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Relationship of the Penn Shoulder Score with Measures of Range of Motion and Strength in Patients with Shoulder Disorders: A Preliminary Report

BRIAN G. LEGGIN, M.S., P.T., O.C.S.,* MICHAEL A. SHAFFER, M.S., P.T., A.T.C., O.C.S., RAMONA M. NEUMAN, P.T., O.C.S.,* GERALD R. WILLIAMS, JR., M.D.,** AND JOSEPH P. IANNOTTI, M.D., PH.D.***

Introduction

Several authors have advocated the use of a disablement model in clinical practice and research [1,2]. Evaluation of clinical outcome should include measures in each domain of disability[3]. The model described by Nagi includes active pathology, impairment, functional limitation, and disability [4]. *Active pathology* refers to an "interruption of or interference with normal processes and the simultaneous efforts of the organism to regain a normal state" [4]. Clinical measures of active pathology in orthopaedics include information defining the extent of the injury, disease, or healing as determined from the interview with the patient, the medical history, the physical examination, the laboratory and imaging studies, and the operation [3]. According to Nagi, *impairment* is defined as any loss or abnormality of anatomic, physiologic, mental, or emotional structure or function [4]. Clinical measures of impairment of the musculoskeletal system can include pain, range of motion, muscle force, and joint stability. Nagi defines a *functional limitation* as a limitation in performance at the level of the whole organism or person [4]. A *disability* is a limitation in performance of scially defined roles and tasks within a sociocultural and physical environment [4]. Measures of functional limitations and disability include performance-based clinical assessments and patient self-report measures.

Self-report measures of outcome are becoming increasingly popular with clinicians, patients, administrators, researchers, and third party payers. Several tools have been developed and used to document outcome of treatment of shoulder pathologies. These include generic quality-of-life or health status measures, condition specific tools, and tools that are applicable to all conditions of the shoulder [5]. Gerber has stated that shoulder assessment measures should include components of pain, patient satisfaction, function, range of motion, and strength [6]. There are a number of these tools available [7–13]. However, no one tool has been widely used and accepted. In order for a measure to be utilized and accepted, it must first demonstrate acceptable levels of reliability, validity, and responsiveness [5]. This information is lacking in many of the shoulder assessment tools currently available. In addition, little is known about the relationship of self-report measures of pain, satisfaction, and function with measures of range of motion and muscle force in patients with various shoulder disorders. This information could help clinicians be more efficient with their examination of patients, provide the patient with a more accurate prognosis, and evaluate progress based on valid measures [14].

The authors have developed a self-report shoulder outcome measure which evaluates the patients report of pain, satisfaction, and function [15]. This tool has demonstrated evidence of test-retest reliability, validity, and responsiveness [15]. Validity, however is an ongoing process and should be reported in a series of investigations that build on previous knowledge [16]. The primary purpose of this report, therefore, is to further validate the Penn Shoulder Score by demonstrating its relationship to impairment measures of range of motion and muscle force. We also sought to evaluate the relationship of selected items of function with measures of range of motion and muscle force, as well as the overall Penn Shoulder Score. We hypothesized that a linear relationship would exist among measures of range of motion, strength and Penn Shoulder Score corresponding to the level of difficulty reported with selected functional measures. A secondary purpose of this paper was to establish estimates of reliability, error, and minimal detectable change of clinical measures of active range of motion and strength.

Method

Subjects

Forty patients undergoing a course of outpatient physical therapy gave their informed consent to participate in this

* From Penn Therapy and Fitness, University of Pennsylvania Health System - Presbyterian, Medical Office Building, Suite 110, 39th and Market Streets, Philadelphia, PA 19104.
** Presbyterian Medical Center, 1 Cupp Pavilion, Philadelphia, PA 19104.
*** Cleveland Clinic, Department of Orthopaedic Surgery, 9500 Euclid Avenue, Cleveland, OH 44195.

study. Twenty-two men (mean age = 42.4 ± 11.7) and eighteen women (mean age = 54.8 ± 17.1) with a variety of shoulder pathologies (Table 1) were included in the study. Twenty-one subjects were rehabilitating their shoulders after surgery, while the remainder was receiving nonoperative management of their shoulder problem.

