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Can self-report instruments of shoulder function capture functional differences in older adults with and without a rotator cuff tear?

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Abstract

Rotator cuff tears (RCT) are prevalent in older individuals and may compound age-associated functional declines. Our purpose was to determine whether self-report measures of perceived functional ability are valid for older patients with RCT. Twenty five subjects participated (12M/13F; age=63.9±3.0 years); 13 with RCT and 12 controls (CON). Participants completed self-report measures of shoulder function (SST, ASES, WORC) and health-related quality of life (SF-36). Isometric joint moment and range of motion (ROM) were measured at the shoulder. Relationships among functional self-reports, and between these measures and joint moment and ROM were assessed; group differences for total and subcategory scores were evaluated. There were significant correlations among self-reports (r_s=0.62–0.71, $p \leq 0.02$). For RCT subjects, ASES was associated

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Conflict of Interest

MTF serves as a consultant for Smith and Nephew, although no financial remuneration was received related to the information from this study. CJT has an ownership interest in a medical device used for measuring tension in rotator cuff tendon repairs with research applications, however, development and testing of this device is outside the scope of the work presented in this manuscript. None of the other authors have any conflicts of interest to disclose related to the content of this article.

with all joint moments except adduction ($p \leq 0.02$); SST, ASES, and WORC were associated with abduction and external rotation ROM ($p \leq 0.04$). For RCT subjects, SST and WORC were associated with SF-36 physical function subcategory scores ($p \leq 0.05$). The RCT group scored worse than CON on all functional self-reports ($p<0.01$) and WORC and ASES subcategories ($p<0.01$). In conclusion, SST, ASES, and WORC demonstrate utility and discriminant validity for older individuals by distinguishing those with RCT, but this work suggests prioritizing ASES given its stronger association with functional group strength.

Clinical Trials Registration Number: NCT#01459536

Keywords

self report; aged; rotator cuff; upper extremity; activities of daily living; strength; range of motion

1. Introduction

As the United States population grows older (National Institute on Aging, 2007), it is important to understand the functional implications of common musculoskeletal conditions that may impact older individuals' ability to maintain independence. Rotator cuff tears (RCT) are a common musculoskeletal injury affecting older adults (Yamaguchi et al., 2006), with a prevalence of 26% for individuals aged 60–69 years, 46% for 70–79 years, and 50% for 80+ years (Yamamoto et al., 2010). Sarcopenia and decreased strength occur in healthy aging (Clark and Manini, 2010; Janssen et al., 2002), and may play a role in an individual's ability to successfully perform activities of daily living (ADLs) (Katz et al., 1963). However, the physiological changes (muscle atrophy, decreased strength) associated with RCT may further diminish one's ability to perform ADLs (Lin et al., 2008).

Self-report instruments have been developed to evaluate overall health and function of the shoulder and rotator cuff (Amstutz et al., 1981; Brophy et al., 2005; Constant and Murley, 1987; Heald et al., 1997; Hudak et al., 1996; Kirkley et al., 2003; Lippitt et al., 1993; Patel et al., 2007; Richards et al., 1994; Smith et al., 2012; Wright and Baumgarten, 2010). These measures assess a patient's self-perceived functional status and can aid clinicians in the diagnosis and treatment decision-making process. Best practice suggests administration of several different self-report measures to obtain a broad assessment of the patient's physical health and functional status (Smith et al., 2012; Wright and Baumgarten, 2010). Further, a more general health-related quality of life instrument, like the RAND 36-Item Short Form Health Survey (SF-36) (RAND; Stewart et al., 1992), should be acquired (Wright and Baumgarten, 2010) because it allows clinicians to examine unanticipated effects (Beaton and Richards, 1996; Patel et al., 2007) of a disease or treatment on physical function, which can be affected by both physical (e.g. reduced strength) and mental (e.g. depressed mood) aspects of a patient's health (Patel et al., 2007).

Existing self-report instruments have been developed for and are traditionally used in younger cohorts (Hegedus et al., 2014). These instruments have not been specifically validated in a cohort of older adults, for whom ADL tasks are of utmost importance. Self-report instruments of shoulder function often query patients on tasks which have little or no relevance to older individuals (e.g. ability to throw a ball) and it is unclear if they are able to effectively discriminate between older adults with and without RCT (Hegedus et al., 2014). Understanding which, if any, existing self-report instruments of shoulder function are useful for clinicians treating an increasingly large number of older adults will allow clinicians to select appropriate self-report measures for their patients.

The purpose of this work was to evaluate the Simple Shoulder Test (SST) (Lippitt et al., 1993), the American Shoulder and Elbow Surgeons Shoulder Outcome Survey (ASES) (Richards et al., 1994), and the Western Ontario Rotator Cuff Index (WORC) (Kirkley et al., 2003) self-report instruments in a sample of older individuals with and without a RCT. We examined whether these self-report measures of shoulder function 1) were related to one another and with the SF-36 in this older cohort; 2) could distinguish between older adults with and without a RCT; and 3) were related to physical symptoms associated with RCT. We hypothesized that self-reported measures of shoulder function 1) would be associated with one another and with the SF-36; 2) could distinguish between older adults with and without a RCT; and 3) would be positively correlated with physical symptoms of RCT.

