AN ABSTRACT OF THE THESIS OF

Todd P. Daniels, ATC-R for the degree of Master of Science in Human Performance presented on August 6, 2001. TITLE: Evaluation of the Lateral Scapular Slide Test Using Radiographic Imaging: A Validity and Reliability Study.

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ABSTRACT APPROVAL ______________________________

Rod A. Harter

Function of the shoulder complex is highly dependent on the relationship between the scapula and the humerus. Etiologies for the disruption of the glenohumeral relationship include impaired or abnormal scapular function, motion, or position. The lateral scapular slide test (LSST) has been developed as a clinical tool to assess this phenomenon, also known as scapular dyskinesis. The primary purpose of this study was to determine the validity of the LSST by comparing the clinical measurements on the skin surface to the actual anatomical distance between the scapula and the spine as seen on radiographic images. The secondary purpose of this study was to determine the intra-rater and inter-rater reliability of the LSST. Nine subjects (18 shoulders) were assessed with the clinical LSST and radiographic images in three test positions (0°, 45°, and 90° of glenohumeral abduction). Comparison of the clinical LSST measurements with the radiographs revealed the LSST to be valid (>0.80) in only the 0° and 45° test positions with respective Pearson correlation values of 0.91 and 0.98. Excellent (>0.75) intra-rater ICC (2,1) reliability (0.91-0.97) was found for all three test positions. Inter-rater ICC (2,1) reliability values were excellent for the 0° (0.87) and 45° (0.83) test positions, and fair to good for the 90° position (0.71). This study demonstrated that the LSST is an accurate and consistent measure of scapular movement and position for the 0° and 45° test positions. Clinicians should exercise caution when interpreting measurements obtained at the 90° test position because the validity and reliability values did not reach established standards.

Evaluation of the Lateral Scapular Slide Test Using Radiographic Imaging: A Validity and Reliability Study

by

Todd P. Daniels, ATC-R

A THESIS

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APPROVED:

Redacted for Privacy

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I understand that my thesis will become a part of the permanent collection of Oregon State University libraries. My signature below authorizes release of my thesis to any reader upon request.

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Todd P. Daniels, ATC-R – Author

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To Ryan Jordan – Proof that someone like me can finish a thesis and masters degree in under a decade.

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To Michael "Sandy" Sandago and Marjorie Albohm – Without you, I never would have had the wonderful opportunity to work and learn at Oregon State University.

To my family, friends, and colleagues – Thank you for listening to my rants, supporting me through this process, and occasionally giving me a needed boot in the hindquarters.

Permission to reprint the image used in Figure 1 was granted by Lippincott, Williams, and Wilkins Publishing of Philadelphia, Pennsylvania. A copy of the authorization is included in Appendix E.

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CONTRIBUTION OF AUTHORS

Todd P. Daniels, ATC-R was the senior author responsible for the overall design, analysis, and writing of this manuscript.

Rod A. Harter, PhD, ATC was involved in the design, analysis, and writing of this manuscript.

All radiographic images were taken under the order and supervision of **Ronald D. Wobig, MD** who was involved in the design and analysis of this study.

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DEDICATION

This manuscript is dedicated to:

the little guy

The Big Guy

and all who seek the truth

PREFACE

My story begins in Baltimore, Maryland at the June 1998 NATA Convention. Less than five minutes after arriving and picking up my registration packet, I ran into Marjorie Albohm. She asked where I was working, and I told her I was working as a leadership development consultant. Her response: "Do you want an athletic training job?"

So in 15 minutes of being at the conference, I was offered a job by an NATA Hall of Famer. I didn't have any hearty intentions of finding a new job, but I brought some resumes just in case something interesting popped up. Later, I had a great interview with Michael "Sandy" Sandago, Deb Graff, and Barney Graff for a graduate assistant position at Oregon State. The position was very appealing, but I still had the offer from Marje.

She and I made arrangement to get together when we both got back to the Indianapolis area. Knowing I was being recruited by OSU, she sat me down like the great person she is and asked what kind of athletic trainer I wanted to be when I grew up. I told her I wanted to work in NCAA Division I or possibly pro athletics. She told me I could have the job at her place, but I would be better served going to Oregon State.

Without visiting, I accepted the job. I packed up and headed out across the plains to Oregon. In August 1998, the next chapter of my academic and professional life began.

Together, this project and I have endured some crazy events. My fist major professor left to become the program director at another university. An intellectual property arbitration had to be conducted to sort out whose ideas were whose when he left. I took a job at the University of Portland, which delayed the writing of the manuscript. My original minor professor retired and left the country for a research project days before my defense, so I had to scramble to find a replacement. Then, while doing the library copy corrections, my computer crashed. Finally, the mission was accomplished, and I continue to smile at the accolade of underestimation.

Evaluation of the Lateral Scapular Slide Test Using Radiographic Imaging: A Validity and Reliability Study

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Evaluation of the Lateral Scapular Slide Test Using Radiographic Imaging:
A Validity and Reliability Study

ABSTRACT FOR SUBMISSION TO THE AMERICAN JOURNAL OF SPORTS MEDICINE

The primary purpose of this study was to determine the validity of the lateral scapular slide test (LSST) by comparing the clinical measurements on the skin surface to the actual anatomical distance between the scapula and the spine as seen on radiographic images. The secondary purpose of this study was to determine the intra-rater and inter-rater reliability of the LSST. Nine subjects (18 shoulders) were assessed with the clinical LSST and radiographic images in three test positions (0°, 45°, and 90° of glenohumeral abduction). Comparison of the clinical LSST measurements with the radiographs revealed the LSST to be valid (>0.80) in only the 0° and 45° test positions with respective Pearson correlation values of 0.91 and 0.98. Excellent (>0.75) intra-rater ICC (2,1) reliability (0.91-0.97) was found for all three test positions. Inter-rater ICC (2,1) reliability values were excellent for the 0° (0.87) and 45° (0.83) test positions, and fair to good for the 90° position (0.71). This study demonstrated that the LSST is an accurate and consistent measure of scapular movement and position for the 0° and 45° test positions. Clinicians should exercise caution when interpreting measurements obtained at the 90° test position because the validity and reliability values did not reach established standards.

INTRODUCTION

Asymptomatic function of the shoulder joint complex is highly dependent on the normal relationship between the scapula and the humerus. This relationship is constantly changing due to the natural alterations in the instant center of rotation for the glenohumeral joint and mechanical advantage of the muscles during arm movement.[10,15] Changes in scapulohumeral kinematics have been associated with shoulder pathologies such as rotator cuff impingement or tears.[2,9-11,13]

Kibler[9,10] described five roles of the scapula necessary to facilitate optimal shoulder function. Most notably, the scapula functions as the stable segment of the glenohumeral articulation, elevates the acromion process during glenohumeral flexion and abduction, and serves as a link in the kinetic chain of overhead activity. The scapula must move in a coordinated fashion with the humerus to maximize the congruence of the already limited contact area between the glenoid fossa and humeral head and constrain the instant centers of rotation for the humerus within a specific physiological pattern.[10] The coordinated scapular motion, therefore, decreases the tensile forces placed on the capsular ligaments and produces the most efficient position for rotator cuff activation and compression of the humeral head into the glenoid. A second critical role of the scapula is elevation of the acromion process.[9,10] The scapula must rotate upwardly during the overhead motion to allow humeral abduction. If the scapula was to remain fixed, the acromion would make contact with the humeral head, causing coracoacromial compression and rotator cuff impingement. During overhead motions such as the baseball pitch, tennis serve, or a freestyle swimming stroke, a sequencing of velocity, energy, and forces begins in the lower extremity and moves through the body to its endpoint at the hand.[10,24] The scapula serves as a link in this kinetic chain of overhead activity.[9,10] Failure of the scapula to perform these roles will cause inefficient biomechanics, which ultimately results in shoulder pathology and diminished performance.[10]

Terms such as "floating scapula,"[7] "lateral scapular slide,"[9] and "scapulothoracic dyskinesis,"[22] have been used to describe abnormal or impaired functioning, motion, and position of the scapula. This phenomenon of *scapular dyskinesis* occurs when the scapula can not adequately perform one or more of the roles described by Kibler.[9,10] Abnormal motion of the scapula leaves the muscles that attach to it without a stable base or origin, compromising the muscle length-tension relationship and reducing maximal muscle torque. As the pivotal link in the transfer of forces from the power-generating lower extremity and trunk to the power-delivering upper extremity, any alterations in scapular function has the capacity to decrease force production and limit performance. The presence of scapular dyskinesis may create a "catch-up" situation where the upper extremity must work at a higher level to compensate for loss of forces generated by the lower body.[10] The shoulder complex is rendered more susceptible to injury because it does not have the size or time required to generate the necessary forces.[10] Once one segment is injured, the shoulder has little capacity to compensate for the affected structure and typically develops detrimental pattern of dyskinetic activity and pathology.[21]

Due to the incidence and severity of orthopedic problems arising from scapular dyskinesis, it is important that valid and reliable clinical assessment tools be developed to quantify scapular position and function. Currently, at least six different clinical measures exist for quantifying scapular motion and position. These test measures include the lateral scapular slide test (LSST),[9] the DiVeta test for normalized scapular abduction,[4] Moiré topographic analysis,[22] digital inclinometer,[8] the Lennie test,[20] and the Perry tool.[18] Based on published data, cost, and ease of use, the most promising of these tests is the LSST.[4,6,8,16-18,20,22]

The LSST measures the linear distance from the inferior angle of the scapula to the closest vertebral segment (Figures 1 and 2) with a tape measure between palpated bony landmarks. The test is repeated in three different positions: 0°, 45°, and 90° of glenohumeral abduction. The LSST was originally described by Kibler in 1991.[9] Over the past few years, two reliability studies have been conducted with mixed results, and only one of those studies claimed to evaluate the validity of the LSST.[6,17] In a 1995 study by Gibson et al,[6] the authors conducted an intra-rater and inter-rater reliability analysis of the LSST with 32 healthy subjects. In 2001, Odom et al.[17] evaluated the validity and reliability of the LSST using 20 subjects with known shoulder pathologies and 26 asymptomatic subjects. The reliability results for these two studies can be found in Table 1.[6,17] Odom et al.[17] elected to evaluate the validity of the LSST based upon their assessment of sensitivity and specificity for the LSST rather than using a criterion measure such as true anatomical motion or position. What remains to be determined is whether the clinical measurements of the LSST derived from distances between anatomical landmarks on the skin surface are accurately assessing scapular position and the actual change in anatomical distance from the spine. If the validity, reliability, sensitivity, and specificity of the LSST can be established, the clinical test could play a role similar to that of knee arthrometry in the evaluation of anterior cruciate ligament (ACL) injuries.

The primary purpose of this study was to determine the validity of the LSST by comparing clinical measurements on the skin surface to the actual distance between the scapula and the spine as seen on radiographic images. The secondary purpose of this study was to determine the reliability of the LSST by comparing the measures taken by one examiner during two different testing sessions and by comparing the measures taken by two examiners during a single testing session.

FIGURE 1 – Lateral Scapular Slide Test at 45° and 120° of glenohumeral abduction.[12] (NOTE: In the current study, joint angles of 0°, 45°, and 90° were utilized for the clinical LSST)

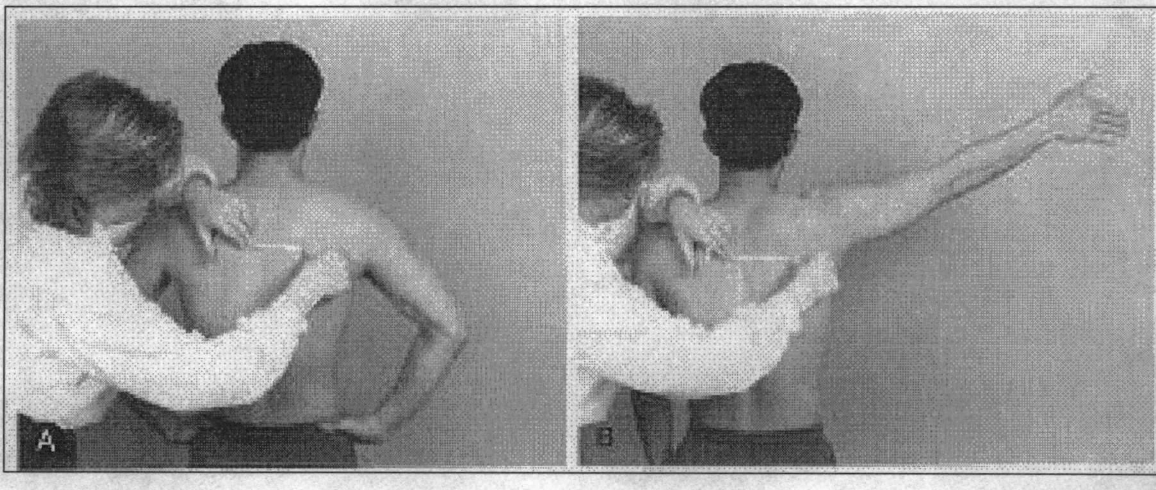


FIGURE 2 – Posterior view of scapula and thorax[13] with depiction of radiopaque marker placement.

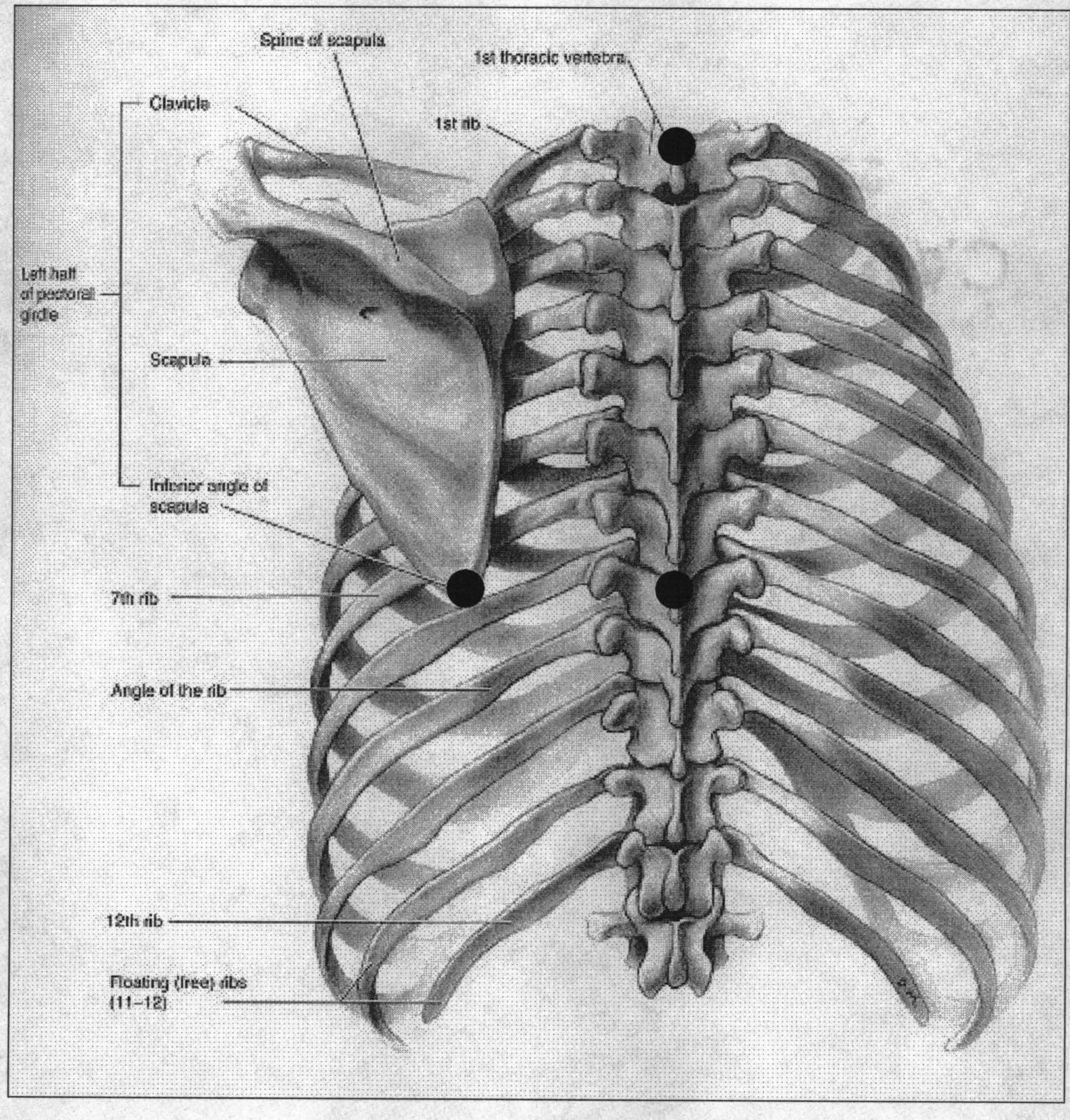


Table 1 – Previously Published Reliability Data for the LSST.

Previously Reported Reliability for the LSST		
Measure (Test Positition)	**ICC**	**SEM (mm)**
Odom et al. Intra-rater (0)	0.52-0.75	0.61-0.78
Gibson et al. Intra-rater (0)	0.91-0.94	0.44-0.54
Odom et al. Intra-rater (45)	0.66-0.77	0.57-0.58
Gibson et al. Intra-rater (45)	0.88-0.92	0.45-0.64
Odom et al. Intra-rater (90)	0.62-0.80	0.80-0.86
Gibson Intra-rater (90)	0.81-0.91	0.56-0.79
Odom et al. Inter-rater (0)	0.67-0.79	0.79
Gibson et al. Inter-rater (0)	0.67-0.69	1.02-1.04
Odom et al. Inter-rater (45)	0.43-0.45	0.78-1.08
Gibson et al. Inter-rater (45)	0.52-0.53	1.17-1.20
Odom et al. Inter-rater (90)	0.57-0.74	1.10-1.20
Gibson et al. Inter-rater (90)	0.18-0.28	1.59-1.65

MATERIALS AND METHODS

SUBJECTS

Nine subjects were recruited for participation from the medical practice of an orthopaedic surgeon [RDW]. Because state law prohibits the use of radiation on humans for the sole purpose of research, only persons who sought medical evaluation and exhibited shoulder pathology were allowed to participate in this study. Criteria for inclusion required that subjects be the age of 18 or over with no history of surgery to the upper extremity in the past three months. Subjects had to be able to actively abduct the humerus to at least a 90° position in the frontal plane and maintain that position for 30 seconds. Four potential subjects who exhibited postural or bony abnormalities in the scapulothoracic region, e.g., scoliosis and winging of the scapula, were excluded from the study. Women who were pregnant or breast-feeding were also excluded from the study. Before participating in the study, all subjects read and signed an informed consent form approved by our university's Institution Review Board for the Protection of Human Subjects.

