The Impact of Workers' Compensation on Patient-Reported Outcomes Measurement Information System Upper Extremity and Legacy Outcome Measures in Patients Undergoing Arthroscopic Rotator Cuff Repair

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Purpose: To examine the preoperative performance of the Patient-Reported Outcomes Measurement Information System (PROMIS) Upper Extremity (UE) Computer Adaptive Test (CAT) with respect to legacy scores in patients receiving rotator cuff repair (RCR). In addition, to define the impact of Workers' Compensation (WC) status on both performance and floor and ceiling effects. **Methods:** The PROMIS UE CAT was administered preoperatively alongside legacy patient-reported outcome measures (PROMs) to patients undergoing isolated arthroscopic RCR from November 2017 to September 2018. Performance was assessed using Spearman correlation coefficients, and floor and ceiling effects were examined. **Results:** One hundred twenty-two patients (WC, n = 32; non-WC, n = 90; 62.3% male, 53.6 ± 11.5 years) were included. PROMs assessing physical function ($r = 0.41$-0.77) correlated more strongly to the PROMIS UE CAT than did multidomain or mental health PROMs ($r = 0.25$-0.61). In WC patients, the PROMIS UE CAT demonstrated diminished correlative strength relative to shoulder function PROMs. WC patients also demonstrated relative floor effects for Single Assessment Numerical Evaluation (SANE; 18.8%) and Constant-Murley (15.6%) and relative ceiling effects for the Brief Resilience Scale (53.1%), Short Form 12 Mental Component Score (50%), and Veterans Rand 12 Mental Component Score (53.1%) and were more likely to report the minimum SANE score ($P < .01$) and the maximum Brief Resilience Scale score ($P < .01$). No absolute or relative floor/ceiling effects for the PROMIS UE CAT were found. **Conclusions:** Compared with a non-WC cohort, WC patients have significantly lower preoperative PROMIS UE CAT scores, are more likely to report the absolute minimum and maximum scores for various PROMs, and demonstrated relative floor and ceiling effects for PROMs assessing mental health. The absence of significant floor/ceiling effects for the PROMIS UE CAT may suggest improved outcome discrimination and may support the adoption of PROMIS UE for the assessment of functional status in WC patients with rotator cuff pathology. **Level of Evidence:** Level III, retrospective comparative trial.

Rotator cuff (RTC) disease is the third most common cause of musculoskeletal disease, with incidence rates ranging from 5% to 39% depending on age and genetic and biological factors.[1,2] Workers' Compensation (WC) status has been found to modulate the incidence of RTC disease, with previous literature

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reporting incidence rates of 16% to 29% depending on exposure to highly repetitive work.[3] In addition to greater incidence of RTC disease, WC patients experience worse outcomes after arthroscopic rotator cuff repair (RCR); specifically, WC status has been linked to both negative functional and patient-reported outcomes (PROs) after RCR, with patients reporting less short-term improvement.[4-6]

Patient-reported outcome measure (PROM) scores are important in the pre- and postoperative clinical assessment of improvement after RCR. However, legacy PROMs are not without important limitations. Currently, multiple PROMs exist for the evaluation of shoulder conditions, and rarely has a particular instrument been established as superior in the assessment of outcomes for a particular condition.[7] Consequently, there is little standardization in PROM administration, with investigators most often deciding to administer a host of PROMs to capture all relevant clinical outcome improvement. Administration of legacy shoulder PROMs in these practices is associated with high questionnaire burden and fatigue.[8] Patient compliance with legacy PROMs has been shown to be high preoperatively, with steady declines in compliance rates thereafter until 1 year.[9]