2. Methods

2.1 Study participants

We recruited 25 subjects; 13 with a RCT (6M/7F) and 12 healthy age- and gender-matched asymptomatic controls (CON) (6M/6F) (Table 1). All subjects provided written informed consent in accordance with the Wake Forest University Health Sciences Institutional Review Board, which approved this study. Patients with RCT were recruited from our institution's orthopaedic clinic. Inclusion criteria included having at least a major thickness (>50% tendon thickness) supraspinatus tear, confirmed with magnetic resonance imaging. Patients were excluded if they had any prior shoulder surgery, concomitant pathology (e.g. severe osteoarthritis), or neurologic disorder. Asymptomatic control subjects with no history of shoulder pain or injury were recruited from the local community. They were further evaluated for a rotator cuff tear with a lateral Jobe's test (Gillooly et al., 2010) (positive likelihood ratio=7.36) in which subjects abducted their arms to 90° in the scapular plane and maintained neutral shoulder rotation as manual resistance was applied.

2.2 Self-report questionnaires

To reduce treatment effect, data were collected from each RCT participant at baseline. Each subject completed three self-report instruments of shoulder function, including 2 region-specific measures (SST, ASES) and a disease-specific measure (WORC), and one self-report measure of health-related quality of life (SF-36). These instruments were chosen because previous studies report that each has demonstrated validity in younger cohorts (Brazier et al., 1992; Godfrey et al., 2007; Kirkley et al., 2003; Michener et al., 2002; Schmidt et al., 2014), they spanned a broad range of subcategories (Table 2), and they did not require any assistance from a physician.

2.3 Strength assessments

We collected measures of maximal voluntary isometric joint moment and active, pain-free range of motion (ROM) at the shoulder. These parameters are reduced in RCT patients (McCabe et al., 2005). Strength and ROM were measured <1 week from completion of the self-report instruments. Joint moments were assessed for the 3 shoulder degrees of freedom using a Biodex dynamometer (Biodex Medical Systems, Shirley, NY) (Table 3). For all tests, subjects were seated with the torso restrained. Standardized verbal encouragement was given to motivate maximal performance. Three 5sec trials were collected with 60sec of rest between trials and 2min of rest between tests. The maximum moment maintained for at least 0.5sec was determined with a custom Matlab (Rev. 2012b, The MathWorks, Natick, MA) program (Holzbaur et al., 2007). The maximum moment achieved across all trials for each functional group was considered the maximum moment variable for analyses.

2.4 Range of motion assessments

Active, pain-free ROM was measured using a goniometer with subjects standing. Subjects were instructed to move their arm in each direction as far as they could without any pain and not bend the torso. Measurements were taken for abduction, flexion/extension, and internal/external rotation (Table 3).

2.4 Statistical analysis

Descriptive statistics were used to summarize participant demographics (Table 1). To test the first hypothesis, the relationships between self-reported functional ability and health-related quality of life were evaluated. Partial Spearman correlations controlling for group were used to evaluate relationships between SST, ASES, and WORC scores and the SF-36 physical function and pain subcategory scores, since previous studies report that these categories are consistently lower for patients with musculoskeletal injuries (Picavet and Hoeymans, 2004). No total score is calculated for the SF-36 (Patel et al., 2007). Sensitivity analyses were repeated using only the RCT group to determine the consistency of estimated effects within the group.

To test the second hypothesis, we used one-way ANOVA to determine whether self-report measures could distinguish between individuals with and without a RCT. Differences between groups were tested for each self-report measure and subcategory score for ASES, WORC, and SF-36. SST only evaluates functional ability, so no subgroup analyses were performed.

To evaluate the third hypothesis, we used partial Spearman correlations controlling for group to separately evaluate associations between self-report scores and joint moment and ROM measurements for subjects in the RCT and CON groups. Sensitivity analyses were repeated to determine the consistency of estimated effects within the RCT group. All statistical analyses were performed using SAS software (version 9.3, Cary, NC), with significance set at $p \leq 0.05$. No Type I error corrections were made due to the exploratory nature of these analyses.

3. Results

3.1 Relationships among self-report questionnaires

Associations among SST, ASES, and WORC were significant for analyses with all subjects (all $p<0.01$) and with the RCT group only (all $p\leq0.02$) (Table 4; Supplement 1). There were also significant correlations between self-report measures of shoulder function and the SF-36. The SF-36 physical function score was correlated with SST ($p<0.01$) and WORC ($p=0.04$) scores for analyses including all subjects. For the RCT group only, SST ($p=0.04$) and WORC ($p=0.05$) were significantly correlated with the physical function score while ASES was not ($p=0.22$). There was only a significant association between the ASES and SF-36 pain category when all subjects were evaluated ($p=0.01$). No correlations were significant when evaluating only the RCT group.

