intramachine and intermachine reliability for selected dynamic muscle performance tests. *Journal of Orthopaedic and Sports Physical Therapy, 18*(5), 609-613.

Beaulieu, C.F., Hodge, D.K., Bergman, A.G., Butts, K., Daniel, B.L., Napper, C.L., Darrow, R.D., Dumoulin, C.L, & Herfkens, R.J. (1999). Glenohumeral relationships during physiologic shoulder motion and stress testing: Initial experience with open MR imaging and active imaging-plane registration. *Radiology, 212*(3), 699-705.

Bigliani, L.V., Pollock, R.G., Soslowsky, L.J., Flatow, E.L., Pawluk, R.J., & Mow, V.C. (1992) Tensile properties of the inferior glenohumeral ligament. *Journal of Orthopedic Research, 10*, 187-197.

Branch, T.P., Lawton, R.L., Iobst, C.A., & Hutton, W.C. (1995). The role of glenohumeral capsular ligaments in internal and external rotation of the humerus. *American Journal of Sports Medicine, 23*(5), 632-637.

Cain, P.R., Mutschler, T.A., Fu, F.H., & Lee, S.K. (1987). Anterior stability of the glenohumeral joint: A dynamic model. *American Journal of Sports Medicine, 15*(2), 144-148.

Chan, K.M., Maffulli, N., Nobuhara, M., & Wu, J. (1996). Shoulder instability in athletes: the Asian perspective. Clinical Orthopedics, 323, 106-112.

Chen, S.K., Simonian, P.T., Wickiewicz, T.L., Otis, J.C., & Warren, R.F. (1999). Radiographic evaluation of glenohumeral kinematics: A muscle fatigue model. *Journal of Shoulder and Elbow Surgery, 8*(1), 49-52.

Cress, M.E., Johnson, J., & Agre, J.C. (1991). Isokinetic strength testing in older women: A comparison of two systems. *Journal of Orthopaedic and Sports Physical Therapy, 13*(4), 199-202.

Ellenbecker, T.S., Mattalino, A.J., Elam, E., & Caplinger, R. (2000). Quantification of anterior translation of the humeral head in the throwing shoulder. *The American Journal of Sports Medicine, 28*(2), 161-167.

Faber, K.J., Homa, K., & Hawkins, R.J. (1999). Translation of the glenohumeral joint in patients with anterior instability: Awake examination versus examination with the patient under anesthesia. *Journal of Shoulder and Elbow Surgery, 8*(4), 320-323.

Fiering, D.C., Ellenbecker, T.S., & Derscheid, G.L. (1990). Test-retest reliability of the biodex isokinetic dynamometer. *Journal of Orthopaedic and Sports Physical Therapy, 11*(7), 298-300.

Francis, K, & Hoobler, T. (1987). Comparison of peak torque values of the knee flexor and extensor muscle groups using the cybex II and lido. *Journal of Orthopaedic and Sports Physical Therapy, 8*(10), 480-483.

Gohlke, F., Essigkrug, B., & Schmitz, F. (1994). The pattern of the collagen fibers of the capsule of the glenohumeral joint. *Journal of Shoulder and Elbow Surgery, 3*, 111-128.

Graichen, H., Stammberger, T., Bonel, H., Englemeier, K.H., Reiser, M., & Eckstein, F. (2000). Glenohumeral translation during active and passive elevation of the shouler-a 3D open-MRI study. *Journal of Biomechanics, 33*(5), 609-613.

Gross, M.T., Huffman, G.M., Phillips, C.N., & Wray, J.A. (1991). Intramachine and intermachine reliability of the biodex and cybex II for knee flexion and extension peak torque and angular work. *Journal of Orthopaedic and Sports Physical Therapy, 13*(6), 329-335.

Harryman, D.T., Sidles, J.A., Harris, S.L., & Matsen, F.A. (1992). Laxity of the normal glenohumeral joint: a quantitative in vivo assessment. *Journal of Shoulder and Elbow Surgery, 2*, 66-76.

Hawkins, R.J., Schutte, J.P, Janda, D.H., & Huckell, G.H. (1996). Translation of the glenohumeral joint with the patient under anesthesia. *Journal of Shoulder and Elbow Surgery, 5*(4), 286-292.

Hodge, D.K., Beaulieu, C.F., Thabit, G.H., Gold, G.E., Bergman, A.G., Butts, R.K., Dillingham, M.F., & Herfkens, R.J. (2001). Dynamic MR imaging and stress testing in glenohumeral instability: Comparison with normal shoulders and clinical/surgical findings. *Journal of Magnetic Resonance Imaging, 13*, 748-756.