Testing Procedure

All patients completed the Penn Shoulder Score. Prior to range of motion and strength testing, patients completed a warm-up regimen consisting of pendulum exercises and active assisted stretches. Two therapists tested each patient. One therapist (BGL) tested every patient while the other two therapists (MAS, RMN) tested 20 patients each. Order of investigators was randomized. All testing was completed within 72 hours.

Clinical Impairment Measures

The clinical impairment measures were active range of motion and muscle force. In order to standardize measurements of range of motion, the American Shoulder and Elbow Surgeons (ASES) recommends that four functionally important measures of range of motion be documented: forward elevation, external rotation with the arm at the side, external rotation in the 90º abducted position, and internal rotation measure by the spinal level reached by the hitchhiking thumb [17]. Shoulder active range of motion was assessed with a standard goniometer (BOK Self Help Aids, International Standards Goniometer). Muscle force of external rotation, internal rotation, and forward elevation were evaluated in the same manner as a previous report [18]. Muscle force measurements of external and internal rotation with the arm at the side, and forward elevation with the arm at 45º in the plane of the scapula (POS) were performed isometrically with the Isobex 2.1 dynamometer (Cursor Ag, Niederwanten, Switzerland).

The Penn Shoulder Score

The Penn Shoulder Score consists of three subscales including pain, satisfaction, and function. A patient can be awarded 30 points for complete absence of pain, 10 points for complete satisfaction with the function of the shoulder, and 60 points for full function of the shoulder. Therefore, the total possible points that can be scored are 100. Most patients can fill out the scale in less than 5 minutes. It takes less than one minute for the clinician to tally the score. Test-retest reliability of the Penn Shoulder Score has been reported to be ICC (2,1) = 0.94, with internal consistency $\alpha = 0.93$ [15]. Standard error of the measure = 5.2 (90% confidence interval), with minimal detectable change = 12.1 (90% confidence interval) [15]. The Penn Shoulder Score has also been correlated with existing shoulder outcome measures with r = 0.85–0.87 [15].

Table 1. Summary of shoulder disorders of patients

Shoulder Disorders	Number
Impingement/Tendonitis	9
Rotator Cuff Tear	8
Instability	5
Adhesive Capsulitis/Frozen Shoulder	4
Proximal Humerus Fracture	6
A/C Joint Arthritis	5
Glenohumeral Joint Arthritis	3
Total	40

Data Analysis

Descriptive statistics were used to characterize the measures of range of motion, muscle force, and the Penn Shoulder Score associated with selected measures of function. Pearson Product Moment Correlation Coefficient was used to calculate the relationship among measures of range of motion, muscle force, and the Penn Shoulder Score.

Intraclass correlation coefficients (ICC 2,1) were used to determine the reliability of measures of range of motion and strength [19]. The error associated with measures of range of motion and muscle force was determined by calculating the standard error of the measure (SEM). The SEM was calculated using the ICC value for each measure. The formula for the SEM is: SEM = standard deviation × [square root (1 – ICC)]. The SEM carries with it only 68% confidence bounds, therefore, the SEM was then multiplied by the z value associated with 90% confidence (1.65) to obtain the 90% confidence interval associated with a single measure of range of motion or muscle force. In order for clinicians to know how much change in range of motion or muscle force is necessary to be confident that "true change" has occurred, the minimal detectable change(MDC) was calculated. The formula is: MDC = (standard deviation × [square root (1 – ICC value)] × square root of 2. As with the error estimate, the 90% confidence interval was calculated by multiplying by 1.65.