3.2 Self-report questionnaire scores between subject groups

There were significant differences between RCT and CON groups for all self-report measures of shoulder function (all $p<0.01$, Figure 1). Further analysis of ASES and WORC subcategories showed that RCT participants had significantly worse scores than CON ($p<0.01$) (Figure 2). Likewise, the RCT group had worse scores than CON on the SF-36 subscales for physical function ($p=0.02$), limitations due to physical health ($p=0.01$), limitations due to emotional problems ($p=0.03$), and pain ($p<0.01$) (Figure 3).

3.3 Relationships between self-report questionnaires and physical symptoms

Significant positive correlations were seen between ASES and SST instruments and abduction, flexion, and internal and external rotation joint moments (all $p\leq0.05$, Table 5; Supplement 2) when all subjects were evaluated. ASES ($p=0.01$) was also associated with extension joint moment. Evaluating only RCT subjects, we saw significant correlations between ASES and all strength measures except adduction ($p\leq0.02$), and between SST and abduction ($p=0.04$) and flexion ($p=0.01$) joint moments.

With regard to ROM (Table 6; Supplement 3), for analyses evaluating all subjects, the ASES was associated with abduction ($p=0.04$), flexion ($p=0.01$), and internal rotation ($p=0.05$) ROM, SST was associated with abduction ($p=0.01$) and internal rotation ($p=0.01$) ROM, and WORC was associated with abduction ($p=0.02$) ROM. Analyses with the RCT group only demonstrated significant correlations between SST, ASES, and WORC scores and abduction and external rotation ROM (all $p\leq0.04$). SST and ASES scores were also associated with flexion ROM ($p\leq0.01$).

4. Discussion

We evaluated the SST, ASES, and WORC in a cohort of older subjects with and without a RCT, an age group for which there has not been specific validation of these instruments. We found that these instruments can distinguish between groups in this older cohort, with RCT subjects reporting worse total and subcategory scores on the self-report measures of shoulder function. Significant correlations were seen between self-report measures of shoulder function and the SF-36 and these instruments were also associated with physical symptoms of a RCT.

4.1 Associations between self-report questionnaires

The pain and physical function categories of the SF-36 captured the reduced function assessed with the SST, ASES, and WORC instruments, confirming part of our first hypothesis. These results are consistent with previous studies reporting associations between the SF-36 and musculoskeletal injuries (Gartsman et al., 1998; Patel et al., 2007; Picavet and Hoeymans, 2004; Smith et al., 2000), where pain and physical function category scores were consistently lower (Picavet and Hoeymans, 2004). Patients with RCT have previously demonstrated reductions in SF-36 sub-scores (Smith et al., 2000). However, when we analyzed only the RCT group, there were no significant associations between pain and self-reported shoulder function, which is contrary to reports where associations were observed from subjects with lower extremity arthritis and joint replacement (Stratford and Kennedy, 2006; Terwee et al., 2006). In our study, 10 of the 13 RCT subjects scored a 40 out of a possible 100 on the SF-36 pain category. The pain category score is determined by the average of only 2 questions. It is possible that the SF-36 does not include enough pain-associated questions to discriminate among patients experiencing some level of pain, or that pain is a greater determinant of self-reported function in the lower limb than in the upper limb (Patel et al., 2007; Terwee et al., 2006). The SF-36 is a validated measure that demonstrated utility in the cohort evaluated in this study, as well as in prior rotator cuff tear participants (Gartsman et al., 1998), but it should not be relied on exclusively (Gartsman et al., 1998; Patel et al., 2007; Shapiro et al., 1996). Use of a disease-specific measure in addition to the SF-36 provides more specific information and clinically-relevant functional limitations (Gartsman et al., 1998; Patel et al., 2007; Shapiro et al., 1996; Wright and Baumgarten, 2010).

The ASES, SST, and WORC instruments are intended to assess how a shoulder injury may change physical function. When we evaluated all subjects together, we saw moderate-to-strong relationships among SST, ASES, and WORC scores, and moderate associations between these measures and SF-36 physical function score, using the interpretation described by Taylor (1990), in which $0.36 \leq r \leq 0.67$ is considered a moderate correlation and $0.68 \leq r \leq 1.0$ is a strong correlation. Results of this study support the notion that region- and disease-specific measures have stronger correlations with one another than with health-related quality of life measures, like the SF-36, because they are intended to evaluate functional ability (Beaton and Richards, 1996). Similarly, the results of analyses for the RCT group demonstrated stronger correlations among SST, ASES, and WORC, than those correlations between the shoulder self-report instruments and the SF-36 physical function category. This may be a consequence of the SF-36 focusing more on lower limb function than upper limb function (Patel et al., 2007), thus being less sensitive to functional changes experienced by individuals with a RCT. Beaton and Richards (1996) and Michener et al. (2002) reported high correlations between ASES scores and the SF-36 physical function score in studies on younger cohorts, but we did not identify significant correlations for this older cohort. Godfrey et al. (2007) did not find a significant association between SST and the physical function component of the SF-12 for a sub-analysis of 14 patients aged >60 with a rotator cuff injury. However, consistent with our results, they reported a significant relationship among SST and ASES. Associations between ASES and WORC scores (Holtby and Razmjou, 2005; Razmjou et al., 2006) and between SST and WORC scores (Getahun et al., 2000) have also been reported for cohorts including younger subjects. The significant correlations found in this study among SST, ASES, and WORC suggest that these assessments of perceived shoulder function perform as expected in this older cohort and confirm our first hypothesis.