Howell, S.M., & Kraft, T.A. (1991). The role of the supraspinatus and infraspinatus muscles in glenohumeral kinematics of anterior shoulder instability. *Clinical Orthopaedics and Related Research, 262*, 128-134.

Jorgensen, U., & Bak, K. (1995). Shoulder instability: Assessment of anterior-posterior translation with a knee laxity tester. *Acta Orthopaedic Scandinavia, 66*(5), 398-400.

Keating, J., Matyas, T.A., & Bach, T.M. (1993). The effect of training on physical therapists' ability to apply specified forces of palpation. *Physical Therapy, 73*, 38-46.

Kvitne, R.S., & Jobe, F.W. (1993). The diagnosis and treatment of anterior instability in the throwing athlete. *Clinical Orthopaedics and Related Research, 291*(June), 107-123.

Kwak, A.M., Brown, R.R., Trudell, D., & Resnick, D. (1998). Glenohumeral joint: comparison of shoulder positions at MR arthrography. *Radiology, 208*(2), 375-380.

Magee, D.J. (1997). *Orthopedic physical assessment*_(Third Edition). Philadelphia, PA: W.B. Saunders Company.

Matsen, F.A., Harryman, D.T., & Sidles, J.A.. (1991). Mechanics of glenohumeral instability. *Clinics in Sports Medicine: Basic Science and Clinical Application in the Athlete's Shoulder, 10*(4), 783-805.

McCluskey, G.M., Getz, B.A. (2000). Pathophysiology of anterior shoulder instability. *Journal of Athletic Training, 35*(3), 268-272.

O'Brien, S.J., Pagnani, M.J., Panariello, R.A., O'Flynn, H.M., & Fealy, S. (1994). Anterior Instability of the Shoulder. *The Athlete's Shoulder*. Andrews, J.R., & Wilk, K.E. Churchill Livingstone: New York 177-201.

Peat, M., & Culham, E. (1994). Functional Anatomy of the shoulder complex. *The Athlete's Shoulder*, Wilk, K.E., Andrews, J.R. New York, Churchill Livingstone.

Pizzari, T., Kolt, G.S., Remedios, L. (1999). Measurement of anterior-to-posterior translation of the glenohumeral joint using the KT-1000. *Journal of Orthopaedic & Sports Physical Therapy, 29*(10), 602-608.

Starkey, C., & Ryan, J.L., (1996). The shoulder and upper arm. *Evaluation of Orthopedic and Athletic Injuries*, F.A.Davis Company: Philadelphia.

Terry, G.C., & Chopp, T.M. (2000). Functional anatomy of the shoulder. *Journal of Athletic Training, 35*(3), 248-255.

Vellet, A.D., Munk, P.L., & Marks, P. (1991). Imaging techniques of the shoulder: Present perspectives. *Clinics in Sports Medicine: Basic Science and Clinical Application in the Athlete's Shoulder, 10*(4), 721-756.

Wilk, K.E., Arrigo, C.A., & Andrews, J.R. (1997). Current concepts: The stabilizing structures of the glenohumeral joint. *Journal of Orthopaedic and Sports and Physical Therapy, 26*(6), 364-379.

APPENDIX A

The American Journal of Sports Medicine

Author's Notes

GUIDELINES FOR AUTHORS

The American Journal of Sports Medicine welcomes the submission of articles on sports medicine from all countries.

Manuscripts

Submit manuscripts to Robert E. Leach, MD, Editor, 230 Calvary Street, Waltham, MA 02453. A cover letter should identify the corresponding author (if multiple authors) along with address, telephone number, and FAX number. Submit four copies of manuscripts (*must* be typed double-spaced), figures, and tables as three copies of the complete article will be forwarded to reviewers. Manuscript elements should be arranged in the following order: title page, abstract (for scientific investigation or clinical study), text, acknowledgments, references, footnotes (where the work was presented, address for corresponding author and reprint requests, disclaimers), figure legends, and tables.

The title page should include the manuscript title, full names and academic degrees of authors, and name of department and institute where the work was performed. **PLEASE NOTE:** *Journal policy prohibits the inclusion of more than five authors on an article!* Include other names of persons who contributed significantly to the work in the acknowledgment section. If there are multiple authors and multiple institutions, be sure to identify all affiliations, if applicable.

Manuscripts must not be under simultaneous consideration by any other publication. Papers presented at AOSSM meetings must be submitted to the Journal for first rights of refusal. Accepted manuscripts become the permanent property of the AOSSM and may not be published elsewhere without written permission from both the author and the copyright holder.