INSTRUMENTATION

Scapular and vertebral bony landmarks were palpated by the senior author [TPD] and identified on the skin for x-ray purposes using 1.5 mm adhesive radiopaque encapsulated lead markers (E-Z Mark, E-Z-EM, Inc., Westbury, NY) typically used in mammography. The existing x-ray equipment and radiology laboratory at the orthopaedic surgeon's [RDW] office were used for all imaging. All radiographs (43 cm x 35.5 cm) were taken in the frontal plane to capture an anterior/posterior image of both the right and left scapulae. A flexible anthropometric tape measure was used to determine all distances in the clinical assessment and results were recorded to the nearest 1.0 mm. The same anthropometric tape measure employed in the clinical assessment was used to determine all distances on the radiographic images.

PROCEDURES

If the physician's [RDW] orthopaedic evaluation of a patient indicated that diagnostic radiographic images of the shoulder were required, the senior author [TPD] approached the patient and explained the nature of the study and procedures involved. If the patient agreed to participate voluntarily, the subject was screened to insure they met all selection criteria, and a written informed consent document was read and signed by the subject.

Test Session 1 – Radiographic Determined Validity. The senior author accompanied the subject to the radiology department and provided a dressing gown that permitted direct visualization and palpation of the vertebral column and both scapulae by the researcher. Subjects were instructed to fix their eyes on a designated object in the room in order to reduce static postural differences. All procedures for the clinical LSST were modeled after those previously described by Kibler and Odom et al.[9,10,17]

Prior to taking each clinical LSST measurement, subjects performed a neutral exercise to standardize starting arm position and posture. The neutral exercise required the subject to raise both hands overhead (approximately 180° of glenohumeral abduction) and then return to the anatomical position of approximately 0° of glenohumeral abduction. The attending radiology technician positioned the subject, x-ray tube, and plate containing radiographic film for proper imaging. The senior author then palpated the prominence (spinous process) of the seventh cervical vertebra (C7), the most infero-medial aspect of the right and left scapulae (inferior angle), and the spinous process of the vertebrae in the same horizontal plane of the inferior angle of the scapula. Adhesive radiopaque encapsulated lead markers were placed on the skin overlying these bony landmarks. The anthropometric tape measure was then used to determine the distance from the center of the marker located on the inferior angle of the scapula to the center of the marker located on the vertebral spinous process in the same horizontal plane as the inferior angle of the scapula (Figure 1). The subject maintained the test position and a radiographic image capturing both scapulae was taken immediately after the senior author had completed the clinical LSST measurement for both shoulders in a single arm position.

The three test positions previously described by Kibler[9,10] were assessed for both shoulders of all subjects in this study. The following descriptions (with associated anatomic positioning) were used to instruct subjects for the three positions:

Position One (0°) – The subject stood with both arms at the sides in a neutral glenohumeral position (less than 5° of glenohumeral abduction in the frontal plane).

Position Two (45°) – The subject stood with both hands resting on the hips and thumbs pointed posteriorly (a position of partial glenohumeral internal rotation and approximately 45° of glenohumeral abduction in the frontal plane).

Position Three (90°) – The subject stood with outstretched arms and thumbs pointed toward the floor (active full extension of the elbows and 90° of glenohumeral abduction in the frontal plane with full glenohumeral internal rotation).

Radiographic images were taken of both shoulders for all nine subjects (18 shoulders) in the 0° position. Using a center balanced design, five subjects (10 shoulders) had x-rays taken in the 45° position and the other four subjects (8 shoulders) had x-rays taken in the 90° position. Ideally, radiographic images would have been taken in all three positions, but in our effort to reduce the subjects' x-ray exposure,* radiographic images were only taken in two LSST positions for each subject: 0° position and either the 45° or 90° position.

* – The total estimated exposure for the two test x-rays is 2 millirem effective dose equivalent or 0.02mSv. This estimated exposure is based on data from the National Council of Radiation Protection and Measures Handbook (report 100), which states the radiation received from one x-ray to the chest region is 1 millirem effective dose equivalent or 0.01mSv. This dosage is equivalent to the average exposure an individual would receive from the natural surroundings of the local area during one day.

All three positions of the clinical LSST were measured on the skin surface using the same anthropometric tape measure. The 0° position was assessed first for all subjects. After the clinical LSST measurement was obtained for the 0° position, the radiographic image was taken. Subjects were then instructed to perform the neutral exercise before moving into the next position. The procedure was repeated for either the 45° or 90° position, based on the random group assignment. Subjects performed the neutral exercise again, and the remaining position was assessed with the clinical LSST only; no x-rays were taken for the remaining position.

Test Session 2 – Intra-rater and Inter-rater Reliability. Within two weeks of the initial data collection session, subjects reported to the Sports Medicine Research Laboratory for a second testing session. The senior author [TPD] and a second clinician [RAH], both certified athletic trainers, performed the clinical LSST on each subject's left and right shoulders. The order of clinician measurement was center balanced and the two researchers were blinded to the each other's measurements, as well as the measurements from the first testing session. The procedures previously described were used to obtain the clinical LSST. No radiographic images were taken in the second session and grease pen dots replaced the radiopaque markers for identification of bony landmarks. All grease pen markings were thoroughly removed by the first examiner prior to any measurements by the second examiner.

All measurements taken from the radiographic images were determined by direct visual inspection using the same anthropometric tape measure employed during data collection. First, the distance from the center of the radiopaque marker located on the inferior angle of the scapula to the center of the corresponding marker located on the vertebral spinous process was recorded bilaterally. This measure was defined as the *marker distance*. Next, an anatomical midline was determined by using a line drawn on a transparent overlay that was placed on the radiographic image so the line bisected each vertebral spinous process. The distance from the most infero-medial aspect of the scapula to the point of perpendicular intersection with the midline was then recorded for both shoulders. This measure was defined as the *anatomical distance*. The *clinical distance* was defined as the distances derived from the clinical LSST taken on the skin surface.

Pilot Study

A preliminary study of the intra-rater and inter-rater reliability for the two investigators was conducted with a small group of six subjects (12 shoulders). Only the clinical LSST was performed. No radiographic images were taken since the purpose of the pilot study was to (a) determine ICC values upon entry into the study, (b) revise data collection procedures if necessary, and (c) familiarize the investigators with the testing method. Intra-rater ICC (2,1) reliability values (with SEM) for the senior author [TPD] were 0.73 (±4.8 mm), 0.69 (±5.2 mm), and 0.73 (±6.2 mm) for the 0°, 45°, and 90° test positions, respectively. Intra-rater ICC (2,1) reliability and SEM values for the second clinician [RAH] were 0.65 (±4.6 mm), 0.60 (±5.2 mm), and 0.81 (±6.6 mm). Inter-rater ICC (2,1) reliability values between the two clinicians were 0.58 (±6.2 mm), 0.56 (±6.0 mm), and 0.66 (±8.2 mm) for the three respective test positions in the pilot study.

Experimental Design and Data Analysis

Descriptive statistics were gathered for the subjects' age, height, weight, and sex. The Pearson product-moment correlation was used to determine the validity coefficient (r).[23] While statistically significant correlations were expected, a correlation of $r \geq 0.80$ was considered to be the minimum value necessary to conclude the LSST is valid.[3] Repeated measures ANOVAs were conducted using the Shrout and Fleiss intraclass correlation coefficient (ICC) formula (2,1) to determine the intra-rater and inter-rater reliability for each test position.[1,19] The ICC values for inter-rater and intra-rater reliability were considered using the following criteria: ICC < 0.40 (poor), ICC = 0.40-0.75 (fair to good), and ICC > 0.75 (excellent).[6] Standard error of measurement (SEM) values were computed ($SD\sqrt{1-ICC}$) to assess the precision of each ICC value. SPSS version 10.0 for Windows and Microsoft Excel for Windows were used to conduct all statistical analysis. Statistical tests were considered significant at the $\alpha = 0.05$ level.

Each shoulder for a single subject was considered as an independent data source or *n* because this study sought only to evaluate the ability of the clinical LSST to estimate an actual linear distance between anatomical landmarks. We had no interest in determining bilateral differences, hand dominance differences, or any possible differences between subject cohorts. Therefore, each subject recruited to this study yielded an *n* of two for all LSST measures.

RESULTS

DEMOGRAPHICS

Nine subjects (7 male, 2 female) with a mean age of 27.5 ± 6.1 years participatd in this study. Subjects had a mean height and weight of 178.1 ± 9.6 cm and 93.3 ± 28.1 kg, respectively. The nine subjects had the following shoulder impairments: glenoid labrum lesion, (3); shoulder pain with possible rotator cuff tendonopathy, (3); supraspinatus tendonopathy and acromioclavicular joint inflammation, (1); multidirectional instability with secondary impingement, (1) and nerve root irritation, (1). Examples of a radiographic image with typical measurement results are depicted in Figures 3, 4, and 5. Figures 6, 7, and 8 represent three views of a radiographic image with the apparent LSST measurement error of the 90° testing position. Means, standard deviations, and ranges for the clinical LSST measurements are presented in Table 2.

VALIDITY EVIDENCE

The validity coefficients comparing the clinical LSST measure with the criterion measure of radiographic anatomical distance were 0.91 ($p < 0.001$), 0.97 ($p < 0.001$), and 0.77 ($p = 0.026$), respectively for the 0°, 45°, and 90° arm positions. A Pearson intercorrelation matrix (Table 3) was constructed comparing the *clinical distance* (scapula marker to spine marker measured on skin surface), *marker distance* (scapula marker to spine marker as observed on radiographs), and the *anatomical distance* (spinal midline to most inferior and medial aspect of scapula as seen on radiograph) for all three arm positions during the first test session. Comparison between the clinical distance and anatomical distance revealed the LSST to be valid ($r > 0.80$) in the 0° and 45° position.

RELIABILITY EVIDENCE

Intra-rater ICC (2,1) values ranged from 0.91 to 0.97 with SEM values ranging from 4.4 to 7.7 millimeters. Inter-rater ICC (2,1) values ranged from 0.71 to 0.87 with SEM values between 9.5 and 15.7 millimeters. The reliability data are summarized in Table 4. Scatterplots with lines of best fit for the intra-rater and inter-rater reliability data for the 0° arm position are depicted in Figures 9 and 10, respectively.

FIGURE 3 – Digital image of an anterior/posterior bilateral shoulder radiograph including radiopaque markers.

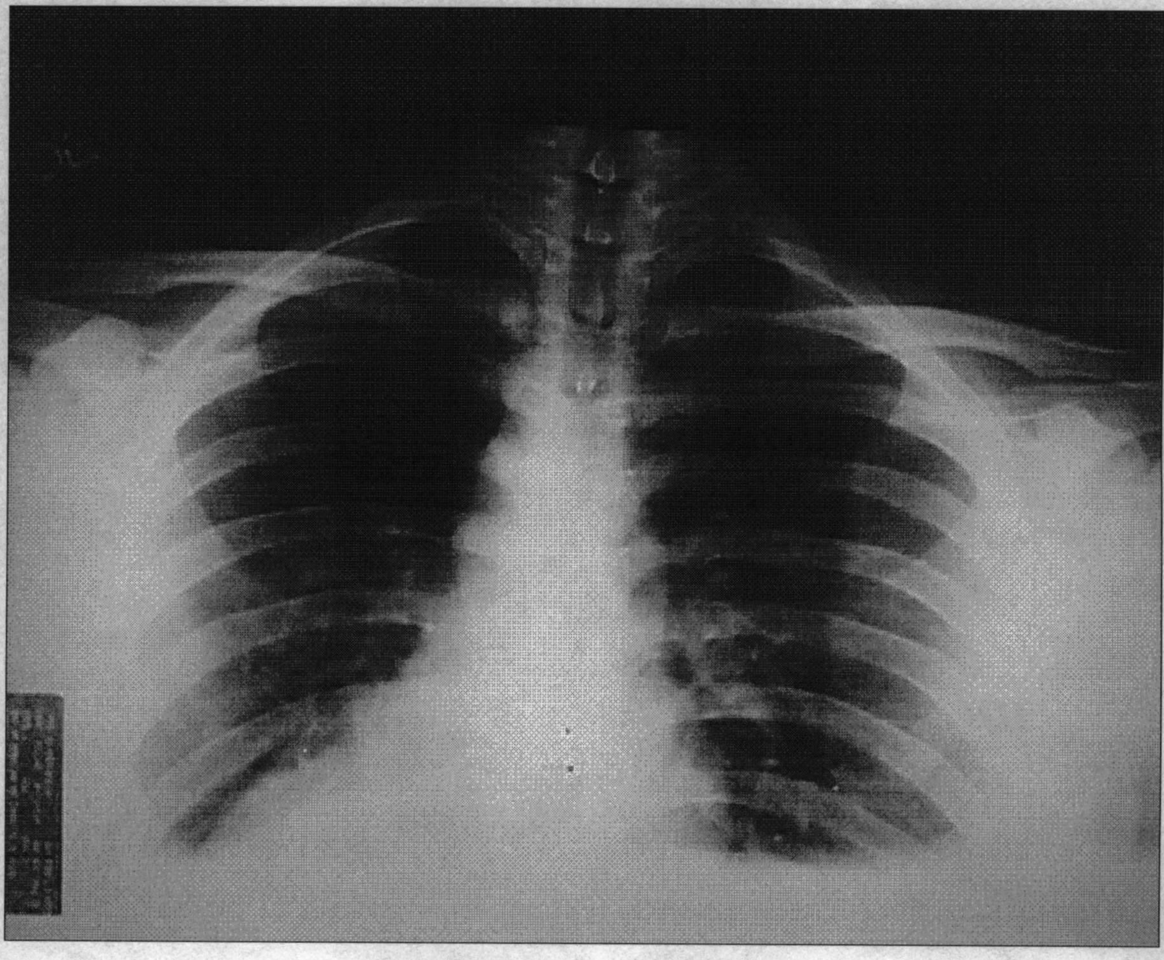


FIGURE 4 – Digital image of one shoulder from an anterior/posterior bilateral shoulder radiograph including radiopaque markers.

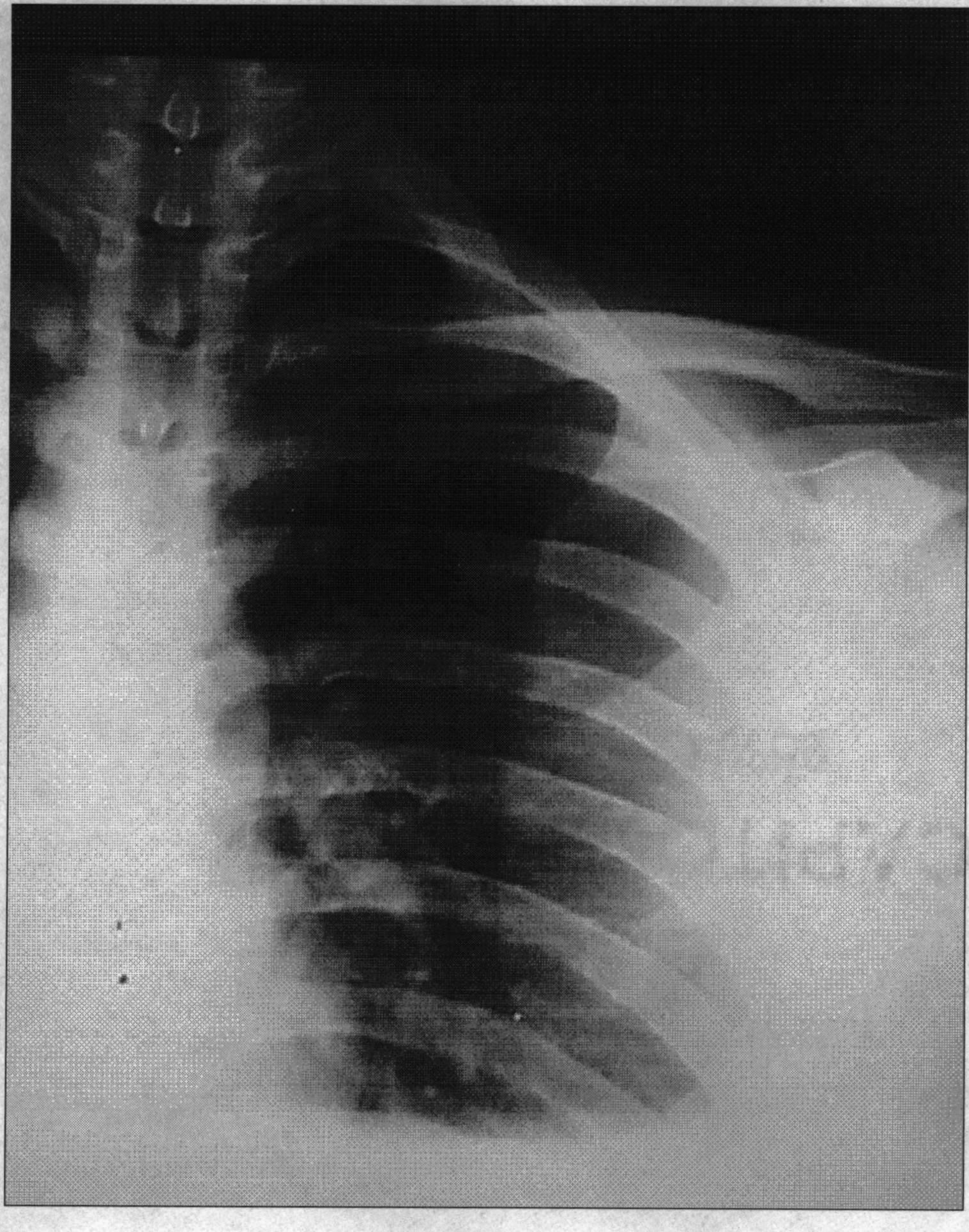


FIGURE 5 – Digital image close-up of a radiograph depicting the inferior angle of the scapula and radiopaque markers.