4.2 Self-report questionnaires between subject groups

The SST, ASES, and WORC each successfully distinguished between RCT and CON groups, confirming our second hypothesis. Additionally, the subcategories of the ASES and WORC and those categories of the SF-36 relating to pain and function were able to distinguish between groups. The higher levels of pain and lower levels of function reported by the RCT group were captured by the ASES and SF-36 instruments. These results were expected for the RCT group because pain is the primary symptom in those who seek treatment (Itoi, 2013). However, it is not clear whether pain is the primary contributor to reduced function or a concurrent symptom. Some suggest that patients consider pain and function together (Roddey et al., 2000) and pain may contribute to strength or movement deficits (Hermans et al., 2013; Stratford and Kennedy, 2006). Further, bursal sided partial-thickness tears may be more painful for patients (Fukuda, 2000). Additional work is needed to elucidate the causative role of pain in functional ability for this group.

4.3 Self-report questionnaires and physical symptoms

Confirming the third hypothesis, the results of this study support the use of SST and ASES for assessment of shoulder function in older individuals based on their correlations with strength. However, within the RCT group, ASES performed better than SST. The ASES was the only questionnaire consistently associated with strength for upper limb functional groups when all subjects or only the RCT group were evaluated. This may indicate that the ASES can be used as a proxy measurement for strength-associated function for this age group. Therefore, in accordance with previous reports from recent reviews (Hegedus et al., 2014; Roe et al., 2013; Schmidt et al., 2014), we recommend use of ASES, particularly if resources are limited. Age-associated strength loss can have functional implications (Clark and Manini, 2010). Previous work has shown that isometric strength is a significant predictor of functional strength in older adults (Daly et al., 2013). Others have suggested that when strength falls below a minimum threshold, disability may occur (Rantanen, 2003). However, more work is needed to determine how the ASES is correlated to specific functional tasks requiring strength. The ASES and SST may be better than the WORC at distinguishing functional strength among RCT patients due to their significant associations with clinically-meaningful ROM measures. Our results for analyses with the RCT group corroborate previous work describing associations between flexion and abduction ROM and self-reported function for younger patients following rotator cuff repair (Gore et al., 1986). While range of motion is an easily measured physical attribute which is reduced following a rotator cuff tear (Bytomski and Black, 2006; McCabe et al., 2005), it is important to consider that many ADLs require motion in two or more degrees of freedom (e.g. hair combing requires abduction and external rotation) (Magermans et al., 2005). Likewise, ROM during functional tasks may differ from planar ROM measures because of the joint posture during task performance (Magermans et al., 2005). Some suggest that diminished motion may be the result of patients altering the ways in which they used their upper extremity or as a result of the aging process in the absence of any pathology (Gore et al., 1986).

4.4 Importance of physical performance measures

Patient function is approximated clinically before and after treatment through the use of self-report measures of function (Hegedus et al., 2014; Jette et al., 2009; Prince et al., 2008). While self-report instruments query patients regarding their perceived functional ability, physical performance measures require patients to perform specific tasks. Inclusion of a physical performance measure is recommended (Kennedy et al., 2002); self-reported measures and physical performance measures are frequently not well correlated because they assess different aspects of function, but together these measures provide a more comprehensive patient assessment (Hegedus et al., 2014; Kennedy et al., 2002; Prince et al., 2008). While a robust physical performance measure is currently lacking for this older adult clinical population, the FIT-HaNSA (MacDermid et al., 2007) has been suggested (Hegedus et al., 2014). However, more work is needed to determine a physical performance measure applicable to an older population with RCT (Hegedus et al., 2014).

4.4 Limitations

Limitations of this study include that a small cohort was evaluated; however, even with this sample we identified significant correlations and differences between groups. Our study was cross-sectional in design. Longitudinal studies are needed to establish test-retest reliability, responsiveness, and further validation for these self-report measures for an older population. Further work is needed to expand these results to include participants older than age 70 years. Asymptomatic subjects were used as a control group in this study. Although these individuals were screened with a modified Jobe’s test, no diagnostic imaging was performed, so it is possible that some subjects may have had an asymptomatic RCT. With the high prevalence of asymptomatic tears in the older adult population (Yamamoto et al., 2011), it is important that future studies also consider these patients. We did not explore whether SST, ASES, and WORC are sensitive to tear severity or different shoulder impairments in older individuals, but future studies should examine this.