In 2004, the National Institutes of Health developed the Patient-Reported Outcome Measurement Information System (PROMIS).[10] PROMIS integrates item response theory (IRT) with computer adaptive testing (CAT) to solve the issue of multiple, noncomparable PROMs by providing a single, generalizable, and validated PROM to assess patients across a broad set of domains.[11,12] CAT specifically offers the advantage of selecting the best items to estimate the measurable outcome of a survey (i.e., pain, upper extremity function), resulting in fewer items for accuracy, while IRT matches actual to predicted responses using parametric category response curves to establish item-trait relationships.[13,14] Using IRT and CAT, PROMIS seeks to provide more precise health state estimations without floor or ceiling effects, while requiring the completion of fewer individual questions than other legacy PROMs.[15] Specifically, the upper extremity version of PROMIS seeks to quantify clinical function for upper extremity musculoskeletal conditions.[16,17] However, a limited amount of literature has examined the performance of the PROMIS Upper Extremity (UE) CAT in RCR, and in addition, WC status is rarely examined as a possible predictor of instrument performance.[17,18]

The purpose of this study is to examine the preoperative performance of the PROMIS UE CAT with respect to legacy scores in patients receiving RCR and in addition to define the impact of WC status on both performance and floor and ceiling effects. We hypothesize (1) the PROMIS UE CAT will demonstrate stronger correlations with PROMs examining shoulder function than multidomain or mental health PROMs, (2) WC status patients will demonstrate weaker correlations with legacy instruments than non-WC patients, and (3) WC patients will also be more prone to relative floor and ceiling effects of PROMs assessing shoulder function than non-WC counterparts.

Methods

Patient Selection and Cohort Establishment

Our study was approved by our university's institutional review board prior to comparative cohort establishment. Based on power analysis for a 2-sided test with a type 1 error rate of 5%, the sample size necessary to provide a confidence interval of 80% was deemed to be n = 105 patients assuming a response distribution of WC patients of 20%. A 20% response distribution was assumed by analyzing institutional data for the frequency of WC patients at our institution. Inclusion criteria involved full completion of all relevant legacy scores preoperatively and receipt of a primary RCR for a full-thickness RTC tear. Exclusion criteria included failure to complete any legacy PROM preoperatively, revision RCR, partial RTC tears, and receipt of significant concomitant procedures. Patients who received concomitant acromioplasty were not excluded.[19] Using our electronic registry, 698 patients were identified as RCR recipients between November 2017 and September 2018. A total of 576 patients were excluded on the basis of failure to complete any preoperative legacy scores (n = 82), revision surgery (n = 101), partial RTC tears (n = 90), and receipt of significant concomitant procedures (n = 303), yielding a total of 122 patients for subsequent analysis (Fig 1). Our final cohort consisted of 32 WC patients and 90 non-WC patients, with a response distribution of WC of 26.2%.

PROMs and Intraoperative Variables

In addition to completion of the PROMIS UE CAT, patients completed the following questionnaires on a computer with the help of a qualified research assistant during preoperative evaluation: the American Society of Shoulder and Elbow Surgery (ASES), Single Assessment Numerical Evaluation (SANE), Quick Disabilities of the Arm, Shoulder and Hand (QuickDASH), Constant-Murley, Short Form 12 (SF-12), Veterans Rand 12 (VR12), Veterans Rand 6 Domain (VR6D), and the Brief Resilience Scale (BRS). SF-12 was split into the SF-12 Physical Component Score (SF-12 PCS) and SF-12 Mental Component Score (SF-12 MCS), while VR12 was split into VR12 PCS and VR12 MCS. Questionnaires were completed using an electronic data collection service (Outcome Based Electronic Research Database; Universal Research Solutions, Columbia, MO). Demographic data collected were inclusive of age,