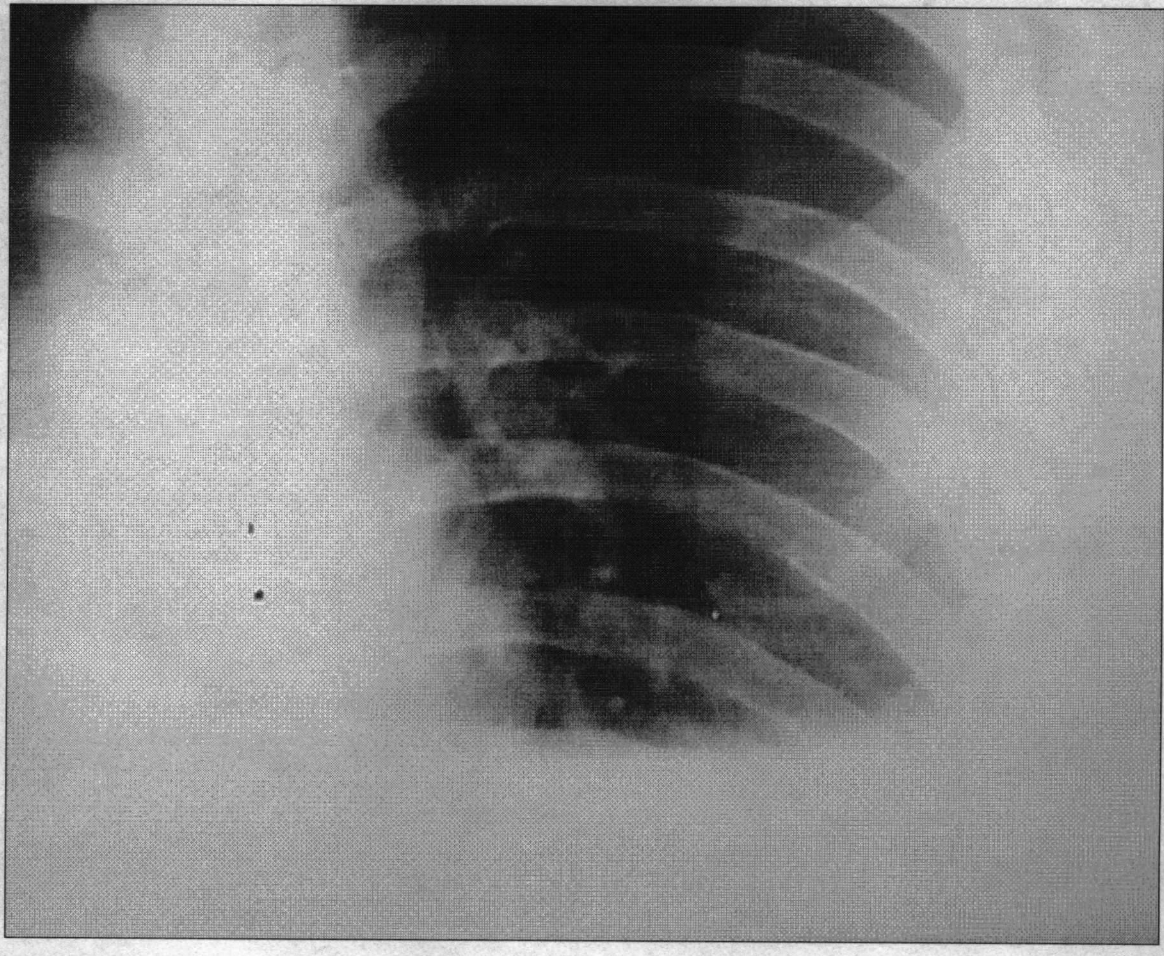


FIGURE 6 – Digital image of a bilateral shoulder radiograph depicting the typical measurement error from the 90° test position.

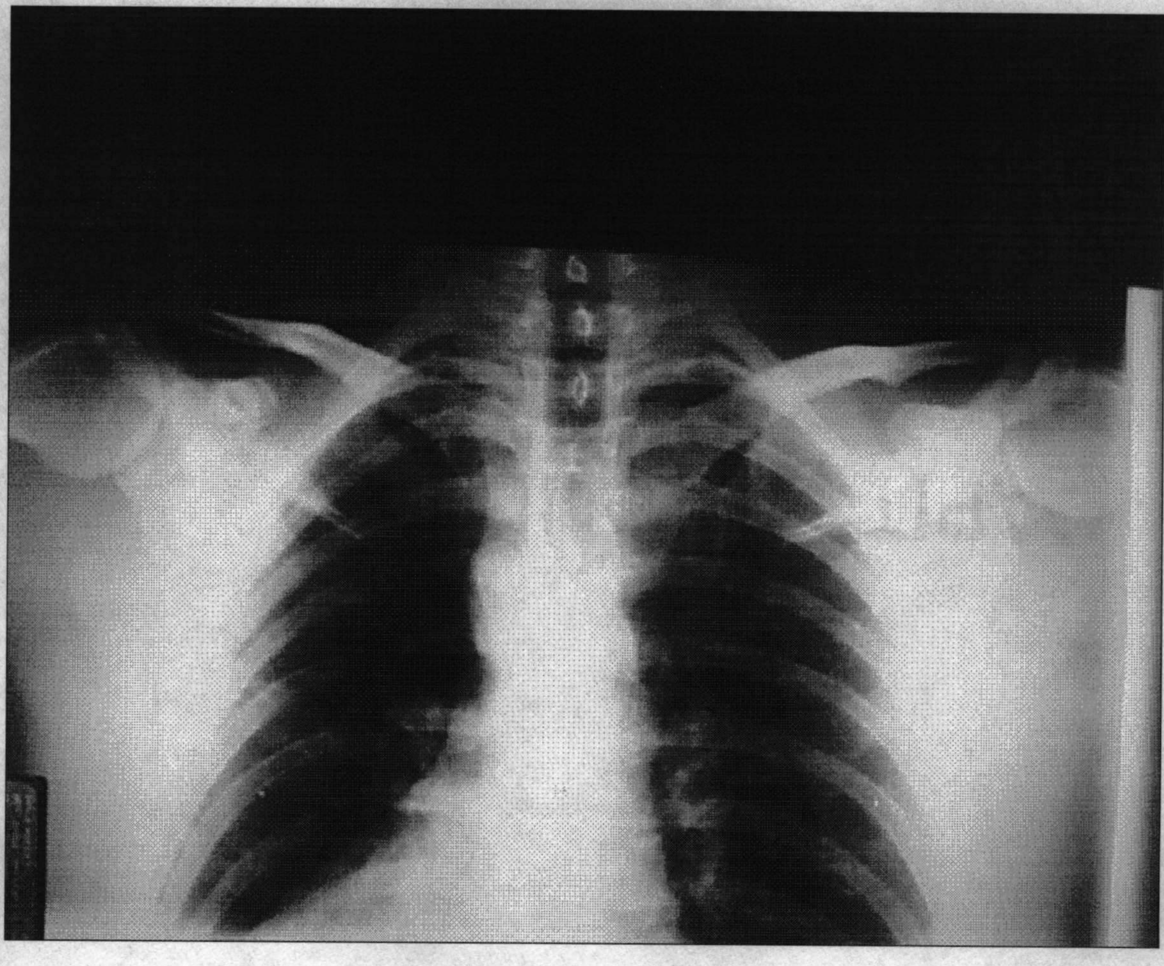


FIGURE 7 – Digital image of one shoulder from the measurement error example.

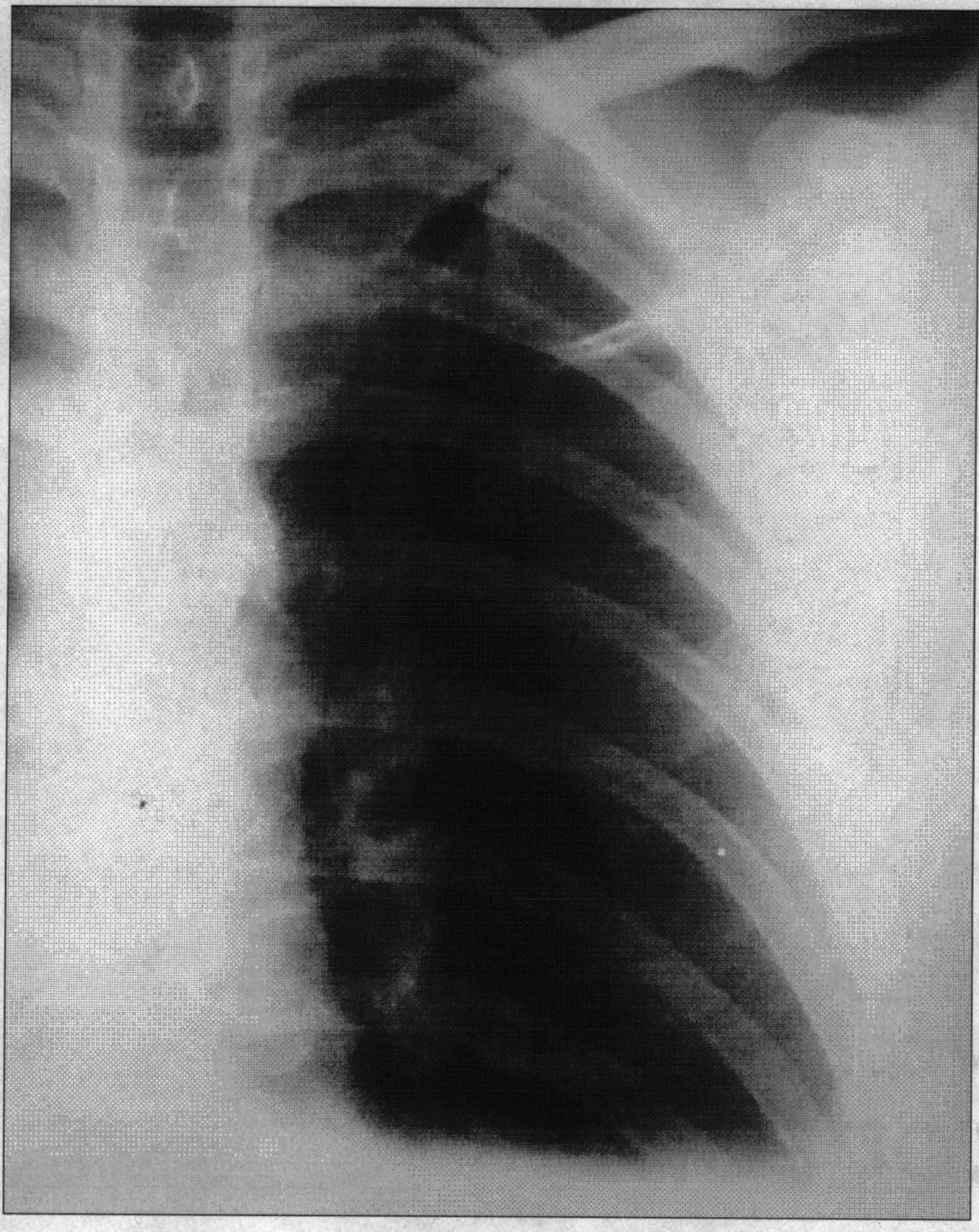


FIGURE 8 – Close-up of measurement error example.

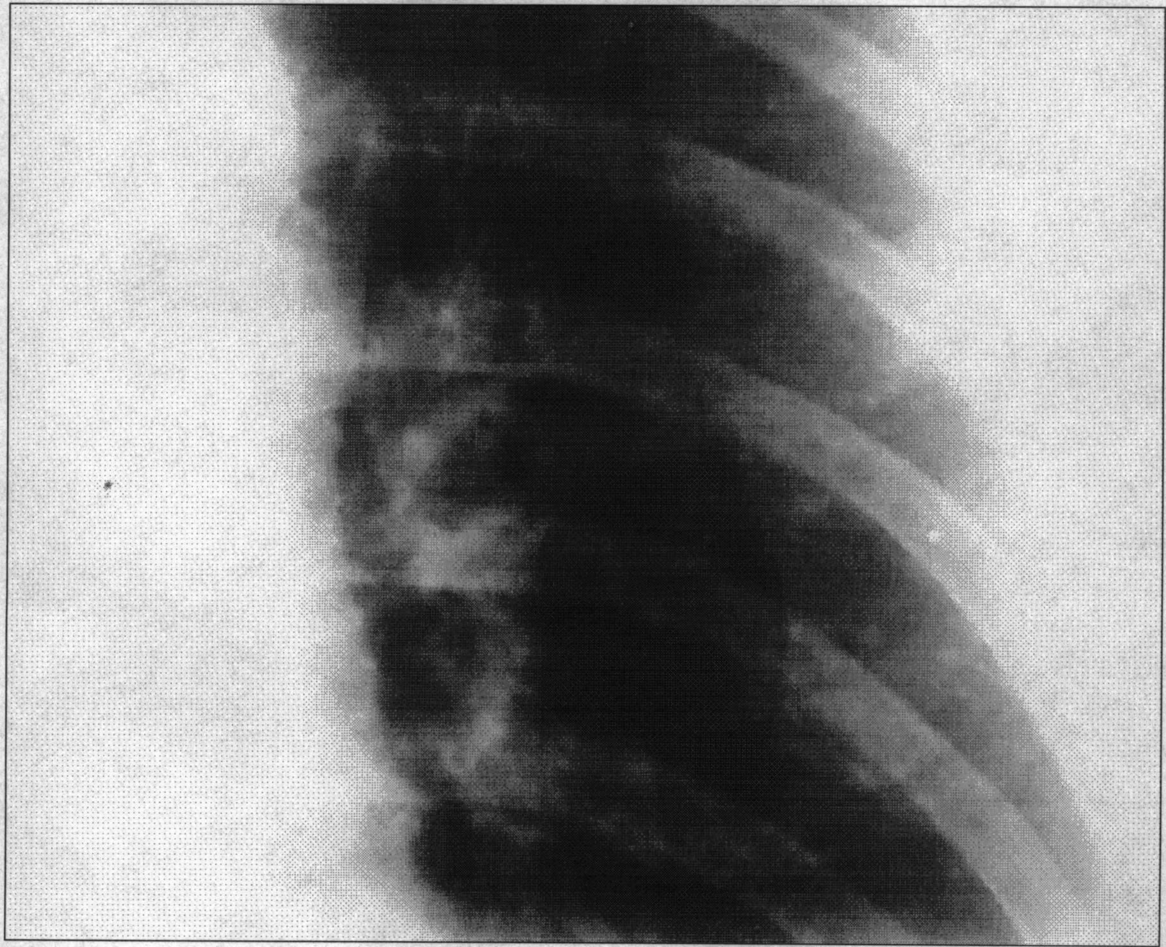


Table 2 – Means, standard deviations, and ranges for the clinical LSST measures.

TPD – Test Session 1	Mean	SD	Range
Arm at 0	96.6	23.7	67.0 – 157.0
Arm at 45	98.3	23.6	70.0 – 160.0
Arm at 90	108.1	27.3	55.0 – 165.0
TPD – Test Session 2	**Mean**	**SD**	**Range**
Arm at 0	93.2	27.4	70.0 – 161.0
Arm at 45	95.7	25.5	70.0 – 158.0
Arm at 90	107.7	31.3	50.0 – 175.0
RAH – Test Session 2	**Mean**	**SD**	**Range**
Arm at 0	107.1	23.1	83.0 – 162.0
Arm at 45	116.8	22.8	87.0 – 167.0
Arm at 90	128.3	24.1	86.0 – 168.0

All data reported in millimeters.

TABLE 3 – Pearson intercorrelation matrix of validity results.

	Clinical			Marker			Anatomical		
	Arm @ 0	Arm @ 45	Arm @ 90	Arm @ 0	Arm @ 45	Arm @ 90	Arm @ 0	Arm @ 45	Arm @ 90
Clinical Distance Arm Position @ 0	r = 1.000 p < 0.001	r = 0.945 p < 0.001	r = 0.886 p < 0.001	r = 0.976 p < 0.001	r = 0.932 p < 0.001	r = 0.695 p = 0.056	**r = 0.914** **p < 0.001**	r = 0.967 p < 0.001	r = 0.809 p = 0.015
Clinical Distance Arm Position @ 45	r = 0.945 p < 0.001	r = 1.000 p < 0.001	r = 0.871 p < 0.001	r = 0.971 p < 0.001	r = 0.995 p < 0.001	r = 0.610 p = 0.108	r = 0.936 p < 0.001	**r = 0.974** **p < 0.001**	r = 0.410 p = 0.314
Clinical Distance Arm Position @ 90	r = 0.886 p < 0.001	r = 0.871 p < 0.001	r = 1.000 p < 0.001	r = 0.900 p < 0.001	r = 0.903 p < 0.001	r = 0.887 p = 0.003	r = 0.815 p < 0.001	r = 0.950 p < 0.001	**r = 0.769** **p = 0.026**
Marker Distance Arm Position @ 0	r = 0.976 p < 0.001	r = 0.971 p < 0.001	r = 0.900 p < 0.001	r = 1.000 p < 0.001	r = 0.970 p < 0.001	r = 0.866 p = 0.005	r = 0.933 p < 0.001	r = 0.984 p < 0.001	r = 0.825 p = 0.026
Marker Distance Arm Position @ 45	r = 0.932 p < 0.001	r = 0.995 p < 0.001	r = 0.903 p < 0.001	r = 0.970 p < 0.001	r = 1.000 p < 0.001		r = 0.946 p < 0.001	r = 0.963 p < 0.001	
Marker Distance Arm Position @ 90	r = 0.695 p = 0.056	r = 0.995 p < 0.001	r = 0.887 p = 0.003	r = 0.866 p = 0.005		r = 1.000 p < 0.001	r = 0.283 p = 0.497		r = 0.817 p = 0.013
Anatomical Distance Arm Positon @ 0	**r = 0.914** **p < 0.001**	r = 0.610 p = 0.108	r = 0.815 p < 0.001	r = 0.933 p < 0.001	r = 0.946 p < 0.001	r = 0.283 p = 0.497	r = 1.000 p < 0.001	r = 0.964 p < 0.001	r = 0.316 p = 0.446
Anatomical Distance Arm Position @ 45	r = 0.967 p < 0.001	**r = 0.974** **p < 0.001**	r = 0.950 p < 0.001	r = 0.984 p < 0.001	r = 0.963 p < 0.001		r = 0.964 p < 0.001	r = 1.000 p < 0.001	
Anatomical Distance Arm Position @ 90	r = 0.809 p = 0.015	r = 0.410 p = 0.314	**r = 0.769** **p = 0.026**	r = 0.825 p = 0.012		r = 0.817 p = 0.013	r = 0.316 p = 0.446		r = 1.000 p < 0.001

All correlations significant at the alpha = 0.05 level (two-tailed)

Clinical Distance = Measure taken on skin surface between radiopaque markers placed on inferior angle and vertebral spinous process
Marker Distance = Distance between radiopaque markers placed on inferior angle and vertebral spinous proccess as seen on radiographs
Anatomical Distance = Distance between most inferior/medial aspect of the scapula and spinal midline as seen on radigraphs

TABLE 4 – Inter-rater and Intra-rater Reliability with SEM values.