Results

The reliability estimates, standard error of the measure (SEM) and minimal detectable change for measures of active range of motion and strength are presented in Table 2. All measures demonstrated excellent interrater reliability

Table 2. Reliability estimates, standard error of the measure (SEM), and minimal detectable change for measures of active range of motion and muscle force

	ICC (2,1)	SEM (90% CI)	MDC (90% CI)
Forward elevation AROM	0.89	12.3	17.4
External rotation at 0 AROM	0.89	10.3	14.6
External rotation at 90° AROM	0.88	17.9	25.3
Internal rotation AROM	0.86	2.4*	3.4*
External rotation force	0.89	1.4	3.3
Internal rotation force	0.91	2.2	3.1
Elevation force	0.93	1.9	2.7

* Corresponds to spinal levels.

ranging from 0.86 (internal rotation AROM) to 0.93 (elevation strength). The SEM (90% CI) for measures of active range of motion of forward elevation, external rotation at the side and at 90° ranged from 10.3° (ER at the side) to 17.9° (ER at 90°). The SEM for internal rotation was 2.4 spinal levels. The SEM (90% CI) for measures of strength ranged from 1.4 kg(external rotation) to 2.2 kg (internal rotation). The MDC (90% CI) for measures of active range of motion of forward elevation, ER at the side and at 90° ranged from 14.6° (ER at side) to 25.3° (ER at 90°). The MDC for internal rotation was 3.4 spinal levels. The MDC for measures of strength ranged from 2.7 kg (elevation) to 3.3 kg (external rotation).

The Pearson Correlations are among measures of range of motion, strength, and components of the Penn Shoulder Score are shown in Table 3. The Pain subscale of the Penn Shoulder Score had a fair correlation with measures of active range of motion with the exception of external rotation with the arm at the side (r = 0.15). Pain correlated fair to moderately with measures of strength (range = 0.48 – 0.51). Satisfaction with the function of the shoulder demonstrated poor to fair correlation with measures of range of motion and strength (range = 0.10 – 0.33). All measures of range of motion and strength demonstrated moderate to good correlation with the function score (range = 0.49 – 0.72), with the strongest correlations coming from forward elevation AROM and external rotation at 90° AROM. Measures of active range of motion and strength also had moderate to good correlations with the total Penn Shoulder Score with the exception of external rotation at the side AROM (r = 0.39).

Pearson Correlations and measurements associated with patient's response to the item "reach the small of your back to tuck in your shirt with your hand" are presented in Table 4. All measures of active range of motion demonstrated moderate correlation with the patient's response to the item. Strength measurements had a fair correlation with response to the item. Averages and standard deviations of the range of motion, strength, and components of the Penn Shoulder Score for patients based on their level of difficulty with the item are also presented. The data suggest a linear decrease in range of motion, strength, pain, satisfaction, function and total Penn Score based on the patient's level of difficulty with the item. In order to predict the level of range of motion necessary to perform a task without difficulty, a regression analysis was performed for active range of motion of internal rotation to the level of difficulty reported performing the task. (Fig. 1). The data suggest that a patient should be able to perform the task with no difficulty if they are able to reach the T 8 spinal level.

Pearson Correlations and measurements associated with patient's response to the item "place a soup can on a shelf at shoulder level without bending your elbow" are presented in Table 5. The strongest correlation with response to the item was forward elevation AROM (r = 0.66). A linear decrease in average measurements of AROM, strength, and Penn Shoulder Score was also seen depending upon response to the item. Because of its strong correlation with response to the item, a regression analysis was performed for forward elevation AROM in order to make clinical predictions of degree of difficulty with the task (Fig. 2). The data suggest that a person with forward elevation AROM of 142° should be able to place a soup can on a shelf at shoulder level with no difficulty.