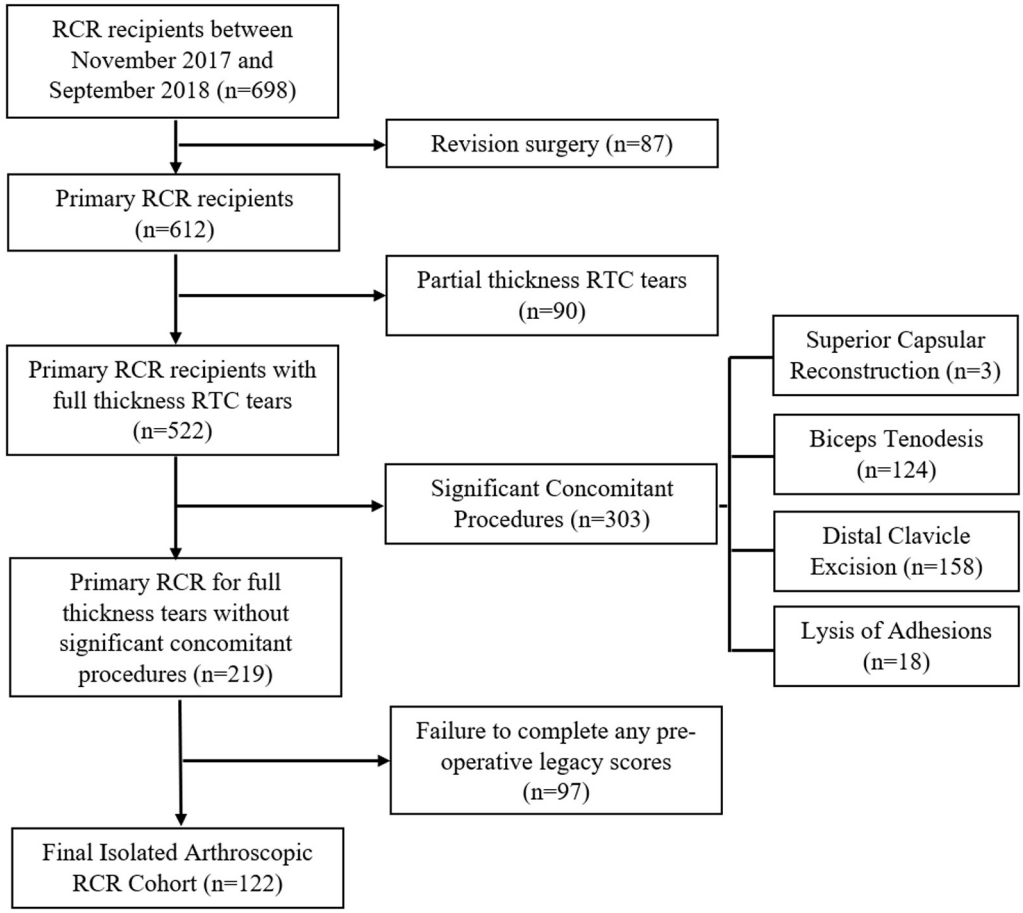

Fig 1. Flow diagram of retrospective cohort construction. All horizontal arrows represent points of exclusion in the construction of our retrospective cohort.

sex, and insurance provider. Tear size data were aggregated based on intraoperative measurements made by the primary surgeon.

Statistical Analysis

The distribution of PRO scores was evaluated for normality using the Shapiro-Wilk test. Given non-normal score distributions for the PROMIS UE CAT, Spearman correlation coefficients were used to associate PROMIS UE CAT scores with all other outcome measures. Performance of the PROMIS UE CAT was assessed by classifying the strength of correlation coefficients, with >0.8 equating to excellent, 0.71 to 0.8 equating to very good, 0.61 to 0.7 equating to good, 0.41 to 0.6 equating to fair, and 0.21 to 0.4 equating to poor.[7,20] PROMs were divided into those examining physical function (QuickDASH, ASES, SANE, SF-12 PCS, VR12 PCS, and Constant-Murley) and those examining either multiple domains (VR6D) or mental health (BRS, SF-12 MCS, VR12 MCS). After initial analysis, the cohort was stratified by WC status and Spearman correlation coefficients were recalculated to compare correlative classifications between patient populations. Absolute floor and ceiling effects were calculated by evaluating the percent of respondents who obtained the absolute lowest and highest possible score on a given PROM, respectively. A relative ceiling or floor effect was defined based on subtracting or adding 5% of the total score scale from the absolute highest or lowest score for each PROM, respectively.[20,21] In both absolute and relative floor and ceiling analysis, a percentage $\geq$15% was deemed as a significant ceiling or floor effect.[7,21,22] Bivariate subgroup analysis was performed to determine the impact of WC status on the achievement of minimum and maximum PRO score for each legacy PROM. Differences in tear size were examined using Student's *t*-test.