Intra-rater	ICC	SEM (mm)
Arm at 0	0.91	7.4
Arm at 45	0.97	4.4
Arm at 90	0.93	7.7

Inter-rater	ICC (2,1)	SEM (mm)
Arm at 0	0.86	9.5
Arm at 45	0.83	11.9
Arm at 90	0.71	15.7

FIGURE 9 – Scatterplot and line of best fit for intra-rater reliability data at 0° arm position.

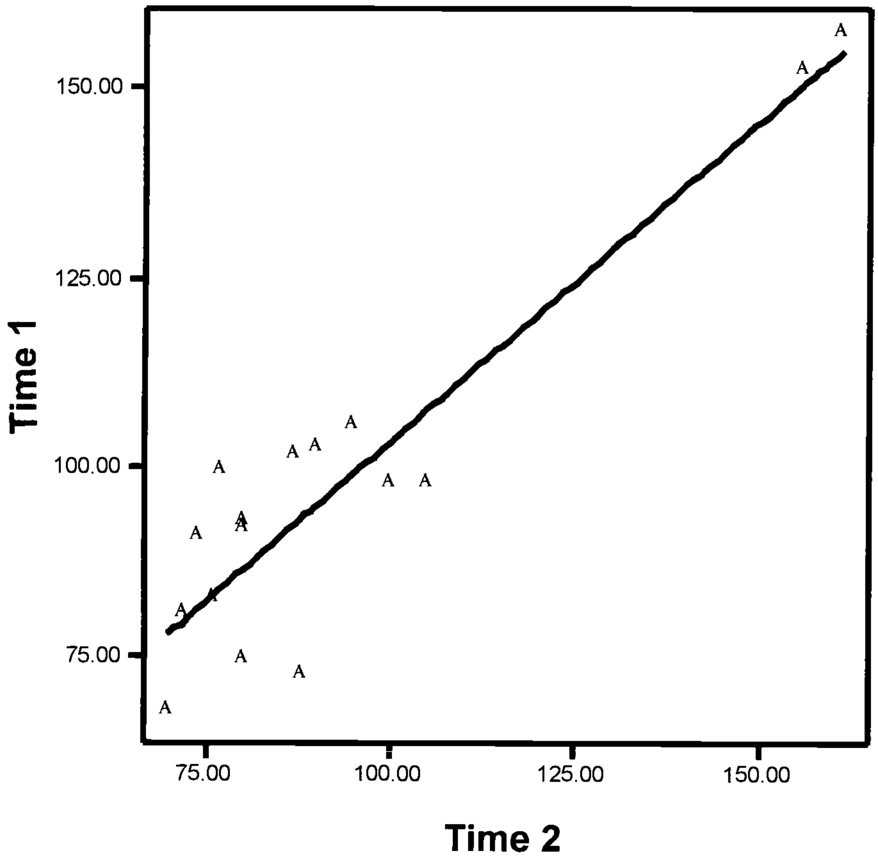
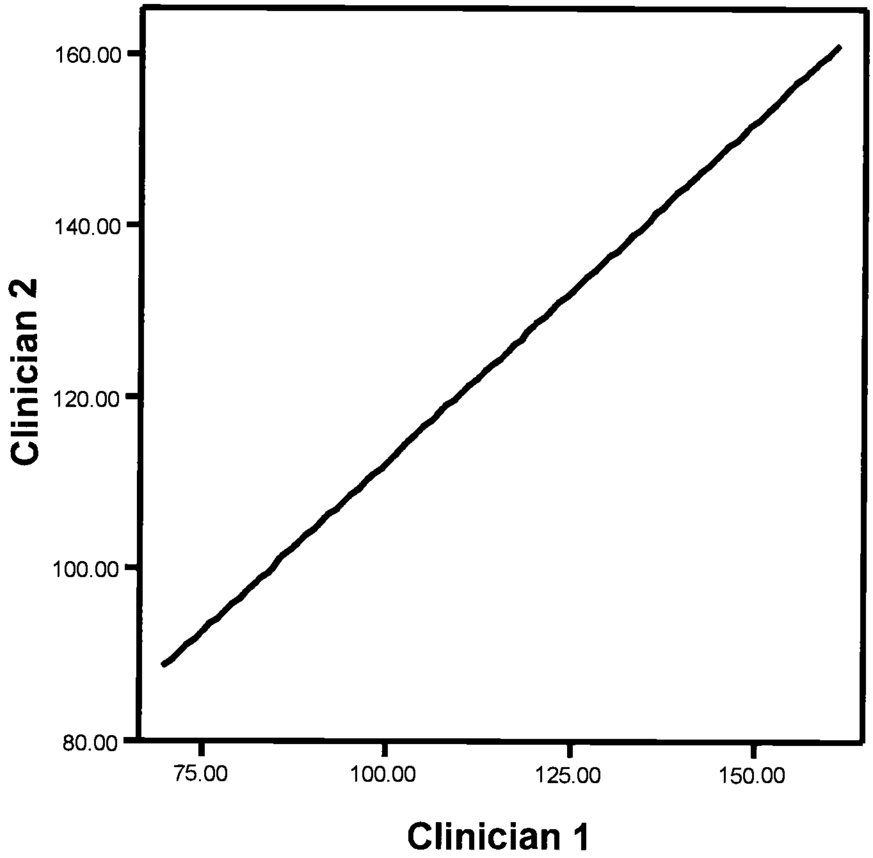


FIGURE 10 – Scatterplot and line of best fit for inter-rater reliability data at 0° arm position.



DISCUSSION

Over the past decade, Kibler's lateral scapular slide test has been used with increased frequency in the clinical setting for the evaluation of scapular motion and position. The LSST has gained sufficient acceptance to be included in a popular orthopaedic clinical assessment text used by certified athletic trainers, physical therapists, and others.[12] However, no reports establishing the validity of this clinical test against a criterion measure have been published, and the two previous reliability studies have shown the LSST to have mixed results.[6,17] Intra-rater ICC values for the LSST have ranged from fair to excellent, while inter-rater ICC values have ranged from poor to excellent, based on the criteria used in our study.[5,6,17]

One goal of this study was to eliminate the future need of radiographs to determine scapular position by demonstrating a high correlation between the x-ray values and the clinical LSST measures. Our experiment assessed criterion-related evidence of validity with a concurrent validity design. This design enabled us to quantify the relationship between the test score (clinical LSST) and the criterion score (actual anatomical distance as seen on radiographic images). Thus, this aspect of the study evaluated the diagnostic effectiveness of the LSST.[23]

Pearson product moment correlations between the clinical LSST measurement and the actual anatomical distance were highly related and statistically significant for all three arm positions, but only two of the three arm positions, 0° and 45°, met our pre-determined criteria ($r \geq 0.80$) for validity.[3] This evidence demonstrated that the clinical LSST is a valid measure of assessing the linear distance between the spine and scapula in the 0° and 45° arm positions.

It is difficult to compare our study of validity to evidence reported by Odom et al.[17] because those authors used sensitivity and specificity data as evidence for validity. The Odom et al.[17] study did not compare the LSST to any criterion standard such as radiographs. Furthermore, the Odom et al.[17] study did not adequately assess the sensitivity or specificity of the LSST for any particular shoulder complex pathology. Their 20 symptomatic subjects had at least six different types of shoulder impairment. If the LSST is to be used in a similar fashion to knee arthrometers in evaluating ACL integrity, it must be associated with a specific pathology, i.e., a knee arthrometer is not used to assess medial collateral ligament or meniscus integrity. Odom et al.[17] did report specificity values increased when the largest subject cohort with a single diagnosis (impingement syndrome/instability) was analyzed. The LSST should be further investigated for its efficacy in the evaluating specific shoulder pathologies.

Although our Pearson product moment correlation value for the 90° arm position of the LSST (0.77) was not above the pre-determined criterion value, it did closely approach 0.80. Exploration of the possible uncontrolled error sources revealed several explanations of why the 90° position was not shown to be a valid measure.

Three possible error sources become evident when the marker distance seen on the radiographs is compared to the clinical distance. In theory, these correlation values should all be a perfect 1.0 because both are measures of the exact same distance; one is taken from marker to marker on the skin surface, and the other is taken from marker to marker on the radiographs. Although one can not entirely rule out the possibility of error due to image magnification, we are confident the radiological procedure used and type of x-ray taken in this study eliminated any measureable magnification. Therefore, we contend that the three major sources of error were (a) extraneous movement by the subjects during testing, (b) the static versus dynamic nature of the three test positions, and (c) increased difficulty palpating bony landmarks in the 90° test position.

Two of the LSST arm positions, 0° and 45° are static in nature, while the 90° position is dynamic in nature. In the 0° and 45° positions, the subject must actively move the shoulder from the neutral position to the test position, but then the limb becomes static once the test position is achieved. The arm hangs passively at the side in the 0° position and the hand rests on the hip in

45° arm position. In contrast, the subject must continue to actively maintain the 90° test position after it is achieved by means of isometric muscle activity. The arm is not permitted to rest on an object or hang passively in the 90° test position. During the first test session, the subject was required to maintain the test position while the clinical LSST measure was taken and while the x-ray was taken without interruption; a period of time that often lasted around 30 seconds and some times slightly longer. If the subject did not hold the arms perfectly still during this duration, some measurement error was bound to occur. Anecdotally, the senior author observed some movement of the subjects' arms between the time the clinical LSST was obtained and the time the x-ray was completed. This occurred most notably when assessing the arm in the 90° position. This observation was corroborated in the Pearson correlation results that indicated the 90° position typically had the lowest (r) values and the other two positions had values closer to a perfect 1.0.

In addition to extraneous movement by the subject, there may have been biomechanical sources of error when assessing the validity of the LSST. The inferior angle of the scapula is more difficult to palpate as the shoulder moves toward the 90° position because the scapula becomes increasingly congruent with the thoracic wall as the glenohumeral angle moves toward 90° and beyond. This occurs because of the rotation and protraction of the scapula when moving towards overhead. In addition to increased scapulothoracic congruence, muscle function in the 90° position makes the scapula more difficult to palpate. In the two static positions, the muscles are relaxed and more compliant. However, in the 90° position, the muscles are in a state of isometric contraction, increasing muscle stiffness. A possible solution for these error sources would be constructing a testing jig or "arm rest" for the 90° arm position, making all three positions static in nature.

The second purpose of this study was to add to the existing body of literature pertaining to the reliability of the LSST by assessing both intra-rater and inter-rater reliability. Our intra-rater reliability values for the LSST were excellent for all three test positions (ICC = 0.91, 0.97, and 0.93). The inter-rater reliability values were excellent for the 0° position (ICC = .87) and 45° position (ICC = 0.83) and fair to good for the 90° position (ICC = 0.71). Similar to the validity evidence, the measurement values for the 90° arm position were the least consistent of the three LSST test positions. The possible sources of measurement error previously described should also be assigned to the reliability evidence. Extraneous subject motion, the static versus dynamic nature of the test position, and increased difficulty of palpation in the 90° position were present in both the first and second testing sessions.

A learning effect can be observed when the reliability data from the pilot study are compared to the data from the clinical study. Intra-rater reliability values improved from approximately 0.70 to over 0.90 for the senior author [TPD], while inter-rater reliability values increased from a range of 0.56 to 0.66 to a range between 0.71 and 0.86. These findings suggest that the examiners become more proficient and consistent as a result of repeated LSST evaluations.

The reliability results reported in this study are consistent with the trends described in the previous studies by Gibson et al.[6] and Odom et al.[17] where the 90° position was shown to be the least reliable of the three LSST test positions (Table 5). Gibson and co-authors reported similarly high values for intra-rater reliability (ICC values between 0.81 and 0.95), but Odom et al.[17] reported much lower values ranging from 0.52 to 0.80. Differences between our findings and theirs are likely explained by the statistical assessment methods used. The method used by Gibson et al.[6] and the method used in our study called for all examiners to evaluate all subjects. In the Odom et al.[17] protocol, sets of two physical therapists (out of a pool of six therapists) were selected to evaluate different groups of subjects. This difference caused Odom et al.[17] to use the ICC (1,1) formula,[19] where our study and the Gibson et al.[6] study used the ICC (2,1) formula.[19] Furthermore, Odom et al.[17] used the bilateral difference value to calculate the intraclass correlation

TABLE 5 – Comparison of reliability data for Odom et al,[17] Gibson et al,[5] and Daniels et al.

Measure (Test Position)	ICC	SEM (mm)
Odom et al. Intra-rater (0)	0.52-0.75	6.1-7.8
Gibson et al. Intra-rater (0)	0.91-0.94	4.4-5.4
Daniels et al. Intra-rater (0)	0.913	7.4
Odom et al. Intra-rater (45)	0.66-0.77	0.57-0.58
Gibson et al. Intra-rater (45)	0.88-0.92	0.45-0.64
Daniels et al. Intra-rater (45)	0.966	0.442
Odom et al. Intra-rater (90)	0.62-0.80	0.80-0.86
Gibson et al. Intra-rater (90)	0.81-0.91	0.56-0.79
Daniels et al. Intra-rater (90)	0.928	0.771
Odom et al. Inter-rater (0)	0.67-0.79	0.79
Gibson et al. Inter-rater (0)	0.67-0.69	1.02-1.04
Daniels et al. Inter-rater (0)	0.865	0.951
Odom et al. Inter-rater (45)	0.43-0.45	0.78-1.08
Gibson et al. Inter-rater (45)	0.52-0.53	1.17-1.20
Daniels et al. Inter-rater (45)	0.827	1.19
Odom et al. Inter-rater (90)	0.57-0.74	1.10-1.20
Gibson et al. Inter-rater (90)	0.18-0.28	1.59-1.65
Daniels et al. Inter-rater (90)	0.713	1.57

coefficient, whereas our study and the Gibson et al.[6] study used the pure linear distance from the scapula to the spine.

Both the Odom et al.[17] and Gibson et al.[6] studies added an extra dimension of complexity to their assessment of the LSST. Odom et al.[17] reported data that were differentiated between subjects with and without shoulder impairments, and Gibson et al.[6] subdivided data based on limb dominance. Neither of these studies reported a common inter-rater or intra-rater ICC value. Our study may have had higher ICC values because we did not add the unnecessary bias of attempting to detect differences between shoulders.

The inter-rater reliability data were also consistent with Gibson et al:[6] inter-rater data was less reliable than intra-rater data, and the 90° position was again shown to be the least reliable of the three positions. The inter-rater ICC values reported by Gibson et al.[6] (0.69 to 0.18) were much lower than those in the present study. Odom et al.[17] reported lower ICC values than the present study, similar to Gibson et al,[6] but the 90° position was not the lowest ICC value of the three positions. Again, these differences may well be attributed to the variations in protocols of the three studies.

Standard error of measurement values (expressed in the same units as the LSST) provide additional reliability evidence by assessing the precision of each ICC value; smaller SEM values indicate a more precise and reliable measure. SEM values for the intra-rater data ranged from 4.4 mm to 7.7 mm. Values for inter-rater data ranged from 9.5 mm to 15.7 mm. These values indicate moderate precision for the ICC values, but are very close to the clinical threshold set by Kibler.[9,10] Kibler[9] originally stated a 10 mm bilateral difference was indicative of pathology, but later revised the threshold to 15 mm.[10] As measurement error approaches the threshold of detection, the test measure becomes less reliable. The results of our study as well as those of Odom et al.[17] and Gibson et al.[6] are problematic because all three studies reported SEM values that were equal to or greater than what Kibler[9,10] would describe as an abnormal or positive finding with the LSST. Additional research should be done to determine an accurate threshold of detection as well as the specificity and sensitivity for individual shoulder impairments.

CONCLUSIONS

The LSST was shown to be valid in the 0° and 45° test positions. Good to excellent intra-rater and inter-rater reliability was reported for all three test positions. This study demonstrated that the LSST is an accurate and consistent measure of scapular movement and position for the 0° and 45° test positions. Clinicians should exercise caution when interpreting measurements obtained at the 90° test position because the validity and reliability values did not reach established standards. The efficacy of the 90° arm position is questionable but should be studied further because of the increased importance of the scapular roles during overhead motion.