Pearson Correlations and measurements associated with patient's response to the item "place a gallon container on a shelf at shoulder level without bending your elbow" are presented in Table 6. Forward elevation AROM and external rotation at 90° correlated most strongly among range of motion measures with response to the item (r = 0.56 & 0.57

Table 3. Pearson Correlation among measures of range of motion, strength, and components of the Penn Shoulder Score

	Pain Score	Satisfaction	Function	Total Score
Forward elevation AROM	0.34	0.33	0.72	0.64
External rotation at 0 AROM	0.15	0.10	0.49	0.39
External rotation at 90° AROM	0.41	0.26	0.71	0.64
Internal rotation AROM	0.27	0.22	0.53	0.47
External rotation strength	0.51	0.22	0.65	0.62
Internal rotation strength	0.48	0.30	0.62	0.61
Elevation strength	0.48	0.11	0.53	0.52

Table 4. Pearson correlation coefficients and measurements associated with the patients' response to the item: "reach the small of your back to tuck in your shirt with your hand"

	r	No Difficulty n = 15	Some Difficulty n = 16	Much Difficulty n = 9
FE AROM*	0.59	144.9 ± 14.8	130.2 ± 19.1	112.0 ± 20.2
ER @ 0 AROM*	0.49	58.9 ± 12.7	42.6 ± 16.9	35.4 ± 22.7
ER @ 90° AROM*	0.49	79.2 ± 26.7	64.2 ± 23.9	41.7 ± 27.9
IR AROM**	0.52	T 8 ± 3	T 10 ± 3.3	L 1 ± 3.3
ER Force***	0.44	5.7kg ± 3.1	3.8 ± 1.7	3.0 ± 1.4
IR Force***	0.34	8.5kg ± 5.7	5.6 ± 2.8	4.7 ± 3.4
Elevation Force***	0.30	7.5kg ± 5.0	5.6 ± 3.4	4.3 ± 3.9
Pain Score	0.49	21.1 ± 5.5	18.8 ± 6.5	12.1 ± 5.3
Satisfaction	0.55	7.1 ± 3.0	6.1 ± 2.6	2.4 ± 1.7
Function	0.75	48.1 ± 8.7	35.0 ± 10.6	19.4 ± 9.7
Total Penn Score	0.73	76.3 ± 15.0	59.9 ± 15.8	34.0 ± 12.4

* Units measured in degrees of motion.
** Units measured by spinal level reached.
*** Units in kilograms.

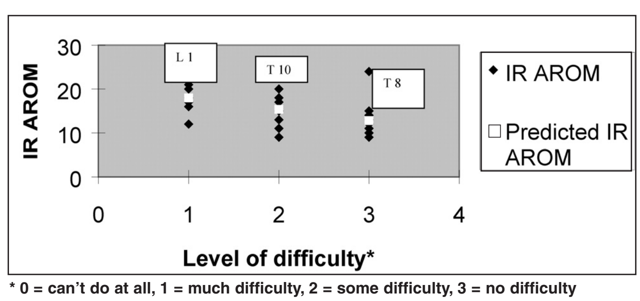


Fig. 1. Relationship between internal rotation (IR) active range of motion (AROM) and predicted level of difficulty with the item: "reach the small of your back to tuck in your shirt with your hand."

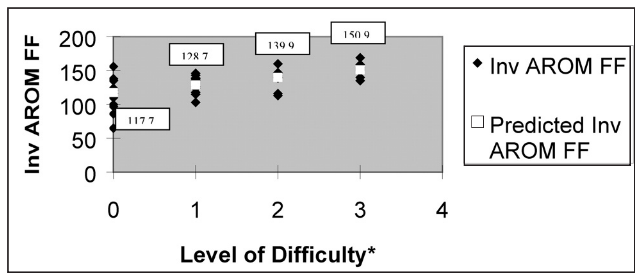
Table 5. Pearson correlation coefficients and measurements associated with the patients' response to the item: "Place a soup can on a shelf at shoulder level without bending your elbow"