Results

A total of 122 patients (n = 71, 58.2% male) met the eligibility criteria, with an average age of 53.6 $\pm$ 11.5 years. Demographic data are summarized in Table 1, demonstrating no significant differences observed between WC and non-WC patients with respect to age, sex, and tear size. Significant differences in

Table 1. Demographic and Preoperative Variables

Variable	Workers' Compensation (n = 32)	Non–Workers' Compensation (n = 90)
Age, years, mean ± standard deviation	51.4 ± 10.2	55.1 ± 8.8
Sex, n (% male)	18 (56.3)	53 (58.9)
Rotator cuff tear size, cm	3.11 ± 1.43	3.26 ± 1.23
Baseline Patient-Reported Outcome Scores (Mean ± Standard Deviation)		
PROMIS UE CAT	**29.3 ± 7.0**	**32.4 ± 6.7**
QuickDASH	**58.1 ± 19.7**	**45.0 ± 20.4**
ASES	**45.0 ± 20.9**	**54.5 ± 24.9**
SANE	33.9 ± 25.7	34.1 ± 23.8
SF-12 PCS	34.8 ± 7.0	35.9 ± 8.1
VR12 PCS	35.5 ± 7.3	38.1 ± 8.8
Constant-Murley	11.2 ± 6.6	13.2 ± 6.4
VR6D	**0.57 ± 0.1**	**0.6 ± 0.1**
BRS	3.7 ± 0.8	3.9 ± 0.7
SF-12 MCS	**44.9 ± 10.7**	**52.3 ± 11.3**
VR12 MCS	**47.6 ± 11.3**	**55.3 ± 10.9**

NOTE. **Bold** indicates significant mean differences between groups on Student's *t*-test at $\alpha = 0.05$.

preoperative PRO scores between WC and non-WC counterparts were observed for multiple PROMs.

The PROMIS UE CAT demonstrated a range of correlative strengths with legacy instruments in the overall cohort ($r = 0.25$-0.77, all $P < .01$). Quick DASH had the strongest correlation with PROMIS UE CAT ($r = 0.77$), and the BRS exhibited the weakest correlation with PROMIS UE CAT ($r = 0.29$). When comparing the correlation of PROMIS UE with legacy measures in WC versus non-WC patients, non-WC patients maintained the same strength of correlation between PROMIS UE and legacy scores for the Quick DASH (strength = very good), ASES (strength = good), SANE (strength = fair), SF-12 PCS (strength = good), and Constant-Murley scores (strength = good). Compared with the overall cohort, correlations between the PROMIS UE CAT and SANE ($P = .65$), SF-12 PCS ($P = .84$), and VR12 PCS ($P = .66$) became insignificant when examining WC patients alone. The WC cohort also demonstrated significantly worse correlative strengths between the PROMIS UE CAT and VR6D ($r = 0.34$ vs 0.61) and the Constant-Murley score ($r = 0.53$ vs 0.62; Table 2).

Neither the PROMIS UE CAT nor any of the legacy PROMs demonstrated significant absolute floor or ceiling effects in the overall cohort. In both WC and non-WC patients, no absolute or relative floor or ceiling effects were identified for the PROMIS UE CAT. SANE was the only legacy measure to demonstrate an absolute floor effect in WC patients (16.63%). WC status was also significantly associated with achievement of the absolute maximum BRS score ($P < .01$) and the minimum SANE score ($P < .01$). Relative floor and ceiling analysis yielded a significant relative floor effect for the Constant-Murley score in both the WC cohort (15.6%) and the non-WC cohort (27.8%) (Figure 2). Relative ceiling effects were observed for 3 mental health PROMs: the BRS (53.1%) and SF-12 MCS (50%) in WC patients, and VR12 MCS in both WC (53.1%) and non-WC (16.7%) patients (Figure 3). WC status was also significantly