REFERENCES

1. Baumgartner TA: Norm-referenced measurement: reliability, in Safrit MJ, Wood TM (eds): *Measurement Concepts in Physical Education and Exercise Science*. Champaign, IL, Human Kinetics, 1989, pp 45-72
2. Bigliani LU, Levine WN: Current concepts review: Subacromial impingement syndrome. *J Bone and Joint Surg 79-A*: 1854-1868, 1997
3. Cohen J: *Statistical Power Analysis for the Behavioral Sciences*. New York, Academic Press, 1969
4. DiVeta J, Walker ML, Skibinski B: Relationship between performance of selected scapular muscles and scapular abduction in standing subjects. *Phys Ther 70(8)*: 470-479, 1990
5. Fleiss, JL: *The Design and Analysis of Clinical Experiments.* New York, Wiley and Son, 1986, pp. 1-32
6. Gibson MH, Goebel GV, Jordan TM, et al: A reliability study of measurement techniques to determine static scapular position. *J Orthop Sport Phys Ther 21(2)*: 100-106, 1995
7. Jobe FW: Personal communication with WB Kibler, 1990. As seen in Kibler WB. The role of the scapula in athletic shoulder function. *Am J Sports Med 26(2)*: 325-337, 1998
8. Johnson MP, McClure P, Karduna AR: New method to assess scapular upward rotation in subjects with shoulder pathology. *J Orthop Sports Phys Ther 31(2)*: 81-89, 2001
9. Kibler WB: The role of the scapula in the overhead throwing motion. *Contemp Orthop 22*: 525-532, 1991
10. Kibler WB: The role of the scapula in athletic shoulder function. *Am J Sports Med 26(2)*: 325-337, 1998
11. Kvitne RS, Jobe FW: The diagnosis and treatment of anterior instability in the throwing athlete. *Clin Orthop 291*: 107-123, 1993
12. Magee DJ: *Orthopedic Physical Assessment,* Third Edition. Philadelphia, WB Saunders Company, 1997, pp. 213-214
13. McQuade KJ, Dawson J, Smidt GL: Scapulothoracic muscle fatigue asscociated with alterations in scapulohumeral rythmn kinematics during maximum resistive shoulder elevation. *J Orthop Sports Phys Ther 24(2)*: 57-65, 1996
14. Moore KL, Dalley AF: *Clinically Oriented Anatomy,* Fourth Edition. Philadelphia, Lippincott Williams and Wilkins, 1999, p. 61
15. Moseley JB, Jr., Jobe FW, Pink M, et al: EMG analysis of the scapular muscles during a shoulder rehabilitation program. *Am J Sports Med 20(2)*: 128-134, 1992
16. Neires L, Worrell TW: Assessment of scapular position. *J of Sports Rehab 2*: 20-25, 1993.
17. Odom CJ, Taylor AB, Hurd CE, et al: Measurement of scapular aymmetry and assessment of shoulder dysfunction using the lateral scapular slide test: A reliability and validity study. *Phys Ther 81(2)*: 799-809, 2001
18. Plafcan DM, Turczany PJ, Guenin BA, et al: An objective measurement technique for posterior scapular displacement. *J Orthop Sport Phy Ther 25(5)*: 36-341, 1997

19. Shrout PE, Fleiss JL: Intraclass correlations: Uses in assessing rater reliability. *Psych Bull 86:* 420-248, 1979

20. Sobush DC, Simoneau GG, Dietz KE, et al: The Lennie test for measuring scapular position in healthy young adult females: a reliability and validity study. *J Orthop Sport Phys Ther 23(1)*: 39-50, 1996.

21. Speer KP, Garrett WE: Muscular control of motion and stability about the pectoral girdle, in Matsen FA, Fu FH, Hawkins RJ (eds): *The Shoulder: A Balance of Mobility and Stability.* Rosemont, IL, American Academy of Orthopedic Surgeons, 1993

22. Warner JJP, Michelli LJ, Arslanian LE, et al: Scapulothoracic motion in normal shoulders and shoulders with glenohumeral instability and impingement syndrome: A study using Moire topographic analysis. *Clin Orthop 285*: 191-199, 1992

23. Wood TM: The changing nature of norm-referenced validity, in Safrit MJ, Wood TM (eds): *Measurement Concepts in Physical Education and Exercise Science*. Champaign, IL, Human Kinetics, 1989, pp. 23-44

24. Young JL, Herring SA, Press JM, et al: The influence of the spine on the shoulder in the throwing athlete. *J Back and Musculoskeletal Rehab 7*: 5-17, 1996

BIBLIOGRAPHY

Baumgartner TA: Norm-referenced measurement: reliability, in Safrit MJ, Wood TM (eds): *Measurement Concepts in Physical Education and Exercise Science*. Champaign, IL, Human Kinetics, 1989, pp 45-72

Bigliani LU, Levine WN: Current concepts review: Subacromial impingement syndrome. *J Bone and Joint Surg 79-A*: 1854-1868, 1997

Cohen J: *Statistical Power Analysis for the Behavioral Sciences*. New York, Academic Press, 1969

Decker MJ, Hintermeister RA, Faber KJ, et al: Serratus anterior muscle activity during selected rehabilitation exercises. *Am J Sports Med 27(6)*: 784-791, 1999

DiVeta J, Walker ML, Skibinski B: Relationship between performance of selected scapular muscles and scapular abduction in standing subjects. *Phys Ther 70(8)*: 470-479, 1990

Fleiss, JL: *The Design and Analysis of Clinical Experiments*. New York, Wiley and Son, 1986, pp. 1-32

Gibson MH, Goebel GV, Jordan TM, et al: A reliability study of measurement techniques to determine static scapular position. *J Orthop Sport Phys Ther 21(2)*: 100-106, 1995

Jobe FW: Personal communication with WB Kibler, 1990. As seen in Kibler WB. The role of the scapula in athletic shoulder function. *Am J Sports Med 26(2)*: 325-337, 1998

Johnson MP, McClure P, Karduna AR: New method to assess scapular upward rotation in subjects with shoulder pathology. *J Orthop Sports Phys Ther 31(2)*: 81-89, 2001

Kibler WB: The role of the scapula in the overhead throwing motion. *Contemp Orthop 22*: 525-532, 1991

Kibler WB: The role of the scapula in athletic shoulder function. *Am J Sports Med 26(2)*: 325-337, 1998

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

Lear LJ and Gross MT: An electromyographical analysis of the scapular stabilizing synergists during a push-up progression. *J Orthop Sports Phys Ther 28(3)*: 146-157, 1998

Lippert L: *Clinical Kinesiology for Physical Therapist Assistants*, 2nd Ed. Philadelphia, Davis Company, 1994, pp 83-122

Ludewig PM, Cook TM, Nawoczenski DA: Three-dimensional scapular orientation and muscle activity at selected postions of humeral elevation. *J Orthop Sports Phys Ther 24(2)*: 57-65, 1996

Magee DJ: *Orthopedic Physical Assessment*, Third Edition. Philadelphia, WB Saunders Company, 1997, pp. 213-214

McQuade KJ, Dawson J, Smidt GL: Scapulothoracic muscle fatigue asscociated with alterations in scapulohumeral rythmn kinematics during maximum resistive shoulder elevation. *J Orthop Sports Phys Ther 24(2)*: 57-65, 1996

Moore KL, Dalley AF: *Clinically Oriented Anatomy*, Fourth Edition. Philadelphia, Lippincott Williams and Wilkins, 1999, p. 61

Moseley JB, Jr., Jobe FW, Pink M, et al: EMG analysis of the scapular muscles during a shoulder rehabilitation program. *Am J Sports Med 20(2)*: 128-134, 1992

Neires L, Worrell TW: Assessment of scapular position. *J of Sports Rehab 2*: 20-25, 1993.

Odom CJ, Taylor AB, Hurd CE, et al: Measurement of scapular aymmetry and assessment of shoulder dysfunction using the lateral scapular slide test: A reliability and validity study. *Phys Ther 81(2)*: 799-809, 2001

Plafcan DM, Turczany PJ, Guenin BA, et al: An objective measurement technique for posterior scapular displacement. *J Orthop Sport Phy Ther 25(5)*: 36-341, 1997

Shrout PE, Fleiss JL: Intraclass correlations: Uses in assessing rater reliability. *Psych Bull 86:* 420-248, 1979

Sobush DC, Simoneau GG, Dietz KE, et al: The Lennie test for measuring scapular position in healthy young adult females: a reliability and validity study. *J Orthop Sport Phys Ther 23(1)*: 39-50, 1996.

Speer KP, Garrett WE: Muscular control of motion and stability about the pectoral girdle, in Matsen FA, Fu FH, Hawkins RJ (eds): *The Shoulder: A Balance of Mobility and Stability.* Rosemont, IL, American Academy of Orthopedic Surgeons, 1993

Warner JJP, Michelli LJ, Arslanian LE, et al: Scapulothoracic motion in normal shoulders and shoulders with glenohumeral instability and impingement syndrome: A study using Moire topographic analysis. *Clin Orthop 285*: 191-199, 1992

Wood TM: The changing nature of norm-referenced validity, in Safrit MJ, Wood TM (eds): *Measurement Concepts in Physical Education and Exercise Science*. Champaign, IL, Human Kinetics, 1989, pp. 23-44

Young JL, Herring SA, Press JM, et al: The influence of the spine on the shoulder in the throwing athlete. *J Back and Musculoskeletal Rehab 7*: 5-17, 1996

APPENDICES

APPENDIX A

INFORMED CONSENT DOCUMENT

INFORMED CONSENT DOCUMENT

Radiographic Determination of the Validity and Reliability of the Lateral Scapular Slide Test

A. TITLE: Radiographic Determination of the Validity and Reliability of the Lateral Scapular Slide Test.

B. INVESTIGATORS: Todd P. Daniels, ATC
Rod A. Harter, PhD, ATC

C. PURPOSE: The primary purpose of this research is to determine if the lateral scapular slide test taken from measurements on the skin is an accurate measure of the actual distance between bony landmarks as seen in x-rays. The secondary purpose of this research is to determine if the lateral scapular slide test can be consistently measured at different times and by different examiners.

D. PROCEDURES: By participating in this study, I understand all of the following methods and procedures will happen:

1. **Pre-Study Screening:**
   Because my physician has ordered x-rays for my injury/condition, I am eligible for this study if all of the following statements are true:
   a. I am seeking medical evaluation for an injury directly related to the scapula or glenohumeral joint,
   b. I am at least 18 years of age,
   c. I have not had surgery on either shoulder in the last year,
   d. I am able to actively move both arms out to the side (at least 90°) and hold that position for 30 seconds,
   e. I have no postural or bony abnormalities including, but not limited to scoliosis or winged scapula, and
   f. If I am a female, I am not currently pregnant or lactating.

2. **What participants will do during study:**
   a. My participation will involve two testing sessions on two different days. The first session will be completed while at the physician's office after my injury has been evaluated. The lateral scapular slide test will be performed on my right and left shoulders. This test will involve exposing both shoulders to measure the distance from the lower part of my right and left scapula to my spine in three positions. The first position will have my arms resting at my side. The second position will have my hands resting on my hips. The third position will have my hands outstretched to the side at a 90° angle. Small markers will be placed on my skin and x-rays will be taken of two of the three arm positions.
   b. In one week or less, at my convenience, I agree to come to the Sports Medicine Lab in Room 8 of the Women's Building at Oregon State University and repeat the LSST diagnostic test.

3. **Foreseeable risks or discomforts.**
   a. I understand there are no foreseeable risks or discomforts for participating in this study.

4. **Benefits to be expected from the research.**
   a. I understand the possible benefits of my participation in this study include learning about the anatomy, function, and role of the scapula in shoulder motion and the problems associated with abnormal scapular position and function. Additionally, this study will test the accuracy and consistency for a measure of scapular position and increase the body of knowledge about the scapula and its role in shoulder motion and injury.
   b. I have been informed that I will not be financially compensated for my participation and there will be no financial obligation for the x-ray images being taken.

E. CONFIDENTIALITY.

1. I understand that the results of the research may be published but that my name or identity will not be revealed. In order to maintain confidentiality of my records, Todd P. Daniels will assign a code number to my name and the matched name and code number list will be secured at all times. Only Todd P. Daniels and Rod A. Harter will have access to the list of code numbers and names. This code number will be used to identify all data obtained from me.

F. COMPENSATION FOR INJURY.

1. I understand that Oregon State University does not provide a research subject with compensation or medical treatment in the event a subject is injured as a result of normal participation in this research project.

G. VOLUNTARY PARTICIPATION STATEMENT

1. I have read the above information. The nature, demands, risks, and benefits of the project have been explained to me. I understand that my participation in this study is completely voluntary. I knowingly assume the risks involved, and understand that I may withdraw my consent and discontinue participation at any time without penalty or loss of benefit to which I am otherwise entitled.

H. IF YOU HAVE QUESTIONS

1. If I have questions concerning the research study or my participation in it before or after my consent, they will be answered by Todd Daniels, 108 Gill Coliseum, Corvallis, Oregon 97331 at (541) 737-7357 or Dr. Rod A. Harter, Langton Hall 226, Oregon State University, Corvallis, Oregon at (541) 737-6801.
2. If I have questions about my rights as a participant in this research, or if I feel I have been placed at risk, I can contact the Coordinator of the Oregon State University Institution Review Board (IRB) for the Protection of Human Subjects, OSU Research Office, Kerr Administration Building, (541) 737-8008.

My signature below indicates that I have read and that I understand the procedures previously described and give my informed consent and voluntary consent to participate in this study. I understand that I will receive a signed copy of this consent form.

Signature of Participant ________________________________ Date____________

Signature of Investigator ________________________________ Date____________

APPENDIX B

COPY OF SUBJECT QUESTIONNAIRE

SUBJECT QUESTIONNAIRE
For
Radiographic Determination of Validity of the Lateral Scapular Slide Test

Todd P. Daniels, ATC -- Investigator
Rod Harter, PhD, ATC – Investigator

____
Name

( ) ____________________ ( ) ____________________
Home Phone Work Phone

____
E-Mail Address

____
Address City State Zip

M F
____
Age Sex Height Weight

THE FOLLOWING INFORMATION WILL BE COMPLETED BY THE EXAMINER

Dominant Limb L R

Affected Limb L R

Chief Complaint____________________________________

Physician Impression____________________________

Notes____

____

APPENDIX C

Application to OSU Institution Review Board

Proposal to IRB Human Subjects Committee

Letter of Approval

/

APPLICATION FOR APPROVAL OF THE OSU INSTITUTIONAL REVIEW BOARD (IRB)
FOR THE PROTECTION OF HUMAN SUBJECTS

Principal Investigator* Rod A. Harter **E-mail** rod.harter@orst.edu

Department Exercise and Sport Science **Phone** 737-6801

Project Title Radiographic Validation of the Validity and Reliability of the Lateral Scapular Slide Test

Present or Proposed Source of Funding ____

Type of Project: ____ **Faculty Research Project**

xxx **Student Project or Thesis*: Student's name** Todd P. Daniels **Phone** 737-7357
E-mail: todd.daniels@orst.edu
Student's mailing address 103 Gill Coliseum

Type of Review Requested: ____ **Exempt** ____ **Expedited** xx **Full Board**

The Oregon State University Institutional Review Board (IRB) for the Protection of Human Subjects is charged with the responsibility of reviewing, prior to its initiation, all research involving human subjects. The Board is concerned with justifying the participation of subjects in research and protecting the welfare, rights and privacy of subjects.

All material, including this cover sheet, should be submitted **IN DUPLICATE** to the Research Office, Kerr A312. Please call x7-8008 if you have questions. The following information must be attached to this form with each item identified and addressed separately or the application will be returned without review.

1. A brief description (one paragraph) of the significance of this project in lay terms.
2. A description of the methods and procedures to be used during this research project. Outline the sequence of events involving human subjects.
3. A description of the benefits (if any) and/or risks to the subjects involved in this research.
4. A description of the subject population, including number of subjects, subject characteristics, and method of selection. Include any advertising, if used, to solicit subjects. Justification is required if the subject population is restricted to one gender or ethnic group.
5. A copy of the informed consent document. The informed consent document must include the pertinent items from the "Basic Elements of Informed Consent" and must be in lay language.
6. A description of the methods by which informed consent will be obtained.
7. A description of the method by which anonymity or confidentiality of the subjects will be maintained.
8. A copy of any questionnaire, survey, testing instrument, etc. (if any) to be used in this project.
9. Information regarding any other approvals which have been or will be obtained (e.g., school districts, hospitals, cooperating institutions).

Signed Rod A. Harter **Date** March 9,2000
Principal Investigator*

***NOTE:** Student projects and theses should be submitted by the major professor as Principal Investigator.

7-99

I. Significance of the Study

There are five major roles attributed to the scapula in overhead shoulder activity;[4] each of these roles contribute to optimal shoulder function. The scapula primarily serves an attachment site for muscles of the upper back and shoulder, and to transfer the muscular forces created to the glenohumeral joint for various upper extremity activities.[4] Also, the acromion process of the scapula must be elevated to avoid compressing the rotator cuff and causing impingement and damage to the muscles.[4]

Given the very important roles of the scapula in shoulder motion, any instability, impaired function, or abnormal position of the scapula can cause shoulder injuries, e.g., impingement syndrome and rotator cuff tears. An important area of inquiry, therefore, is to quantify scapular dysfunction and develop a useful clinical assessment test for this problem, known as scapular dyskinesis.

At this time, several measurement techniques have been developed to evaluate scapular position and function.[1-3, 7-11] The most promising of these tests is the lateral scapular slide test (LSST).[2, 3, 8] The LSST measures the distance from the lowest or most inferior aspect of the scapula to the closest vertebral segment (Figures 1 and 2). Before this test measure can be used with confidence in a clinical setting, research must demonstrate that it is a valid and reliable measure of the distance between the scapula and spine.

Previous research has shown the LSST to be a highly reliable measure of scapular motion.[3, 8] Two studies reported different testers and the same testers on different occasions all obtained very similar measurements for healthy subjects.[2, 8] Unfortunately, no data evaluating the validity of the LSST have been published. What remains to be determined is whether the clinical measurements on the skin are accurately assessing scapular position and distance from the spine.

The primary purpose of this study will be to determine the validity of the LSST by comparing clinical measurements on the skin to the actual distance between the scapula and the spine as seen on x-ray images. The secondary purpose of this study will be to determine the reliability of the LSST by comparing the measures taken by one examiner on two different testing sessions and by comparing the measures taken by two examiners during a single testing session. We anticipate that the results of this study will demonstrate that the LSST is a valid and reliable measure of scapular position and indicator of dysfunction.