	r	No difficulty n = 21	Some difficulty n = 12	Much difficulty n = 2	Can't do at all n = 5
FE AROM*	0.66	140.0 ± 14.0	133.0 ± 18.3	118.5 ± 3.5	95.8 ± 21.0
ER @ 0 AROM*	0.41	55.0 ± 15.0	43.0 ± 18.0	19.5 ± 16.3	37.4 ± 21.9
ER @ 90° AROM*	0.53	76.0 ± 25.0	64.0 ± 14.7	31.0 ± 43.8	33.6 ± 38.9
IR AROM**	0.43	T 9 ± 3.0	T 10 ± 3.9	L 5 ± 1.4	T 12 ± 0.9
ER Force***	0.40	5.0 ± 3.0	4.5 ± 1.3	3.8 ± 0.9	1.7 ± 1.3
IR Force***	0.36	7.6 ± 5.3	6.5 ± 2.6	6.5 ± 2.5	2.4 ± 2.0
Elevation Force***	0.33	6.5 ± 4.5	7.5 ± 3.7	6.0 ± 2.2	1.3 ± 0.8
Pain Score	0.50	20.0 ± 5.9	19.5 ± 5.7	13.5 ± 3.5	9.6 ± 6.1
Satisfaction	0.32	6.7 ± 2.9	4.7 ± 3.3	3.0 ± 1.4	4.4 ± 2.2
Function	0.80	45.5 ± 10.6	34.8 ± 6.1	18.5 ± 3.5	12.2 ± 6.8
Total Penn Score	0.74	72.2 ± 17.4	58.9 ± 11.9	35.0 ± 1.4	26.2 ± 10.9

* Units measured in degrees of motion.
** Units measured by spinal level reached.
*** Units in kilograms.

respectively). All strength measurements had moderate to good correlation (range = 0.58 – 0.72) with external rotation strength correlating the strongest (r = 0.72). A linear decrease in range of motion, strength, and Penn Shoulder Score was also seen based upon response to the item. Regression analysis for forward elevation AROM and external rotation strength is presented in Figs. 3 and 4. The data suggest that 151° of forward elevation AROM and external rotation strength of 7.5 kg are predictive of the ability to perform the task without difficulty.

Pearson Correlations and measurements associated with the patients' response to the item "place a soup can on a shelf overhead without bending you elbow" are shown in Table 7. Forward elevation and external rotation at 90° demonstrate the strongest correlation with response to the item (r = 0.71 & 0.61). A linear decrease in range of motion, strength, and Penn Shoulder Score was again seen based upon response to the item. Regression analysis for forward elevation AROM is presented in Fig. 5. Forward elevation of 146° is predictive of the ability to perform the task without difficulty.

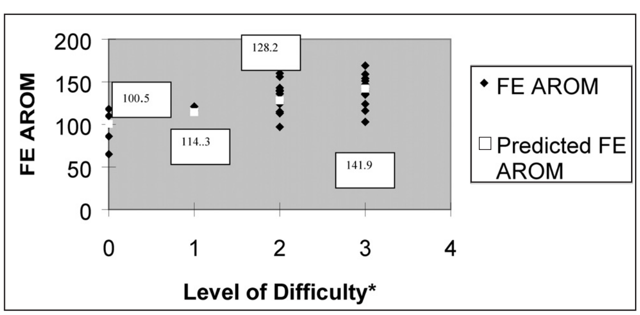


* 0 = can't do at all, 1 = much difficulty, 2 = some difficulty, 3 = no difficulty

Fig. 3. Relationship between forward elevation (FE) active range of motion (AROM) and predicted level of difficulty with the item: "Place a one gallon container on a shelf at shoulder level without bending your elbow."