4.5 Conclusions

We evaluated the SST, ASES, and WORC in a cohort of older adults with and without RCT. While each of the self-report measures of shoulder function distinguished between older patients with and without RCT, the SST and ASES performed better than the WORC. This finding is likely because the SST and ASES focus more on physical function and ADLs, which are more relevant to older individuals. Within the RCT group, ASES was significantly correlated with most measurements of strength and ROM, suggesting that it may be a better instrument to use for patients with a known RCT. While additional validation is needed for these instruments in an older adult cohort, we recommend use of the ASES in this population.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

Acknowledgments

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Michael Miller is a Professor in the Department of Biostatistical Sciences at Wake Forest School of Medicine. He received his BA in mathematics from the College of Wooster in 1983, his MS in Biostatistics from the University of Cincinnati in 1985, and his PhD in Biostatistics from the University of Michigan in 1988. His statistical research interests include development of methods for analysis of clustered discrete observations and accounting for missing outcomes. Collaborative interests encompass the fields of aging, cognition and learning, diabetes, fitness and physical activity, neurosciences and behavior, and statistics and mathematics.

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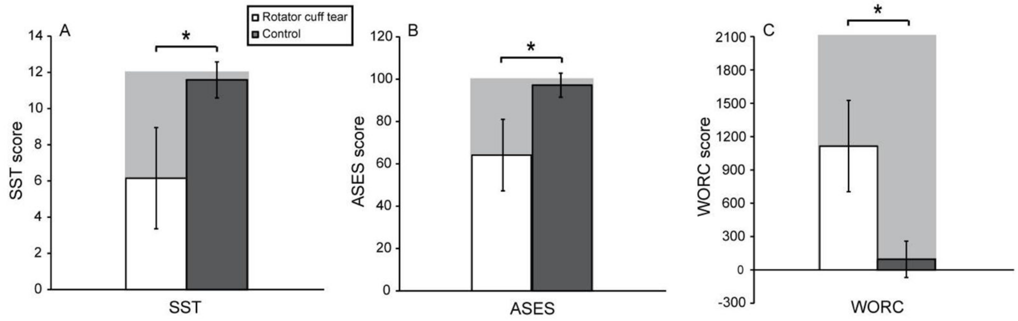

Figure 1.

Mean±SD self-report measures of shoulder function for rotator cuff tear (white) and control (gray) groups. Maximum scores indicating best (SST, ASES) or worst (WORC) outcome are indicated by gray bars in the background. Rotator cuff tear group had worse scores than controls for (A) SST (p<0.01); (B) ASES (p<0.01); and (C) WORC (p<0.01). * indicates statistical significance. Note: standard deviations from this cohort are reported; it is not possible to obtain a score larger than what is indicated by the shaded gray bars in the background.

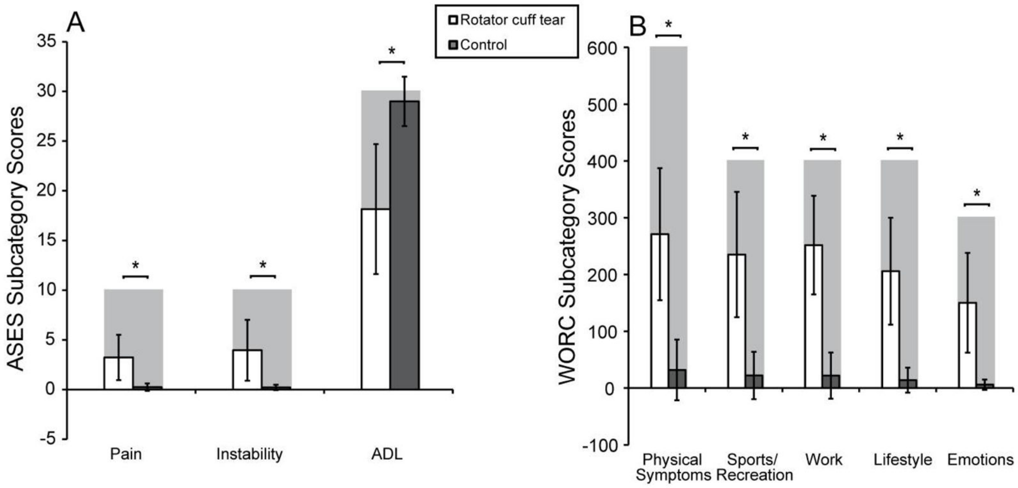

Figure 2.

Mean±SD for ASES and WORC subcategories for rotator cuff tear (white) and control (gray) groups. Shaded bars in background indicate the best (ASES: ADL) or worst (ASES: pain, instability; WORC: all categories) score. (A) Rotator cuff tear group had significantly worse ASES category scores for pain ($p<0.01$), instability ($p<0.01$), and ADL ($p<0.01$); (B) Rotator cuff tear group had significantly worse scores on all WORC categories (all $p<0.01$); * indicates statistical significance. Note: standard deviations from this cohort are reported; it is not possible to obtain a score larger than what is indicated by the shaded gray bars in the background.