FIGURE 1 – Lateral Scapular Slide Test at 45° and 120° of glenohumeral abduction.[5] (NOTE: In the current study, joint angles of 0°, 45°, and 90° will be utilized for the clinical LSST)

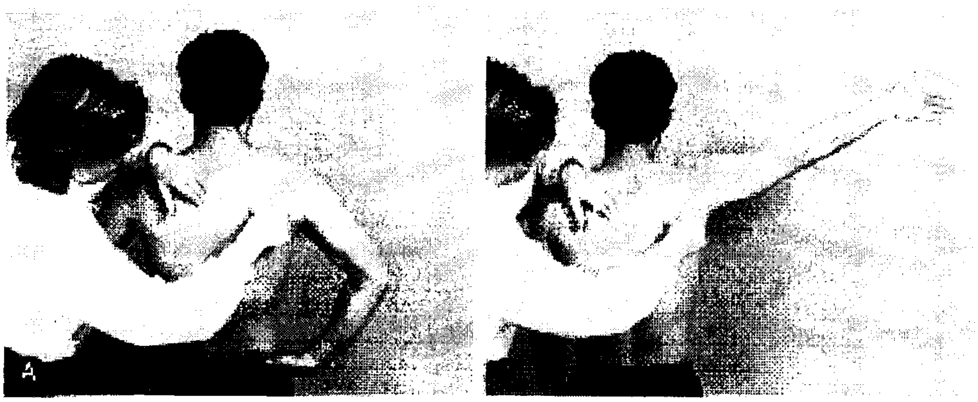
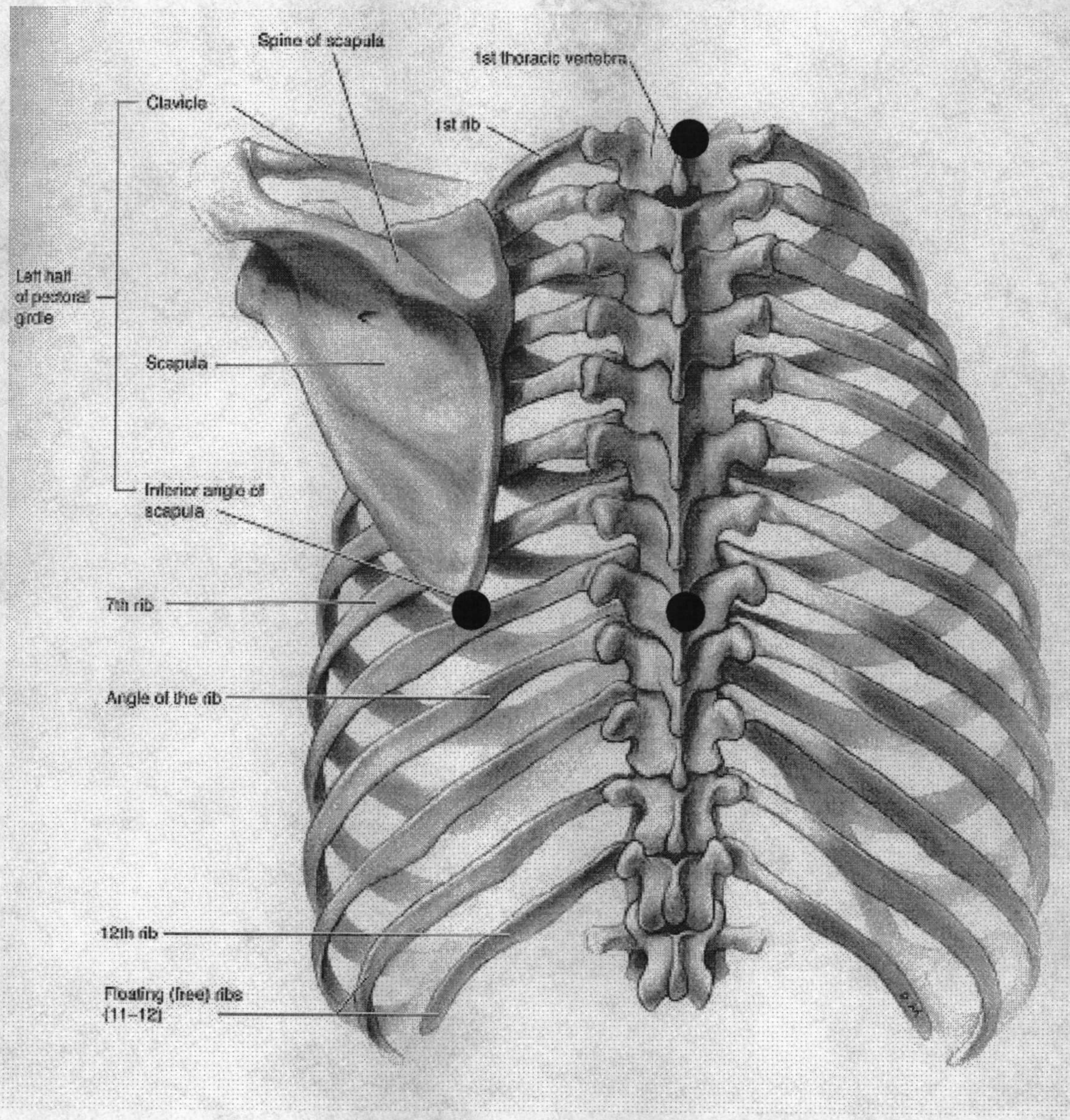


FIGURE 2 – Posterior view of scapula and thorax,[6] with depiction of placement of radiopaque markers.



II. METHODS AND PROCEDURES

SUBJECT POPULATION AND SELECTION

Twenty subjects (N=40 shoulders) will be recruited from the medical practice of orthopaedic surgeon, Ronald Wobig, M.D. of Specialty Physicians and Surgeons of Corvallis, Oregon (SPSC). Because Oregon statutes prohibit the use or radiation on human beings for the sole purposes of research, only persons who seek medical evaluation and exhibit shoulder pathology directly related to the scapula or glenohumeral joint will be allowed to participate in this study. Criteria for inclusion will require that subjects be the age of 18 or over, have no history of surgery to the upper extremity in the last year, be able to actively abduct the humerus to at least a 90° position in the frontal plane, and maintain that position for 30 seconds. Subjects who exhibit any postural or bony abnormalities will be excluded from the study. These abnormal conditions include, but are not limited to scoliosis and winging of the scapula. Women who are pregnant or breast-feeding will be excluded from the study.

Before participating in the study, all subjects will read and sign an informed consent form approved by the Oregon State University Institution Review Board for the Protection of Human Subjects (Appendix A). Both shoulders will be evaluated for all subjects using the radiographic LSST and clinical LSST measures.

INSTRUMENTATION

All bony landmarks will be palpated and identified with an adhesive radiopaque encapsulated lead marker (E-Z Mark, E-Z-EM, Inc., Westburg, NY), typically used in mammography exams. The existing x-ray equipment and laboratory at the Radiology Department of SPSC will be used for all imaging. The distance of the x-ray tube lens to the film plate will be standardized for all x-rays. All radiographs will be taken in the frontal plane to capture a posterior image of both the right and left scapulae. An object of known dimensions will be placed in the field of each image for use as a scaling factor.

A fiberglass anthropometric tape measure will be used to measure the scapular distance to the spine and recorded to the nearest 0.5mm. A skinfold caliper will be used to determine the subscapular skinfold thickness for all patients as quantification of one possible source of measurement error for the clinical LSST.

PROCEDURE

If the medical evaluation of a patient by Dr. Wobig and his medical staff requires diagnostic radiographic images (x-rays) of the shoulder, the student researcher [TPD] will approach the patient and explain the nature of the study and procedures involved. If the patient agrees to voluntary participation, the subject will be screened to insure they meet all selection criteria, and a written informed consent document (Appendix A) will be read and signed by the subject. Copies of the informed consent document will be provided to all subjects.

At the Radiology Department of SPSC, under the direction of a registered radiation technician, subjects will be provided a dressing gown that will permit direct visualization and palpation of the vertebral column and both scapulae. Subjects will be instructed to fix their eyes on a designated object in the room in order to reduce static posture differences. All procedures for the clinical LSST will be modeled after those described by Odom et. al.[8]

Before each measure is taken, subjects will perform a neutral (starting) exercise by placing both hands overhead and allowing them to fall back to their sides. The attending radiology technician will position the subject, x-ray tube, and plate containing radiographic film for proper imaging. The investigator will then palpate the prominence (spinous process) of the seventh cervical vertebra (C7), the inferior-most aspect of the right and left scapulae (inferior angle), and the spinous process of the vertebrae in the same horizontal plane of the inferior angle of the scapula. Adhesive radiopaque encapsulated lead markers will be placed on the skin for these four bony landmarks. The anthropometric tape measure will then be used to determine the distance from the center of the marker located on the inferior angle of the scapula and the center of the marker located on the vertebral spinous process closest to the inferior angle of the scapula (Figure 1).[5] Three positions, 0°, 45°, and 90°, will be assessed in this study:

Position One (0°) – The subject will stand with both arms at the sides in a neutral glenohumeral position (less than 5° of glenohumeral abduction in the frontal plane).

Position Two (45°) – The subject will stand with both hands resting on the hips and thumbs pointed posteriorly (a position of partial glenohumeral internal rotation and approximately 45° of glenohumeral abduction in the frontal plane).

Position Three (90°) – The subject stand with outstretched arms and thumbs pointed toward the floor (active full extension of the elbows and 90° of glenohumeral abduction in the frontal plane with full glenohumeral internal rotation).

Radiographic images will be taken for all subjects in the 0° position. Subjects will be randomly selected so that 10 subjects (N=20 shoulders) will have x-rays taken in the 45° position and the other 10 subjects (N=20 shoulders) will have x-rays taken in the 90° position.

The 0° position will be assessed first for all subjects. After the clinical LSST measurement is obtained for the 0° position, the radiographic image will be taken while the subject maintains the testing position. Subjects will then be instructed to perform the neutral exercise before moving into the next position. The procedure is repeated for either the 45° or 90° position, based on the random group assignment. Subjects will perform the neutral exercise again, and the final position will be assessed with the clinical LSST only; no x-rays will be taken for the final position.

At the conclusion of the first session, the subject will complete the first portion of a questionnaire (Appendix B) with the following contact information: subject's name, phone number, and E-mail address. A code number will be assigned to the subject according to their order of entry into the study, e.g., S1, S2, or S3.

Within seven days of the initial session, the subject will come to the Oregon State University Sports Medicine Research Laboratory for a second testing session. The student researcher [TPD] and a second clinician [RAH], both certified athletic trainers, will perform the clinical LSST on the subject's left and right shoulders. The order of clinician measurements will be randomized to reduce testing order bias. The previous procedures will be followed, but radiographic images will not be taken in the second session and grease pen dots will replace the radiopaque markers for identification of bony landmarks. Three measures will be taken for both right and left sides in all three test positions by both examiners to establish a 3-trial average for each position and side. All grease pen markings will be thoroughly removed by the first examiner prior to any measurements by the second examiner.

At the conclusion of the second session, the subject will complete the questionnaire (Appendix B) by providing the following information: mailing address, age, sex, dominant limb, affected limb, primary complaint, and physician's impression. The student researcher [TPD] will assess the height, weight, and subscapular skinfold thickness of each subject.

The student researcher [TPD] will perform all clinical measurements for the LSST in the first session and calculate the scapular displacement depicted on the x-ray images. Two examiners [TPD and RAH] will perform all clinical LSST measures during the second session. This study will be single blind in nature, as the examiners will not know which limb is affected, the nature of pathology, or the severity of injury until the conclusion of testing.

III. BENEFITS AND/OR RISKS TO SUBJECTS

The benefits to participants in this study include learning about the anatomy, function, and role of the scapula in shoulder motion and the problems associated with abnormal scapular position and function. There will be no monetary compensation for participation in the study, and there will be no additional cost to the patient for the x-rays or measurements. The x-ray film cost will be paid for by the study; therefore, the total cost for the patient's visit to Specialty

Physicians and Surgeons may actually be lower, dependent on the patient's insurance coverage. The involvement of subjects in this study will help provide vital information on the accuracy and consistency of a clinical measure for scapular position. If the LSST is shown to be highly valid and reliable, x-rays will no longer be needed to determine scapular position and dysfunction.

The only risk that will be encountered by participants is a very limited exposure to gamma radiation from the x-rays. The total estimated exposure for the two posterior-anterior chest x-rays is 2 millirem effective dose equivalent or 0.02μSv. This estimated exposure is based on data from the National Council of Radiation Protection and Measures Handbook (report 100), which states the radiation received from one x-ray to is 1 millirem effective dose equivalent or 0.01μSv. This dosage is equivalent to the average exposure an individual would receive from the natural surroundings of Corvallis during one day.

IV. SUBJECT POPULATION AND SELECTION

Twenty subjects (N=40 shoulders) will be recruited from the medical practice of orthopedic surgeon, Ronald Wobig, M.D. of Specialty Physicians and Surgeons of Corvallis, Oregon (SPSC). Because Oregon statutes prohibit the use or radiation on human beings for the sole purposes of research, only persons who seek medical evaluation and exhibit shoulder pathology directly related to the scapula or glenohumeral joint will be allowed to participate in this study. Criteria for inclusion will require that subjects be the age of 18 or over, have no history of surgery to the upper extremity in the last year, be able to actively abduct the humerus to at least a 90° position in the frontal plane, and maintain that position for 30 seconds. Subjects who exhibit any postural or bony abnormalities will be excluded from the study. These abnormal conditions include, but are not limited to scoliosis and winging of the scapula. Women who are pregnant or breast-feeding will be excluded from the study.

There are no grounds for exclusion of subjects from this study based strictly on sex, ethnic group, body type or age, provided they are able to give legal consent (age 18 or over). This study will attempt to recruit an equal number of male and female subjects.

V. INFORMED CONSENT DOCUMENT

See Appendix A.

VI. METHODS FOR OBTAINING INFORMED CONSENT

If the medical evaluation of the patient by Ronald Wobig, M.D. and his medical staff requires diagnostic radiographic images (x-rays), the student researcher [TPD] will approach the patients and explain the nature of the study and the procedures involved. If a subject agrees to voluntary participation, the patient will be screened to insure they meet all selection criteria, and a written informed consent document (Appendix A) will be read and signed by the subject. Copies of the informed consent document will be provided to all subjects.

VII. METHODS FOR MAINTAINING SUBJECT CONFIDENTIALITY

The results of the present study and future use of data from this study may be published, but the names and identities of the subjects will not be revealed. All subjects will be assigned a code number in place of the subject's name for the purpose of identifying the data collect from each individual. The master copy of the code numbers and corresponding names will be kept secure by the researchers at all times.

VIII. SUBJECT QUESTIONNAIRE

See Appendix B

IX. OTHER APPROVALS

This project received unanimous approval from the student researcher's [TPD] Graduate Committee at his Master of Science degree thesis proposal meeting held April 6, 2000.

Ronald Wobig, M.D. of Specialty Physicians and Surgeons of Corvallis, Oregon has agreed to assist this study by identifying patients from his practice with shoulder pain or pathology who would be candidates for participation.

Funding for this project will be from the Graduate Student Research Fund, available through the College of Health and Human Performance. The maximum available per project is $450.00.

REFERENCES

1. DiVeta J, Walker ML, Skibinski B: Relationship between performance of selected scapular muscles and scapular abduction in standing subjects. *Phys Ther 70(8)*: 470-479, 1990
2. Gibson MH, Goebel GV, Jordan TM, et al: A reliability study of measurement techniques to determine static scapular position. *J Orthop Sport Phys Ther 21(2)*: 100-106, 1995
3. Kibler WB: The role of the scapula in the overhead throwing motion. *Contemp Orthop 22*: 525-532, 1991
4. Kibler WB: The role of the scapula in athletic shoulder function. *Am J Sports Med 26(2)*: 325-337, 1998
5. Magee DJ: *Orthopedic Physical Assessment,* Third Edition. Philadelphia, WB Saunders Company, 1997, pp. 213-214
6. Moore KL, Dalley AF: *Clinically Oriented Anatomy,* Fourth Edition. Philadelphia, Lippincott Williams and Wilkins, 1999, p. 61
7. Neires L, Worrell TW: Assessment of scapular position. *J of Sports Rehab 2*: 20-25, 1993.
8. Odom CJ, et al: Intratester and intertester reliability of the lateral scapular slide test. In review for publication.
9. Plafcan DM, Turczany PJ, Guenin BA, et al: An objective measurement technique for posterior scapular displacement. *J Orthop Sport Phy Ther 25(5)*: 36-341, 1997
10. Sobush DC, Simoneau GG, Dietz KE, et al: The Lennie test for measuring scapular position in healthy young adult females: a reliability and validity study. *J Orthop Sport Phys Ther 23(1)*: 39-50, 1996.
11. Warner JJP, Michelli LJ, Arslanian LE, et al: Scapulothoracic motion in normal shoulders and shoulders with glenohumeral instability and impingement syndrome: A study using Moire topographic analysis. *Clin Orthop 285*: 191-199, 1992

OREGON STATE UNIVERSITY

COPY

Report of Review by the Institutional Review Board for the Protection of Human Subjects

TO: Rod Harter, ExSS

COPY: Todd Daniels, ExSS

RE: Radiographic validation of the validity and reliability of the lateral scapular slide test.

The referenced project was reviewed under the guidelines of Oregon State University's Committee for the Protection of Human Subjects and the U.S. Department of Health and Human Services. The committee has **approved** your application. The approval of this application expires upon the completion of the project or one year from the approval date, whichever is sooner. The informed consent form obtained from each subject should be retained in program/project's files for three years beyond the end date of the project.

Any proposed change to the protocol or informed consent form that is not included in the approved application must be submitted to the IRB for review and must be approved by the committee before it can be implemented. Immediate action may be taken where necessary to eliminate apparent hazards to subjects, but this modification to the approved project must be reported immediately to the IRB.