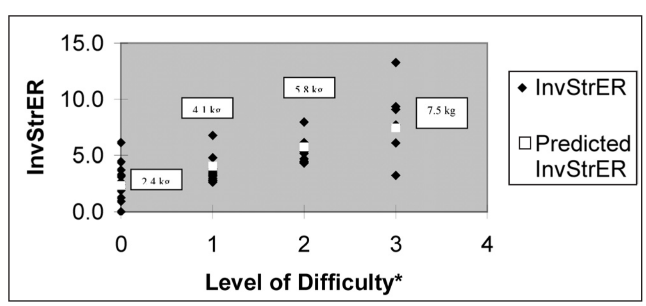
Discussion

This study established reliability estimates for measurement of shoulder active range of motion and strength. Previous studies examining reliability of shoulder range of motion measures were done with passive movements [20,21]. The reliability estimates for strength measurements were similar to that of a previous study. However, that study was done in a nonpatient population [18]. Data regarding the error associated with these measurements and



* 0 = can't do at all, 1 = much difficulty, 2 = some difficulty, 3 = no difficulty

Fig. 2. Relationship between forward elevation (FE) active range of motion (AROM) and predicted level of difficulty with the item: "Place a soup can on a shelf at shoulder level without bending your elbow."



* 0 = can't do at all, 1 = much difficulty, 2 = some difficulty, 3 = no difficulty

Fig. 4. Relationship between external rotation strength and predicted level of difficulty with the item: "Place a one gallon container on a shelf at shoulder level without bending your elbow."

Table 6. Pearson correlation coefficients and measurements associated with the patients' response to the item: "Place a one gallon container on a shelf at shoulder level without bending your elbow"

	r	No difficulty n = 6	Some difficulty n = 8	Much difficulty n = 12	Can't do at all n = 13
FE AROM*	0.56	151.3 ± 12.4	137.9 ± 15.9	130.8 ± 13.5	116.8 ± 24.9
ER @ 0 AROM*	0.37	55.3 ± 10.9	54.8 ± 20.6	44.5 ± 14.6	38.6 ± 20.5
ER @ 90° AROM*	0.57	89.0 ± 19.7	80.1 ± 12.7	63.4 ± 26.6	44.7 ± 29.6
IR AROM**	0.26	T 9 ± 3.0	T 8 ± 3.8	T 11 ± 4.1	T 11 ± 4
ER Force***	0.72	8.1 ± 3.4	5.3 ± 1.2	3.6 ± 1.2	2.7 ± 1.6
IR Force***	0.64	12.9 ± 6.3	8.0 ± 2.2	5.0 ± 2.5	4.4 ± 3.0
Elevation Force***	0.58	10.8 ± 4.8	8.1 ± 2.6	4.8 ± 3.6	3.9 ± 3.5
Pain Score	0.41	23.7 ± 6.4	18.0 ± 4.3	19.2 ± 5.5	14.5 ± 7.4
Satisfaction	0.41	8.3 ± 1.5	4.5 ± 2.6	7.0 ± 2.9	3.5 ± 2.6
Function	0.75	53.5 ± 4.9	45.0 ± 8.4	36.0 ± 7.9	23.5 ± 13.5
Total Penn Score	0.69	85.5 ± 11.1	67.5 ± 12.8	62.2 ± 13.9	41.6 ± 20.2

* Units measured in degrees of motion.
** Units measured by spinal level reached.
*** Units in kilograms.

the amount of change necessary to be reasonably certain that true change has occurred was also presented. This data can help clinicians make decisions regarding the effectiveness of treatment and progress toward goals.

This study also further validated the Penn Shoulder Score by demonstrating that it correlates well with measures of range of motion and strength. Forward elevation AROM and external rotation at 90° abduction AROM as well as all measures of strength correlated most strongly with the total Penn Shoulder Score. The function subsection correlated well with all measures of range of motion and strength. There were positive, but weak correlations with the satisfaction subsection, indicating that these impairments contribute little to the patient's satisfaction with the function of their shoulder. The pain subscale correlated most strongly with the strength measurements. There were also fair correlations with forward elevation AROM and external rotation at 90° AROM. External rotation with the arm at the side correlated poorly with pain and satisfaction and had only fair correlation with function and the total Penn Shoulder Score. This is not surprising because while this motion may be important to the clinician, it is not routinely used for any functional activity.