Table 2. Performance of PROMIS Stratified by Insurance Status

	Workers' Compensation (n = 32)		Non–Workers' Compensation (n = 90)		Overall (n = 122)	
Instrument	*r*	*P*	*r*	P	*r*	P
Physical Function Assessments						
QuickDASH	0.63	<.01	0.78	<.01	0.77	<.01
ASES	0.59	<.01	0.59	<.01	0.61	<.01
SANE	0.08	.650	0.52	<.01	0.41	<.01
SF-12 PCS	0.04	.837	0.55	<.01	0.44	<.01
VR12 PCS	0.08	.659	0.61	<.01	0.52	<.01
Constant	0.53	.01	0.62	<.01	0.62	<.01
Multidomain and Mental Health Assessments						
VR6D	0.34	.060	0.65	<.01	0.61	<.01
BRS	0.29	.111	0.23	.031	0.25	<.01
SF-12 MCS	0.47	.008	0.34	<.01	0.42	<.01
VR12 MCS	0.47	.007	0.46	<.01	0.50	<.01

NOTE. Data displayed by cohort, with *r* correlation coefficient followed by *P* value for instrument.

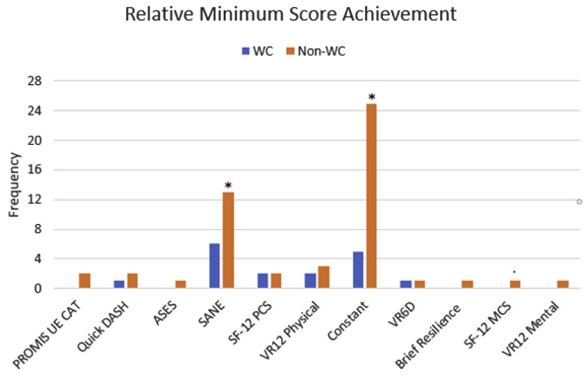

Fig 2. *Denotes significant relative floor effect (>15% of subgroup size).

associated with reporting a relative maximum score for the BRS (n = 17, $P < .01$), SF-12 MCS (n = 16, $P < .01$), and VR12 MCS (n = 17, $P < .01$) (Table 3).

Discussion

The most important finding of our study is that WC status modulates the preoperative performance of PROMIS UE CAT relative to legacy outcome measures. Specifically, the PROMIS UE CAT did not correlate as well with legacy PROMs in WC patients. Additionally, relative floor effects for the SANE and Constant scores and relative ceiling effects for the BRS, SF-12 MCS, and VR12 MCS were found in WC patients. No ceiling or floor effects were found for PROMIS UE or ASES, however. Our findings suggest that in WC patients, PROMIS has different psychometric properties than established legacy measures. The absence of a relative ceiling or floor effect for PROMIS UE in WC patients suggests increased outcome discrimination and may support adoption of the PROMIS UE CAT for assessment of functional status in WC patients with RTC pathology.

The performance of the PROMIS UE CAT in our cohort adds to previous work detailing its performance in individuals with RTC pathology.[17,18] We found QuickDASH to have the strongest correlation with PROMIS UE CAT ($r = 0.77$), similar to work by Hung et al.[23] who reported comparable levels of responsivity between PROMIS UE CAT and QuickDASH instruments at 3 month (PROMIS standardized response mean [SRM], effect size [ES], 1.26, 1.05; QuickDASH SRM, ES, 1.44, 1.12) and 6 month (PROMIS SRM, ES, 1.42, 0.85; QuickDASH SRM, ES, 1.35, 0.80) time points in an upper extremity population. ASES ($r = 0.61$, $P < .01$) demonstrated a good correlation in our patient population, comparable to the very good correlation reported by Anthony et al.[7] ($r = 0.71$, $P < .01$) in a shoulder instability population and the fair correlation reported by Beckmann et al.[16] in a hand and upper extremity population ($r = 0.59$, $P < .001$). Additionally, the PROMIS UE CAT correlated better with physical function assessments ($r = 0.41$-0.77, strength = fair to very good) than with multidomain or mental health–focused scores ($r = 0.25$-0.61, strength = poor to good). Similar trends were reported by Hancock et al.,[20] who studied the performance of the PROMIS PF CAT preoperatively in patients undergoing meniscal surgery and found that physical function PROMs correlate better than multidomain PROMs. These findings demonstrate that although the PROMIS UE CAT has good disease-specific application, the tool is less adequately equipped to measure general health and mental health–related function.