Date: 04/14/00

Warren N. Suzuki, Chair
Committee for the Protection of Human Subjects
(Education, 7-6393, suzukiw@orst.edu)

APPENDIX D

Review of Literature

REVIEW OF LITERATURE

SCAPULOTHORACIC KINESIOLOGY

The scapula is a thin triangular-shaped flat bone with a slightly concave contour.[15] These features allow the scapula to glide along the thoracic wall and provide a large surface area for muscle attachment. The scapula is attached indirectly to the axial skeleton via the ligaments of the sternoclavicular and the acromioclavicular articulations.[12,15] The clavicle attaches proximally to the sternum and distally to the acromion process of the scapula.[15] The only direct connection of the scapula to the thorax is via musculotendinous units. Scapular stability is therefore highly dependent on the muscular attachments of the scapula to the ribs and spinous processes of the vertebrae. These muscles include the trapezius, rhomboid, levator scapulae, pectoralis minor, and serratus anterior.[12,15] This mechanism of articulation allows for the scapula to rotate and translate along the thoracic wall.[9,12] Three general functional groups of muscles attach to the scapula: the scapular stabilizers, extrinsic muscles of the shoulder joint, and the internal muscles of the rotator cuff.[9,12]

The five muscles responsible for stabilization and motion of the scapula are the levator scapulae, pectoralis minor, rhomboid major and minor, serratus anterior, and trapezius.[12,15] The motions of the scapula produced by these muscles include elevation, depression, protraction, retraction, upward rotation, and downward rotation.[12] The levator scapulae originates on the transverse processes of the first four cervical vertebrae and inserts on the vertebral border of the scapula between the spine and superior angle. The levator scapula is involved in scapular elevation and downward rotation.[12] The pectoralis minor originates on the third through fifth rib and inserts on the coracoid process. The pectoralis minor depresses, protracts, and assists in downward rotation of the scapula.[12]

The rhomboids originate on the spinous processes of the seventh cervical through fifth thoracic vertebrae and insert on the vertebral border of the scapula between the spine and inferior angle. The rhomboids produce retraction and downward rotation motions.[12] The serratus anterior is a group of finger-like projections that originate on the first eight ribs and insert on the vertebral border of the scapula. The serratus anterior is involved in protraction and upward rotation of scapula.[12]

The trapezius can be functionally divided into three sections: upper, middle, and lower fibers. The upper fibers originate on the occipital bone and insert on the lateral portion of scapular spine and the acromion process. The upper fibers elevate and upwardly rotate the scapula. The middle fibers originate on the spinous processes of the seventh cervical through third thoracic vertebrae and insert on the scapular spine. Scapular retraction is the lone function of these horizontal fibers. The lower fibers originate on the spinous processes of the middle and lower thoracic vertebrae and insert on the vertebral aspect of the scapular spine. These fibers assist in depression and upward rotation of the scapula.[12]

Many force couples are present in the motions and stabilization of the shoulder. A force couple occurs when two or more muscles contract synchronously with different lines of pull to achieve the same motion.[12,22] This occurs in both instances of scapular rotation. The upper trapezius fibers, lower trapezius fibers, and serratus anterior combine different lines of pull to create an upward rotation in a slightly counterclockwise manner. The levator scapulae, rhomboids, and pectoralis minor use a force couple to create downward rotation in a slightly clockwise fashion.[2] The force couples of the scapular muscles are necessary to provide a stable base for the articulation and motion of the humerus.[2] These force couples also move the scapula into a position that allows free humeral motion and proper positioning of the humeral head during overhead motion.[3] Force couples are also used by the rotator cuff muscles to stabilize the humeral head in the glenoid fossa.[22]

ROLES OF SCAPULA IN OVERHEAD MOTION

Kibler[8,9] has described five roles of the scapula necessary for proper shoulder function. These five roles are concerned with achieving appropriate motions and positions that facilitate optimal shoulder function. Failure of the scapula to perform these roles will cause inefficient biomechanics, and subsequently, shoulder pathology and poor performance.[9]

The first role the scapula is to be a stable part of the glenohumeral articulation.[8,9] The relationship between the glenoid and humeral head is easily compromised because of the anatomical configuration of the scapula. The scapula must move in a coordinated fashion with the moving humerus to maintain the already limited contact area of the glenohumeral articulation. The coordinated motion of the scapula constrains the instant center of rotation for the humerus within a specific physiological pattern. Movement of the instant center of rotation's position is minimized throughout the extremes of abduction, external rotation, horizontal adduction, and internal rotation during a throwing motion. A physiological "safe zone" is also created by the coordinated movement by keeping the glenohumeral angle in a tolerable range.[9] The safe zone and constrained instant centers of rotation maximize the congruence of the glenohumeral relationship, and combine to decrease the tensile forces placed on the capsular ligaments. Proper alignment of the glenoid also allows the most efficient position for rotator cuff contraction and compression of the humeral head into the glenoid by the rotator cuff.

A second role of the scapula is to serve as a base for muscle attachment.[8,9] The scapular stabilizers, extrinsic muscles of the shoulder, and intrinsic muscles of the rotator cuff all have attachment sites on the scapula. The scapula has no direct bony articulation or ligamentous attachment to the thorax and is anchored by the scapular stabilizing muscles. Muscle activity is most efficient when specific length-tension relationships of the fibers are maintained. During overhead activity, optimal length tension relationships for the extrinsic shoulder muscles and the rotator cuff are attained through proper scapular motion and alignment.

The third role of the scapula is retraction and protraction along the thoracic wall.[8,9] The scapula must retract maximally to allow proper arm position in the wind up, and cocking phases of overhead activities such as the baseball pitch. In what Kibler[9] describes as the "full tank of energy" position at the end of the cocking phases, maximal humeral abduction and external rotation occurs and potential energy accumulates in the anterior musculature. Efficient achievement of this position results in retensioning of the anterior musculature and efficient transition from eccentric to concentric muscle activity in the anterior muscles and concentric to eccentric action in the posterior musculature. The shoulder progresses into a phase of rapid acceleration, and the scapula must protract maximally to allow motion. Controlled protraction also functions to dissipate the forces generated and reduce the potential for injury from tensile loads placed on other structures.

The fourth critical role of the scapula is elevation of the acromion process.[8,9] The scapula must rotate upwardly during the cocking and acceleration phases of the baseball pitch to allow humeral abduction. If the scapula were to remain fixed, the acromion would make contact with the humeral head causing rotator cuff impingement and coracoacromial compression.

The final role of the scapula is to serve as a link in the kinetic chain of overhead activity.[8,9] During the throwing motion, a sequencing of velocity, energy, and forces begins at the ground and moves through the body to its endpoint at the hand.[9] Potential energy is generated in the legs, pelvis and torso during the wind-up and cocking phases of the baseball pitch.[25] During acceleration this potential energy changes to kinetic energy. The instantaneous angular velocity of internal rotation during glenohumeral acceleration may exceed $7000°/sec^{-1}$, creating torque values the shoulder girdle is incapable of producing on its own.[25] The forces generated by the lower body and trunk are transferred to the upper extremity through the scapula, and the musculature of the shoulder therefore serves a more prominent role of stabilizing and protecting the joint, and a lesser role of accelerating the upper limb.[25] This again illustrates the importance of the scapula's role in maintaining the relationship with the humerus.

SCAPULAR LINK TO SHOULDER PATHOLOGY

Function of the shoulder complex is highly dependent on the relationship between the scapula and the humerus. This relationship is constantly changing because of the alterations in the center of rotation and mechanical advantage of the muscles during arm movement.[17] Any alterations in relationship between the scapula and humerus may be cause for shoulder pathologies such as rotator cuff impingement or tears. One etiology for a disruption in the glenohumeral relationship is impaired or abnormal scapular motion and position.

Terms such as "floating scapula,"[6] "lateral scapular slide,"[8] "scapulothoracic dyskinesis,"[23] have been used describe abnormal or impaired functioning, motion, and position of the scapula. This phenomenon of scapular dyskinesis occurs when the scapula can not adequately perform one or more of the roles described by Kibler.[8,9]

Inability to fully retract the scapula will result in an inefficient and less effective cocking of the upper limb. Decreased or uncontrolled protraction will increase the tensile forces placed on other structures during the deceleration phase. Uncoordinated protraction and retraction may also cause antetilting of the scapula, placing increased shear forces on other stabilizing structures.[9]

Failure to upwardly rotate the scapula decreases acromial elevation and increases pressure in the subacromial space.[9] Alterations in function of serratus anterior muscle have received the most attention in determining causes of insufficient upward rotation and acromial elevation.[3,11,13,15,17,22]

Abnormal motion of the scapula leaves the muscles that attach to scapula without a stable base. Maximal muscle torque is compromised without a stable origin during concentric muscle activity. Uncoordinated motion of the scapula disrupts the length-tension relationships of muscle fibers causing decreased force production. If the scapula is truly unstable on the thoracic wall, a reversal of the muscle origin and insertion can occur. The scapula can actually be pulled laterally by the muscle because the more fixed origin becomes the distal end on the more stable humerus. This phenomenon only exacerbates lateral scapular slide or scapular dyskinesis.[9]

Loss of function in the kinetic chain is another important factor to consider in abnormal functioning of the scapula. As the pivotal link in transferring forces from the force generating lower body to the upper extremity, any alterations in scapular function has capacity to decrease force production and limit performance. Scapular dyskinesis may create a "catch-up" situation where the upper extremity work at a higher level to compensate for loss of forces generated by the lower body.[9] The structures are more susceptible to injury because they do not have the size or time to needed to generate to necessary forces.[9] Once one segment is injured, the shoulder has little capacity to compensate for the affected structure and typically develops detrimental pattern of dyskinetic activity and pathology.[22]

CURRENT CLINICAL MEASURES OF SCAPULAR POSITION

Due to the frequency of orthopedic problems arising from scapular dyskinesis, it is important that valid and reliable clinical assessment tools be developed to quantify scapular position and function. Currently, at least six different clinical measures exist for quantifying scapular motion and position. These test measures include the lateral scapular slide test (LSST),[8] the DiVeta test for normalized scapular abduction,[4] Moiré topographic analysis,[23] digital inclinometer,[7] the Lennie test,[21] and the Perry tool.[20]

The LSST measures the distance from the inferior angle of the scapula to the closest vertebral segment (Figures 1 and 2) with a tape measure between palpated bony landmarks. This test is repeated in three different positions: 0°, 45°, and 90° of glenohumeral abduction. The LSST was originally described by Kibler in 1991.[8] Over the past decade, two reliability studies have been conducted and the test has become a common clinical assessment tool. The test has been included in a highly regarded textbook for orthopaedic clinical assessment.[14] Previous research has shown the LSST to be a reliable measure of scapular motion. Two studies reported moderate to high ICC values for intra-rater reliability, however, the ICC values for inter-rater reliability have been lower with greater SEM values (Table 1).[5,19] Only one study claiming to evaluate the validity has been published.[19] Odom et al.[19] elected to evaluate the validity of the LSST based upon their assessment of sensitivity and specificity for the LSST rather than using a criterion measure such as true anatomical motion or position.

Of the remaining clinical measures for shoulder position and motion, the DiVeta test for normalized scapular abduction is most similar to the LSST.[4] The DiVeta test also measures the distance from the scapula to the spine, but differs from the LSST in the landmarks used. First, a measure is taken from inferior angle of the acromion process to a standardized spinal landmark, the spinous process of the third thoracic vertebrae. This measure is defined as the total scapular distance. This value of scapular abduction is then normalized by dividing total scapular distance by the length of the scapula. Length of the scapula is measured from the inferior angle of the acromion process to the medial border of the scapula at the origin of the scapular spine. Normalized scapular abduction is calculated for only one shoulder position, approximately 0° of glenohumeral abduction.

DiVeta et al.[4] evaluated 60 healthy subject and reported intra-rater test-retest reliability ICC(1,1) values for one examiner of 0.85 for scapular length and 0.94 for scapular distance. Interestingly, DiVeta et al. did not report any reliability data for the supposed end product measure of normalized scapular abduction. Neiers and Worrell reported similar reliability values for the two sub-measures and an ICC value of 0.34 for normalized scapular abduction in their evaluation of 50 healthy subjects.[18] Gibson et al.[5] reported an intra-rater ICC(2,1) value of 0.95 and inter-rater ICC(2,1) values of 0.91 to 0.92 for normalized scapular abduction using 32 healthy subjects. The DiVeta test is simple and inexpensive, but has no published validity data and mixed reliability results. This method may be similar to the LSST, but the LSST has the added advantage of three different testing positions. Although DiVeta[4] and associates' concept of normalization is good, clinical usage would be better served by identifying bilateral differences in a single subject (an aim of the LSST) rather than a comparison to norm-referenced values for scapular abduction.

Moiré topographic analysis is a technique that uses a grid of horizontal lines illuminated by a point light source to create a shadow pattern of surface topography rings on the subject skin surface.[23] This pattern is then photographed and evaluated by a clinician in a somewhat subjective manner. A bilateral comparison is made of the subjects scapular region, and given a rating of symmetrical (0), asymmetrical (1+), increased topography (2+), and scapular winging (3+). Warner et al.[23] used the technique to examine 22 asymptomatic subjects, 22 subjects with shoulder instability, and 7 subjects with impingement syndrome. No validity or reliability values were reported for this measure of scapular position and its clinical use appears impractical.[23]

A slightly less sophisticated tool for assessing scapular position is the digital inclinometer. This device is a digital protractor or level used in carpentry or other crafts. Johnson et al.[7] developed a jig that was fashioned to the digital inclinometer so that it could be affixed to the bony landmarks of the shoulder and scapula. This device was then validated against a three-dimensional tracking device (Polhemus 3Space FasTrak) using 16 subjects with known shoulder pathologies and 23 healthy subjects. Johnson et al.[7] reported concurrent validity values ranging from 0.74 to 0.91 and inter-rater reliability ICC (3,1) values ranging from 0.85 to 0.96. Although the validity and reliability of the device appears good, the LSST test may be more cost-effective that the ~$200 digital inclinometer.

The Lennie test is actually a series of seven different angles and distances measured using marks on the spine and scapular landmarks.[21] Intra-rater ICC values ranged from 0.75 to 0.96 for the seven measures and Inter-rater ICC values ranged from 0.62 to 0.94.[21] Sobush et al.[21]

evaluated the validity of the Lennie test by comparing the clinical measures to radiographic images of 15 healthy female subjects, reporting values between 0.43 to 0.82 for the different measures. The multiple measures used in this technique make it difficult to determine which might be the most indicative of shoulder pathology and increases the possibility of error, limiting its diagnostic effectiveness.

The Perry Tool is designed to measure the posterior displacement of the inferior angle of the scapula. This device consists of a stabilizing jig mounted to the wall, the measurement tool, and an adjustable lever arm.[20] Description of the device was confusing, but it appears to be a non-digital protractor. Both inter-rater and intra-rater reliability values (ICC 2,1) were above 0.90 for two examiners and 40 healthy subjects, but the LSST appears to be a far more simple and portable measurement method.[20]

Based on published data, cost, and ease of use, the most promising of the tests for scapular motion and position is the LSST.[4,5,18-21,23] The reliability of the LSST has been established with mixed results, but the validity of the test has not been assessed. What remains to be determined is whether the clinical measurement of the LSST derived from anatomical landmarks on the skin surface are accurately assessing scapular position and the change in distance from the spine.

RATIONALE

Much like the important role of knee arthrometers in the diagnosis of ACL injury, it is hoped that the clinical tests like the LSST will be used to quantify the motion and position of the scapula in shoulder pathology. To date, only two reliability studies have been performed using the LSST.[5,19] This study will seek to determine the validity of the LSST by comparison with radiographic images taken in the same testing session as a clinical LSST. It is an aim of the researchers to eliminate the future need of radiographs to determine scapular motion and position.

This study will also add to the existing body of literature pertaining to the reliability of the LSST by assessing both intra-rater and inter-rater reliability.

Future directions for research in this area include the assessment of patients with known pathology to determine an accurate cut-off point of abnormal scapular position. In Kibler's initial work, he stated that a 1-cm bilateral difference is indicative of shoulder pathology, but no results were reported to support this assertion.[8] Clinical trials are needed to determine an accurate reference point for pathology and to determine exactly which shoulder pathologies are associated with a positive LSST sign. If sufficiently valid, this test could also be used to assess the effect of repetitive motion on the shoulders of overhead athletes.

The primary purpose of this study was to determine the validity of the LSST by comparing clinical measurements on the skin to the actual distance between the scapula and the spine as seen on radiographic images. The secondary purpose of this study was to determine the reliability of the LSST by comparing the measures taken by one examiner during two different testing sessions and by comparing the measures taken by two examiners during a single testing session.

TABLES AND FIGURES FOR APPENDIX D

Table 1 – Previously Published Reliability Data for the LSST.

Figure 1 – Lateral Scapular Slide Test at 45° and 120° of glenohumeral abduction.