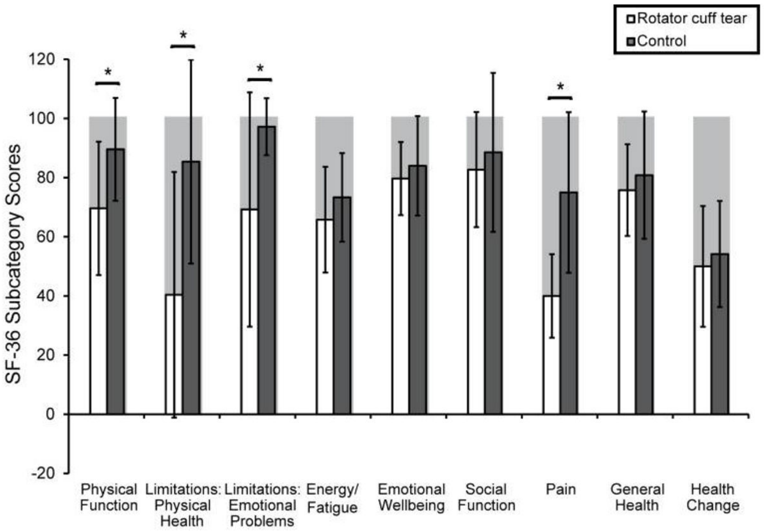

Figure 3.

Mean±SD for each subcategory score for the SF-36 for rotator cuff tear (white) and control (gray) groups. Shaded bars in background indicate the best score. The rotator cuff tear group had worse scores on all categories than controls, with significantly worse scores on the physical function (p=0.02), limitations due to physical health (p=0.01), limitations due to emotional problems (p=0.03), and pain categories (p<0.01). Note: standard deviations from this cohort are reported; it is not possible to obtain a score larger than what is indicated by the shaded gray bars in the background.

Table 1

Participant demographics. R = rotator cuff tear patient; C = control subject; F = female; M = male; N/A = not applicable.

Subject	Age	Height (cm)	Body Mass (kg)	Dominant Arm	Injured Arm
RF01	64	162.6	58.5	Right	Right
RF02	65	165.1	83.9	Right	Right
RF03	65	149.9	53.5	Right	Left
RF04	63	160	73.5	Right	Right
RF05	60	180.3	122.5	Right	Right
RF06	75	162.6	55.3	Right	Right
RF07	65	162.6	65.8	Right	Left
RM01	64	175.3	73	Right	Left
RM02	61	167.6	83.9	Right	Left
RM03	64	177.8	108	Left	Left
RM04	64	182.9	88.5	Right	Left
RM05	62	177.8	95.3	Left	Left
RM06	66	168.9	87.1	Right	Left
CF01	64	152.4	74.8	Left	N/A
CF02	63	172.7	54.4	Right	N/A
CF03	67	172.7	70.8	Right	N/A
CF04	65	162.6	65.8	Right	N/A
CF05	60	157.5	79.4	Right	N/A
CF06	64	160	60.3	Right	N/A
CM01	64	172.7	70.3	Right	N/A
CM02	61	177.8	99.8	Right	N/A
CM03	64	182.9	86.2	Right	N/A
CM04	62	172.7	73.5	Right	N/A
CM05	61	175.3	70.3	Right	N/A
CM06	66	182.9	83.9	Right	N/A
Rotator cuff tear mean±SD	64.5±3.6	168.7±9.6	80.7±20.5		
Control mean±SD	63.4±2.1	170.2±9.9	74.1±12.1		

Table 2

Characteristics of the SST, ASES, WORC, and SF-36. ICF classifications were reported in Roe et al., 2013.

Questionnaire	Type	Number of Questions	Format of questions	Categories assessed		ICF Classifications	
SST	Shoulder-specific self-report measure of function	12	Yes/No	**1**	Function	**1**	Sleep functions
						2	Sensation of pain
						3	Lifting and carrying objects
						4	Hand and arm use
						5	Washing oneself
						6	Remunerative employment
ASES	Shoulder-specific self-report measure of function	12	Visual analog scale; Ordinal scale	**1**	Pain	**1**	Sleep functions
				2	Instability	**2**	Sensation of pain
				3	Activities of daily living	**3**	Mobility of joint functions
						4	Stability of joint functions
						5	Muscle power functions
						6	Structure of shoulder region
						7	Maintaining a body position
						8	Lifting and carrying objects
						9	Hand and arm use
						10	Washing oneself
						11	Caring for body parts
						12	Toileting
						13	Dressing
						14	Remunerative employment
						15	Recreation and leisure
						16	Products or substances for personal consumption