In the current study, we report significant relative floor and ceiling effects on legacy measures when stratifying patients by WC status. We also report absolute (16.6%) and relative (18.8%) floor effects for SANE in WC patients, and a relative floor effect for the Constant-Murley in WC patients (15.6%) and non-WC patients (27.8%). These results suggest that SANE and the Constant-Murley score may not sufficiently discriminate lower scores in WC patients. Interestingly, the PROMIS UE CAT (min, 1.6%; max, 1.6%) demonstrated less relative maximum score achievement than did ASES (min, 0.8%; max, 4.0%), suggesting it may display superior outcome discrimination at higher score ranges. SANE and ASES have both previously been reported to demonstrate significant postoperative ceiling effects in total shoulder arthroplasty, RCR, and subacromial impingement patients.[24,25] In our study, the Constant-Murley score was associated with relative floor effects in both WC and non-WC patients. Our findings call for more evidence in support of the Constant-Murley score in RTC pathology, adding to a recent systematic review reporting poor Evaluating Measures of Patient Reported Outcomes (EMPRO) scores in fracture patients (EMPRO, 43.5), arthritic patients (EMPRO, 41.7), and instability patients (EMPRO, 30.6).[26]

Paradoxically, relative ceiling effects were demonstrated by all 3 mental health instruments in WC patients, including the BRS (53.1%), SF-12 MCS (50%),

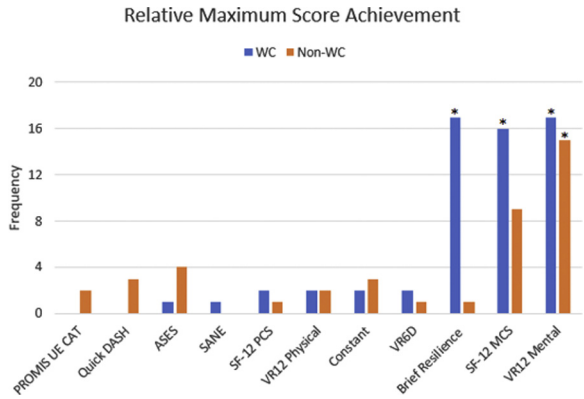

Fig 3. *Denotes significant relative ceiling effect (>15% of subgroup size).

Table 3. Floor and Ceiling Effects of Patient-Reported Outcome Measures

	Absolute Floor and Ceiling Analysis*				Relative Floor and Ceiling Analysis†			
	Absolute Minimum Score Achievement		Absolute Maximum Score Achievement		Relative Minimum Score Achievement		Relative Maximum Score Achievement	
Instrument	WC	Non-WC	WC	Non-WC	WC	Non-WC	WC	Non-WC
PROMIS UE CAT	0 (0.0)	0 (0.0)	2 (1.6)	0 (0.0)	0 (0.0)	2 (2.2)	0 (0.0)	2 (2.2)
Quick DASH	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	1 (3.1)	2 (2.2)	0 (0.0)	3 (3.3)
ASES	0 (0.0)	0 (0.0)	1 (0.8)	0 (0.0)	0 (0.0)	1 (1.1)	1 (3.1)	4 (4.4)
SANE	5 (4.9)	9 (6.6)	1 (0.8)	0 (0.0)	**6 (18.8)**	13 (14.4)	1 (3.1)	0 (0.0)
SF-12 PCS	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	2 (6.3)	2 (2.2)	2 (6.3)	1 (1.1)
VR12 Physical	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	2 (6.3)	3 (3.3)	2 (6.3)	2 (2.2)
Constant	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	**5 (15.6)**	**25 (27.8)**	2 (6.3)	3 (3.3)
VR6D	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	1 (3.1)	1 (1.1)	2 (6.3)	1 (1.1)
BRS	0 (0.0)	0 (0.0)	3 (2.5)	11 (9.0)	0 (0.0)	1 (1.1)	**17 (53.1)**	1 (1.1)
SF-12 MCS	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	1 (1.1)	**16 (50)**	9 (10)
VR12 Mental	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	1 (1.1)	**17 (53.1)**	**15 (16.7)**