Figure 2 – Posterior view of the scapula and thorax

Table 1 -- Previously Published Reliability Data for the LSST

Previously Reported Reliability for the LSST		
Measure (Test Positition)	**ICC**	**SEM (mm)**
Odom et al. Intra-rater (0)	0.52-0.75	0.61-0.78
Gibson et al. Intra-rater (0)	0.91-0.94	0.44-0.54
Odom et al. Intra-rater (45)	0.66-0.77	0.57-0.58
Gibson et al. Intra-rater (45)	0.88-0.92	0.45-0.64
Odom et al. Intra-rater (90)	0.62-0.80	0.80-0.86
Gibson Intra-rater (90)	0.81-0.91	0.56-0.79
Odom et al. Inter-rater (0)	0.67-0.79	0.79
Gibson et al. Inter-rater (0)	0.67-0.69	1.02-1.04
Odom et al. Inter-rater (45)	0.43-0.45	0.78-1.08
Gibson et al. Inter-rater (45)	0.52-0.53	1.17-1.20
Odom et al. Inter-rater (90)	0.57-0.74	1.10-1.20
Gibson et al. Inter-rater (90)	0.18-0.28	1.59-1.65

FIGURE 1 – Lateral Scapular Slide Test at 45° and 120° of glenohumeral abduction.[14] (NOTE: In the current study, joint angles of 0°, 45°, and 90° were utilized for the clinical LSST)

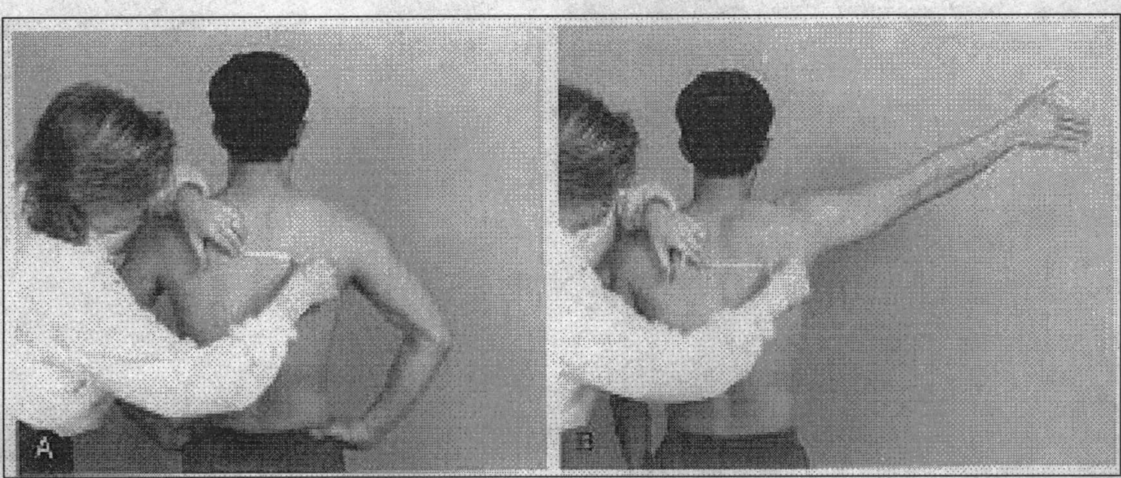
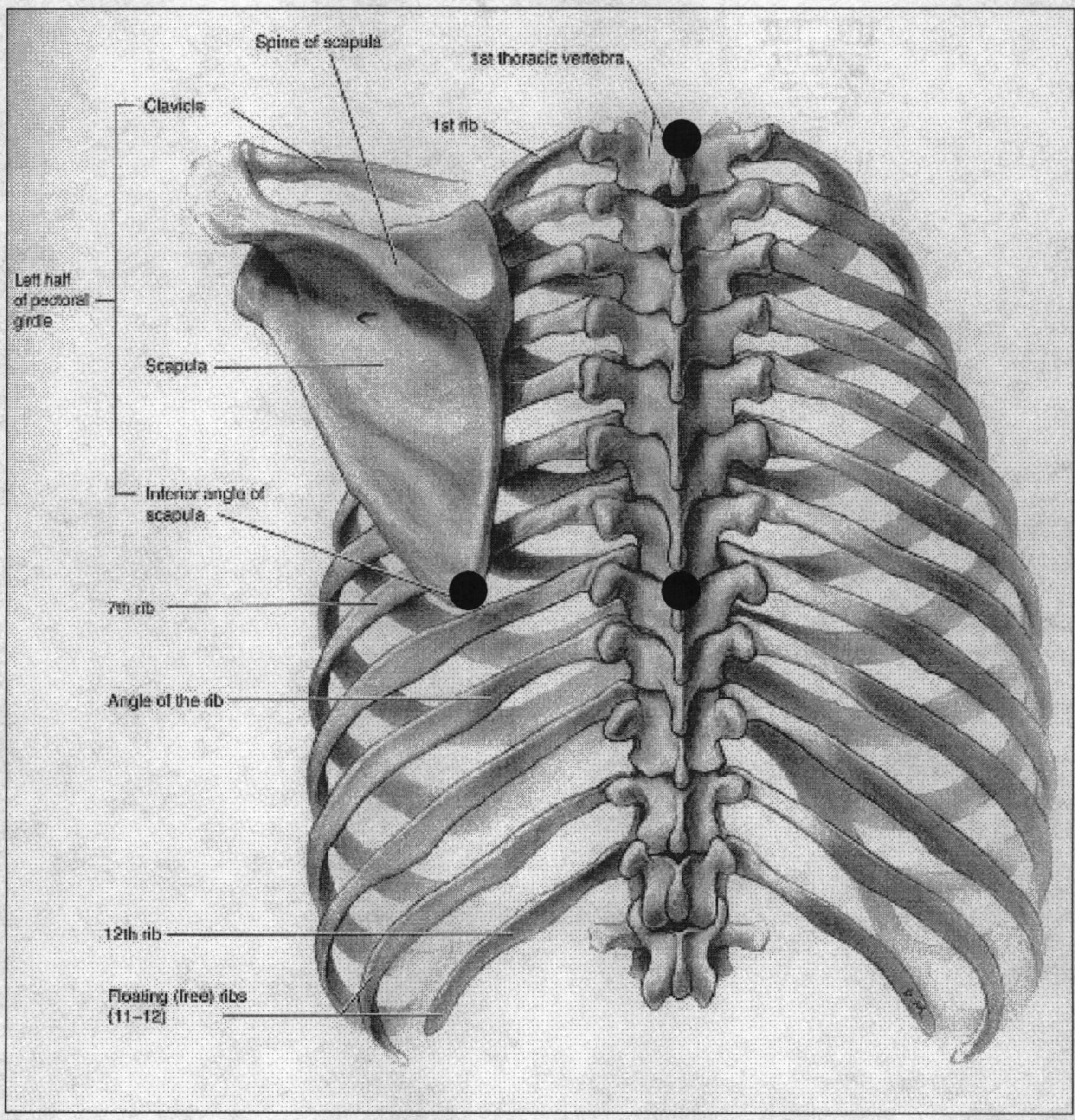


FIGURE 2 – Posterior view of scapula and thorax[15] with depiction of radiopaque marker placement.



REFERENCES

1. Baumgartner TA: Norm-referenced measurement: reliability, in Safrit MJ, Wood TM (eds): *Measurement Concepts in Physical Education and Exercise Science*. Champaign, IL, Human Kinetics, 1989, pp 45-72
2. Bigliani LU, Levine WN: Current concepts review: Subacromial impingement syndrome. *J Bone and Joint Surg 79-A*: 1854-1868, 1997
3. Decker MJ, Hintermeister RA, Faber KJ, et al: Serratus anterior muscle activity during selected rehabilitation exercises. *Am J Sports Med 27(6)*: 784-791, 1999
4. DiVeta J, Walker ML, Skibinski B: Relationship between performance of selected scapular muscles and scapular abduction in standing subjects. *Phys Ther 70(8)*: 470-479, 1990
5. Gibson MH, Goebel GV, Jordan TM, et al: A reliability study of measurement techniques to determine static scapular position. *J Orthop Sport Phys Ther 21(2)*: 100-106, 1995
6. Jobe FW: Personal communication with WB Kibler, 1990. As seen in Kibler WB. The role of the scapula in athletic shoulder function. *Am J Sports Med 26(2)*: 325-337, 1998
7. Johnson MP, McClure P, Karduna AR: New method to assess scapular upward rotation in subjects with shoulder pathology. *J Orthop Sports Phys Ther 31(2)*: 81-89, 2001
8. Kibler WB: The role of the scapula in the overhead throwing motion. *Contemp Orthop 22*: 525-532, 1991
9. Kibler WB: The role of the scapula in athletic shoulder function. *Am J Sports Med 26(2)*: 325-337, 1998
10. Kvitne RS, Jobe FW: The diagnosis and treatment of anterior instability in the throwing athlete. *Clin Orthop 291*: 107-123, 1993
11. Lear LJ and Gross MT: An electromyographical analysis of the scapular stabilizing synergists during a push-up progression. *J Orthop Sports Phys Ther 28(3)*: 146-157, 1998
12. Lippert L: *Clinical Kinesiology for Physical Therapist Assistants*, 2nd Ed. Philadelphia, Davis Company, 1994, pp 83-122
13. Ludewig PM, Cook TM, Nawoczenski DA: Three-dimensional scapular orientation and muscle activity at selected postions of humeral elevation. *J Orthop Sports Phys Ther 24(2)*: 57-65, 1996
14. Magee DJ: *Orthopedic Physical Assessment*, Third Edition. Philadelphia, WB Saunders Company, 1997, pp. 213-214
15. McQuade KJ, Dawson J, Smidt GL: Scapulothoracic muscle fatigue asscociated with alterations in scapulohumeral rythmn kinematics during maximum resistive shoulder elevation. *J Orthop Sports Phys Ther 24(2)*: 57-65, 1996
16. Moore KL, Dalley AF: *Clinically Oriented Anatomy*, Fourth Edition. Philadelphia, Lippincott Williams and Wilkins, 1999, p. 61
17. Moseley JB, Jr., Jobe FW, Pink M, et al: EMG analysis of the scapular muscles during a shoulder rehabilitation program. *Am J Sports Med 20(2)*: 128-134, 1992
18. Neires L, Worrell TW: Assessment of scapular position. *J of Sports Rehab 2*: 20-25, 1993.

19. Odom CJ, Taylor AB, Hurd CE, et al: Measurement of scapular aymmetry and assessment of shoulder dysfunction using the lateral scapular slide test: A reliability and validity study. *Phys Ther 81(2)*: 799-809, 2001

20. Plafcan DM, Turczany PJ, Guenin BA, et al: An objective measurement technique for posterior scapular displacement. *J Orthop Sport Phy Ther 25(5)*: 36-341, 1997

21. Sobush DC, Simoneau GG, Dietz KE, et al: The Lennie test for measuring scapular position in healthy young adult females: a reliability and validity study. *J Orthop Sport Phys Ther 23(1)*: 39-50, 1996.

22. Speer KP, Garrett WE: Muscular control of motion and stability about the pectoral girdle, in Matsen FA, Fu FH, Hawkins RJ (eds): *The Shoulder: A Balance of Mobility and Stability*. Rosemont, IL, American Academy of Orthopedic Surgeons, 1993

23. Warner JJP, Michelli LJ, Arslanian LE, et al: Scapulothoracic motion in normal shoulders and shoulders with glenohumeral instability and impingement syndrome: A study using Moire topographic analysis. *Clin Orthop 285*: 191-199, 1992

24. Wood TM: The changing nature of norm-referenced validity, in Safrit MJ, Wood TM (eds): *Measurement Concepts in Physical Education and Exercise Science*. Champaign, IL, Human Kinetics, 1989, pp. 23-44

25. Young JL, Herring SA, Press JM, et al: The influence of the spine on the shoulder in the throwing athlete. *J Back and Musculoskeletal Rehab 7*: 5-17, 1996

APPENDIX E

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AN ABSTRACT OF THE THESIS OF

TODD P. DANIELS, ATC-R for the degree of Master of Science in Human Performance.

TITLE: Evaluation of the Lateral Scapular Slide Test Using Radiographic Imaging: A Validity and Reliability Study.

Function of the shoulder complex is highly dependent on the relationship between the scapula and the humerus. Etiologies for the disruption of the glenohumeral relationship include impaired or abnormal scapular function, motion, or position. The lateral scapular slide test (LSST) has been developed as a clinical tool to assess this phenomenon, also known as scapular dyskinesis. The primary purpose of this study was to determine the validity of the LSST by comparing the clinical measurements on the skin surface to the actual anatomical distance between the scapula and the spine as seen on radiographic images. The secondary purpose of this study was to determine the intra-rater and inter-rater reliability of the LSST. Nine subjects (18 shoulders) were assessed with the clinical LSST and radiographic images in three test positions (0°, 45°, and 90° of glenohumeral abduction). Comparison of the clinical LSST measurements with the radiographs revealed the LSST to be valid (>0.80) in only the 0° and 45° test positions with respective Pearson correlation values of 0.91 and 0.98. Excellent (>0.75) intra-rater ICC (2,1) reliability values (0.91-0.97) were found for all three test positions. Inter-rater ICC (2,1) reliability values were excellent for the 0° (0.87) and 45° (0.83) test positions, and fair to good for the 90° position (0.71). This study demonstrated that the LSST is an accurate and consistent measure of scapular movement and position for the 0° and 45° test positions. Clinicians should exercise caution when interpreting measurements obtained at the 90° test position because the validity and reliability values did not reach established standards.

FIGURE 2 – Posterior view of scapula and thorax[13] with depiction of radiopaque marker placement.

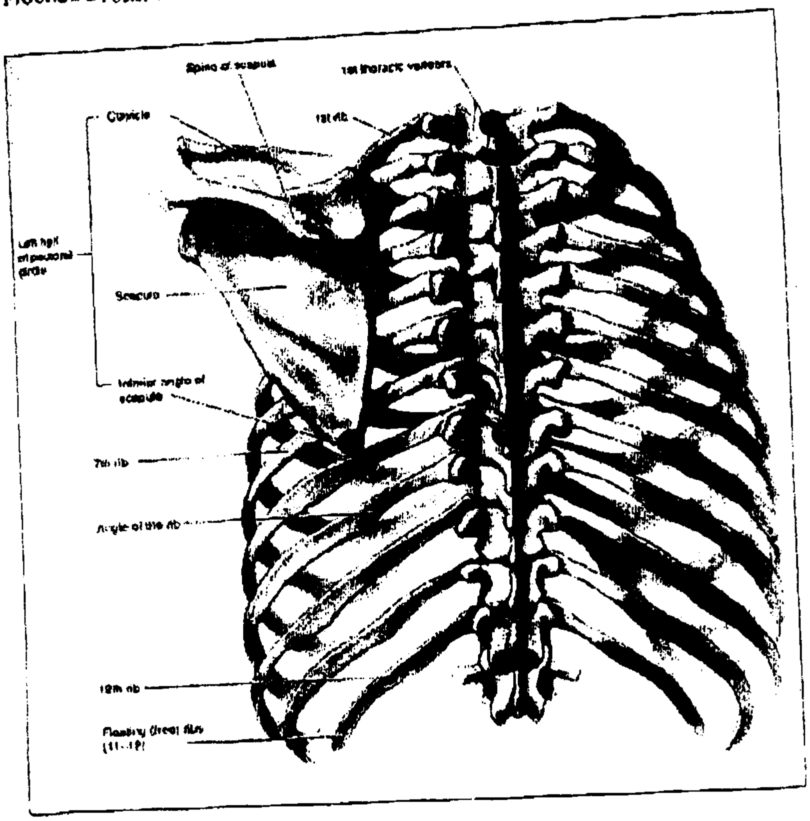

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FIGURE 1 - Lateral Scapular Slide Test at 45° and 120° of glenohumeral abduction.[13] (NOTE: In the current study, joint angles of 0°, 45°, and 90° were utilized for the clinical LSST)

APPENDIX F

ICC (2,1) Formula from Shrout and Fleiss

ICC (2,1) FORMULA

Two-way ANOVA Table Summary

Source of Variance	Mean Squares
Between Subjects	BMS
Within Subjects	
Treatment/Trials	JMS
Error	EMS
Total	

$$\mathrm{ICC}(2,1) = \frac{\mathrm{BMS} - \mathrm{EMS}}{\mathrm{BMS} + (k-1)\mathrm{EMS} + k(\mathrm{JMS} - \mathrm{EMS})/n'}$$

Shrout PE, Fleiss JL: Intraclass correlations: Uses in assessing rater reliability. *Psych Bull 86:* 420-248, 1979

APPENDIX G

Intra-rater Reliability ANOVA Table for the 0° position

Intra-rater Reliability ANOVA Table for the 45° position

Intra-rater Reliability ANOVA Table for the 90° position

Inter-rater Reliability ANOVA Table for the 0° position

Inter-rater Reliability ANOVA Table for the 45° position

Inter-rater Reliability ANOVA Table for the 90° position

INTRA-RATER RELIABILITY ANOVA TABLE FOR THE 0° POSITION

Source	SS	DF	MS	F-ratio
Between Subjects(S)	19186.97	15	1279.131	20.98011
Within Subjects(W)	975.5	16	60.96875	
Treatment/Trials(T)	140.2813	1	140.2813	2.519363
Error(E)	835.2187	15	55.68125	
Total	20162.47	31	650.4022	
ICC (2,1)	0.913166			

INTRA-RATER RELIABILITY ANOVA TABLE FOR THE 45° POSITION

Source	SS	DF	MS	F-ratio
Between Subjects(S)	18689.22	15	1245.948	50.79023
Within Subjects(W)	392.5	16	24.53125	
Treatment/Trials(T)	116.2813	1	116.2813	6.31463
Error(E)	276.2188	15	18.41459	
Total	19081.72	31	615.5393	

ICC (2,1) 0.966471

INTRA-RATER RELIABILITY ANOVA TABLE FOR THE 90° POSITION

Source	SS	DF	MS	F-ratio
Between Subjects(S)	24695	15	1646.333	26.15823
Within Subjects(W)	1007	16	62.9375	
Treatment/Trials(T)	105.125	1	105.125	1.748441
Error(E)	901.875	15	60.125	
Total	25702	31	829.0968	

ICC (2,1) 0.928093

INTER-RATER RELIABILITY ANOVA TABLE FOR THE 0° POSITION

Source	SS	DF	MS	F-ratio
Between Subjects(S)	18506.5	15	1233.767	8.832334
Within Subjects(W)	2235	16	139.6875	
Treatment/Trials(T)	1540.125	1	1540.125	33.24609
Error(E)	694.875	15	46.325	
Total	20741.5	31	669.0806	
ICC (2,1)	0.864566			

INTER-RATER RELIABILITY ANOVA TABLE FOR THE 45° POSITION

Source	SS	DF	MS	F-ratio
Between Subjects(S)	22707.88	15	1513.858	8.466177
Within Subjects(W)	2861	16	178.8125	
Treatment/Trials(T)	1152	1	1152	10.11118
Error(E)	1709	15	113.9333	
Total	25568.88	31	824.8024	

ICC (2,1)	0.827051

INTER-RATER RELIABILITY ANOVA TABLE FOR THE 90° POSITION

Source	SS	DF	MS	F-ratio
Between Subjects(S)	21102.47	15	1406.831	3.979369
Within Subjects(W)	5656.5	16	353.5313	
Treatment/Trials(T)	3382.513	1	3382.513	22.3124
Error(E)	2273.969	15	151.5979	
Total	26758.97	31	863.1925	

ICC (2,1)	0.713054