Questionnaire	Type	Number of Questions	Format of questions	Categories assessed		ICF Classifications	
WORC	Rotator cuff-specific self-report measure of function	21	Visual analog scale	**1**	Physical symptoms	**1**	Sleep functions
				2	Sports/recreation	**2**	Emotional functions
				3	Work	**3**	Sensation of pain
				4	Lifestyle	**4**	Mobility of joint functions
				5	Emotions	**5**	Muscle power functions
						6	Sensations related to muscles and movement functions
						7	Lifting and carrying objects
						8	Hand and arm use
						9	Caring for body parts
						10	Dressing
						11	Looking after one’s health
						12	Doing housework
						13	Caring for household objects
						14	Remunerative employment
SF-36	Health-related quality of life	36	Likert scale	**1**	Physical function	**1**	Energy and drive functions
				2	Role limitations due to physical health	**2**	Emotional functions
						3	Sensation of pain
				3	Role limitations due to emotional problems	**4**	Carrying out daily routine
				4	Energy/fatigue	**5**	Changing basic body position
				5	Emotional well-being	**6**	Lifting and carrying objects
				6	Social functioning	**7**	Hand and arm use
				7	Pain	**8**	Walking
				8	General health	**9**	Moving around
				9	Health change	**10**	Washing oneself
						11	Dressing
						12	Doing housework
						13	Remunerative employment
						14	Work and employment, other specified and unspecified
						15	Recreating and leisure

Table 3

Testing postures used to assess maximal voluntary isometric joint moment and active, pain-free range of motion.

Isometric joint moment		
Abduction/Adduction	**Flexion/Extension**	**Internal/External Rotation**
Humerus abducted 30° in the coronal plane Elbow braced in extension Wrist braced in neutral	Humerus forward flexed 30° in the sagittal plane Elbow braced in extension Wrist braced in 90° pronation	Humerus abducted 30° in the coronal plane Elbow flexed 90°, restrained with an elastic bandage wrap Wrist braced in neutral

Active, pain-free range of motion		
Abduction	**Flexion/Extension**	**Internal/External Rotation**
Humerus in neutral in the sagittal plane Elbow fully extended Wrist in neutral	Humerus in neutral in the sagittal plane Elbow fully extended Wrist in neutral	Humerus abducted 30° in the coronal plane Elbow flexed 90° Wrist in neutral

Table 4

Spearman correlations (r_s), corresponding p-values, and lower and upper limits of the 95% confidence interval (CI) for all subjects and rotator cuff tear subjects for SST, ASES, WORC, and SF-36 pain and physical function categories.

	All subjects (N=25)			Rotator cuff tear subjects (N=13)		
	SST	**ASES**	**WORC**	**SST**	**ASES**	**WORC**
ASES	r_s=0.71 (p<0.01)* CI=0.42, 0.86	-	-	r_s=0.71 (p=0.01)* CI=0.23, 0.90	-	-
WORC	r_s=−0.62 (p<0.01)* CI=-0.82, −0.28	r_s=−0.70 (p<0.01)* CI=−0.86, −0.40	-	r_s=−0.66 (p=0.02)* CI=−0.88, −0.14	r_s=−0.63 (p=0.02)* CI=−0.87, −0.09	-
SF-36 Pain	r_s=0.31 (p=0.14) CI=−0.11, 0.63	r_s=0.51 (p=0.01)* CI=0.13, 0.76	r_s=−0.29 (p=0.18) CI=−0.61, 0.14	r_s=0.11 (p=0.71) CI=−0.47, 0.62	r_s=0.47 (p=0.11) CI=−0.13, 0.80	r_s=−0.02 (p=0.94) CI=−0.57, 0.54
SF-36 Physical Function	r_s=0.62 (p<0.01)* CI=0.28, 0.82	r_s=0.40 (p=0.05) CI=−0.01, 0.69	r_s=−0.42 (p=0.04)* CI=−0.70, −0.01	r_s=0.59 (p=0.04)* CI=0.03, 0.85	r_s=0.37 (p=0.22) CI=−0.24, 0.76	r_s=−0.56 (p=0.05)* CI=−0.84, 0.01

* indicates statistical significance.

Table 5

Spearman correlations (r_s), corresponding p-values, and lower and upper limits of the 95% confidence interval (CI) for comparisons between SST, ASES, and WORC total scores and abduction, adduction, flexion, extension, internal rotation, and external rotation joint moment (Nm).

All subjects (N=25)

	Abduction joint moment	**Adduction joint moment**	**Flexion joint moment**	**Extension joint moment**	**Internal rotation joint moment**	**External rotation joint moment**
SST	$r_s=0.44$ (p=0.03)* CI=0.03, 0.71	$r_s=0.38$ (p=0.07) CI=−0.04, 0.67	$r_s=0.53$ (p=0.01)* CI=0.15, 0.76	$r_s=0.38$ (p=0.06) CI=−0.03, 0.68	$r_s=0.41$ (p=0.05)* CI=−0.00, 0.69	$r_s=0.56$ (p<0.01)* CI=0.18, 0.78
ASES	$r_s=0.43$ (p=0.04)* CI=0.02, 0.70	$r_s=0.35$ (p=0.09) CI=−0.06, 0.66	$r_s=0.45$ (p=0.03)* CI=0.04, 0.72	$r_s=0.52$ (p=0.01)* CI=0.14, 0.76	$r_s=0.42$ (p=0.04)* CI=0.01, 0.70	$r_s=0.52$ (p=0.01)* CI=0.14, 0.76
WORC	$r_s=-0.18$ (p=0.41) CI=−0.54, 0.25	$r_s=-0.15$ (p=0.47) CI=−0.52, 0.27	$r_s=-0.26$ (p=0.22) CI=−0.60, 0.17	$r_s=-0.26$ (p=0.23) CI=−0.59, 0.17	$r_s=-0.14$ (p=0.51) CI=−0.51, 0.28	$r_s=-0.29$ (p=0.17) CI=−0.61, 0.14