Articles intended for the Current Concepts section of the Journal are solicited by the Associate/Current Concepts Editor. Please do NOT submit articles for this section; a query letter may be written to Dr. Foster regarding possible material or suggestions for this section.

When accepted articles have been assigned to an issue, authors will be required to carefully read and correct their edited manuscripts (computer printouts); they will later proofread the page proofs. Any changes made by authors on the page proofs (except typographical errors) will be charged to authors at the rate of $3.50 a line. Authors are responsible for ordering reprints of their articles; a reprint order form is provided with the page proofs for this purpose.

Abstract

The abstract should summarize in *200 words or less* the materials and methods, results, and conclusions of the work. Be concise, yet thorough: abstracts are often printed in other publications without benefit of the entire study. Do not use any abbreviations in abstracts.

Text

In general, follow the standard IMRAD (Introduction, Materials and Methods, Results, Discussion) format for writing scientific articles.

The author is responsible for all statements made in the work, including copy editor changes, which the author will have an opportunity to verify. Any material reproduced in an article that has been copyrighted previously must conform to the current copyright regulations. The author is responsible for obtaining permission and for providing the editorial office with documentation before the material will be reproduced in the Journal.

Reports on knee surgery, except in rare instances, require a minimum followup of two years.

Use generic names of drugs. If a particular brand was used in a study, insert the brand name along with the name and location of the manufacturer in parentheses after the generic name.

Put the name and location of equipment manufacturers in parentheses behind the name of the product.

Units of measure following a number are abbreviated (such as kg, cm, ml). Use metric units in measurements (i.e., centimeter versus inch, kilogram versus pound). Common abbreviations are used without definition (such as ACL, EMG). When uncommon abbreviations are used, give the full term followed by the abbreviation in parentheses the first time it is mentioned in the text (such as femur-ACL-tibia complex [FATC]).

Figures (Illustrations)

Submit four copies of figures as black and white unmounted glossy prints, preferably 5 × 7 inches but other sizes are acceptable as long as the figure is sharp and clear and reproducible. Please be sure that any text on figures is large enough to be read if the figure is reduced for publication. (Figures may be from original artwork, photographs, graphs, charts, radiographs, photomicrographs, etc.) On the back of each figure, clearly identify the top; include the figure number and name(s) of the author(s). Use a fine ball-point pen or apply a typed label to avoid contaminating other figures. If color figures are supplied, and if they are deemed worthy of inclusion by the Editorial Board, *authors are required to bear the expense of the color separation cost*, which will be provided on an individual basis when the manuscript has been assigned to a particular issue. For color figures, transparencies (slides) or original artwork is preferred.

If symbols, lettering, or arrows are to be used, please indicate the location of those on a photocopy of the figure or have a professional illustrator apply them to the original. Labeling and legend terminology must be consistent with the text.

Examine all figures carefully to ensure that the data are presented with the greatest possible clarity and that they help the reader better understand the text. Likewise, determine if a figure would communicate the information more effectively than narrative.

All photographs of patients that disclose their identity must be accompanied by signed permission. If this is not provided, we will occlude the patient's eyes to prevent recognition.

Tables

Each table must be typewritten on a separate page, numbered consecutively, and have a title. Tables should enhance, not duplicate, information in the text.

Acknowledgments

Type acknowledgments on a separate page, following the text. Give credit to sponsors, donors, or grantors; technical assistants; and professional colleagues who contributed to the quality of the paper but are not listed as authors. Do not acknowledge the assistance of the manuscript typist.

References

References should be typed double-spaced *in alphabetical order* and numbered according to their alphabetical listing. In general, use *Index Medicus* form for abbreviating journal titles and the *AMA Style Guide* for format. List only the first three authors; use et al. for four or more authors. *It is imperative that authors double-check their references and assure that they are correct and complete!*

Journal example:

1. Daluga DJ, Dobozi W: The influence of distal clavicle resection and rotator cuff repair on the effectiveness of anterior acromioplasty. *Clin Orthop 247*: 117–123, 1989

Book example:

2. McCue FC, Gieck JH, West JO: Throwing injuries to the shoulder, in Zarins B, Andrews JR, Carson WG (eds): *Injuries to the Throwing Arm*. Philadelphia, WB Saunders Co, 1985, pp 95–111

References to government publications should include the department, bureau, or office; title; location and name of the publisher; year; and pages cited. Most important, include the publication series, report, or monograph number. For example:

3. United States Department of Health, Education and Welfare, Public Health Service, Bureau of Health Manpower, Health Manpower Perspective: 1967. Washington DC: Government Printing Office, 1967 (PHS Publication No. 1667), p 12