The most clinically useful data presented in this paper is that of the measurements associated with individual items from the Penn Shoulder Score. This data also further validates the Penn Shoulder Score in that a linear relationship does exist among measures of range of motion, strength, and Penn Shoulder Score corresponding to the level of difficulty reported with selected functional measures. Clinicians can use the data from the regression analysis to predict the amount of active range of motion and/or strength necessary to perform a particular task with or without difficulty.

Knowledge of the relationship among impairments such as range of motion and strength and function is essential to help clinicians develop a treatment plan and goals for patients with shoulder disorders. This study established that the Penn Shoulder Score correlates well with measures of

Table 7. Pearson correlation coefficients and measurements associated with the patients' response to the item: "Place a soup can on a shelf overhead without bending your elbow."

	r	No difficulty n = 16	Some difficulty n = 12	Much difficulty n = 5	Can't do at all n = 7
FE AROM*	0.71	142.9 ± 12.1	136.4 ± 17.1	126.4 ± 10.2	99.3 ± 19.3
ER @ 0 AROM*	0.46	55.1 ± 16.7	48.2 ± 17.5	42.2 ± 15.7	31.0 ± 20.4
ER @ 90° AROM*	0.61	77.4 ± 27.3	72.8 ± 12.6	56.0 ± 10.7	28.0 ± 30.5
IR AROM**	0.41	T 9 ± 3.7	T 8 ± 3.2	T 11 ± 4.5	L 2 ± 2.4
ER Force***	0.41	5.3 ± 3.1	4.4 ±1.7	3.8 ± 3.1	2.4 ±1.5
IR Force***	0.40	8.6 ± 5.4	5.9 ± 2.7	5.9 ± 3.8	3.7 ± 2.8
Elevation Force***	0.32	7.2 ± 4.6	6.4 ± 3.7	6.3 ± 5.1	3.0 ± 2.7
Pain Score	0.44	21.3 ± 5.3	17.7 ± 5.6	17.2 ± 6.4	13.0 ± 8.6
Satisfaction	0.45	7.5 ± 2.5	4.5 ± 3.3	4.8 ± 3.0	3.7 ± 1.8
Function	0.84	48.4 ± 7.6	37.3 ± 8.5	29.0 ± 8.9	14.9 ± 8.1
Total Penn Score	0.77	77.2 ± 12.3	59.4 ± 14.6	51.0 ± 18.1	31.6 ± 15.4

* Units measured in degrees of motion.
** Units measured by spinal level reached.
*** Units in kilograms.

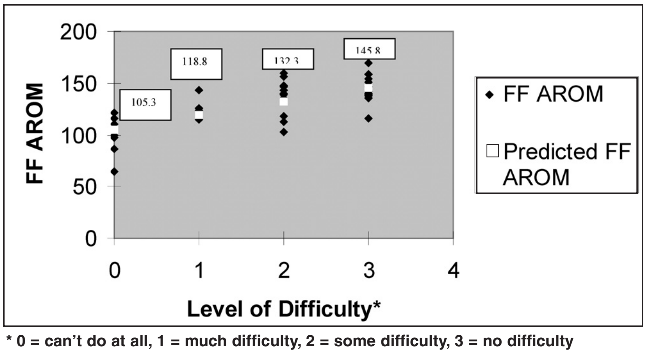


Fig. 5. Relationship between forward elevation (FE) active range of motion (AROM) and predicted level of difficulty with the item: "Place a soup can on a shelf overhead without bending your elbow."

range of motion and strength. This study also provides the clinician with data to help predict the level of difficulty a patient may have with selected items from the Penn Shoulder Score. In addition, the method of measuring range of motion and strength were highly reliable. In order to help clinicians make decisions regarding individual patients, error and minimal detectable change associated with measures of range of motion and strength were also established.

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