Rotator cuff tear subjects (N=13)

	Abduction joint moment	**Adduction joint moment**	**Flexion joint moment**	**Extension joint moment**	**Internal rotation joint moment**	**External rotation joint moment**
SST	$r_s=0.58$ (p=0.04)* CI=0.01, 0.85	$r_s=0.08$ (p=0.79) CI=−0.50, 0.60	$r_s=0.67$ (p=0.01)* CI=0.16, 0.89	$r_s=0.40$ (p=0.17) CI=−0.21, 0.77	$r_s=0.49$ (p=0.09) CI=−0.10, 0.81	$r_s=0.43$ (p=0.14) CI=−0.18, 0.79
ASES	$r_s=0.63$ (p=0.02)* CI=0.10, 0.87	$r_s=0.30$ (p=0.32) CI=−0.31, 0.73	$r_s=0.72$ (p=0.01)* CI=0.25, 0.90	$r_s=0.74$ (p<0.01)* CI=0.29, 0.91	$r_s=0.68$ (p=0.01)* CI=0.17, 0.89	$r_s=0.62$ (p=0.02)* CI=0.08, 0.87
WORC	$r_s=-0.17$ (p=0.59) CI=−0.65, 0.43	$r_s=-0.01$ (p=0.99) CI=−0.55, 0.55	$r_s=-0.42$ (p=0.15) CI=−0.78, 0.18	$r_s=-0.23$ (p=0.45) CI=−0.69, 0.38	$r_s=-0.15$ (p=0.63) CI=−0.64, 0.44	$r_s=-0.16$ (p=0.60) CI=−0.65, 0.43

* indicates statistical significance.

Table 6

Spearman correlations (r_s), corresponding p-values, and lower and upper limits of the 95% confidence interval (CI) for comparisons between SST, ASES, and WORC total scores and abduction, flexion, extension, internal rotation, and external rotation range of motion (ROM) (degrees).

All subjects (N=25)

	Abduction ROM	**Flexion ROM**	**Extension ROM**	**Internal rotation ROM**	**External rotation ROM**
SST	r_s=0.53 (p=0.01)* CI=0.15, 0.77	r_s=0.36 (p=0.08) CI=−0.06, 0.66	r_s=0.18 (p=0.40) CI=−0.25, 0.54	r_s=0.53 (p=0.01)* CI=0.15, 0.77	r_s=0.34 (p=0.10) CI=−0.08, 0.65
ASES	r_s=0.43 (p=0.04)* CI=0.02, 0.71	r_s=0.51 (p=0.01)* CI=0.13, 0.75	r_s=0.08 (p=0.70) CI=−0.33, 0.47	r_s=0.41 (p=0.05)* CI=−0.00, 0.69	r_s=0.32 (p=0.13) CI=−0.11, 0.63
WORC	r_s=−0.45 (p=0.02)* CI=−0.72, −0.06	r_s=−0.21 (p=0.33) CI=−0.56, 0.22	r_s=0.26 (p=0.22) CI=−0.17, 0.60	r_s=−0.39 (p=0.06) CI=−0.68, 0.02	r_s=−0.34 (p=0.10) CI=−0.65, 0.08

Rotator cuff tear subjects (N=13)

	Abduction ROM	**Flexion ROM**	**Extension ROM**	**Internal rotation ROM**	**External rotation ROM**
SST	r_s=0.84 (p<0.01)* CI=0.52, 0.95	r_s=0.66 (p=0.01)* CI=0.15, 0.88	r_s=−0.00 (p=0.99) CI=−0.55, 0.55	r_s=0.34 (p=0.25) CI=−0.27, 0.74	r_s=0.79 (p<0.01)* CI=0.39, 0.93
ASES	r_s=0.82 (p<0.01)* CI=0.46, 0.94	r_s=0.81 (p<0.01)* CI=0.44, 0.94	r_s=−0.06 (p=0.84) CI=−0.59, 0.51	r_s=0.13 (p=0.67) CI=−0.46, 0.63	r_s=0.58 (p=0.04)* CI=0.02, 0.85
WORC	r_s=−0.72 (p=0.01)* CI=−0.90, −0.25	r_s=−0.39 (p=0.19) CI=−0.77, 0.22	r_s=0.40 (p=0.17) CI=−0.21, 0.77	r_s=−0.34 (p=0.25) CI=−0.75, 0.27	r_s=−0.68 (p=0.01)* CI=−0.89, −0.18

* indicates statistical significance.