NOTE. Results reported as n, %; **Bold** denotes significant relative floor or ceiling effects (>15% of subgroup).
WC, Workers' Compensation.
*Absolute floor/ceiling effects calculated using total cohort size (n = 122).
†Relative floor/ceiling effects calculated using WC subgroup size (n = 32) and non-WC subgroup (n = 90).

and VR12 MCS (53.1%). WC patients are often duty restricted, and their injury by definition prevents them from performing their regular work, perhaps explaining why they may be predisposed to a relative floor effect for functional PROMs.[25,27] Regarding mental health–related PROMs, WC patients may be more likely to perceive themselves as resilient compared with the general population and thus are more likely to report higher mental component and resiliency scores. In a WC cohort of 1,010 patients, 33.9% reported high levels of stress associated with their WC benefit claim.[28] Selecting for WC patients may bias toward higher BRS scores if these patients view their WC claim as a significant obstacle they have overcome. The current study highlights the nuances associated with assessing outcomes and functional status in a WC cohort. Careful consideration must be made for both the disease-specific and general/mental health–related measures of function. Future studies aimed at assessing mental health, resilience, and patients' perspectives of shoulder function in WC patients are warranted.

Lastly, significant differences in preoperative PRO scores were observed between cohorts for the PROMIS UE CAT, QuickDASH, ASES, VR6D, SF-12 MCS, and VR12 MCS. Although threshold values for clinically significant outcomes have yet to be established for the PROMIS UE CAT, VR6D, SF-12 MCS, and VR12 MCS, recent work defined threshold values ranging from 8.0 to 12.85 for the minimally clinically important difference (MCID) for the QuickDASH in shoulder pain and upper extremity disorder populations, respectively.[29,30] The mean difference of 3.1 observed between WC and non-WC patients in our cohort suggests the significant differences observed for QuickDASH lack clinical significance.[31] However, with respect to ASES, the mean difference observed between WC and non-WC subgroups in our cohort was 9.5, suggesting a trend toward clinical significance despite not surpassing published MCID values of 11.1 to 11.7 in patients undergoing RCR.[32] This suggests that observed functional differences in WC and non-WC patients trend toward clinical significance. This finding also supports the different psychometric properties demonstrated between WC and non-WC patients in our cohort. Future research examining outcomes after RCR should consider stratifying cohorts by WC status, and further examining achievement rates of clinically significant outcomes (i.e., MCID) for WC and non-WC patients.

Limitations

Our present study is not without important limitations. First, we are unable to assess the role of questionnaire fatigue on patient responses. Previous studies have used programs to randomize questionnaire completion as a method to control for question fatigue; however, participants in our study answered questionnaires in the same order each time, beginning with the PROMIS UE CAT and ending with SF-12 and VR12 instruments. Second, our study design involved narrow inclusion and exclusion criteria without any significant concomitant procedures, selecting for patients with full-thickness RTC tears undergoing isolated, arthroscopic RCR. As such, our study population is primary RCR patients without significant additional procedures, limiting the generalizability of our results. Third, our study is limited to preoperative assessment due to a significant increase in loss to follow-up at postoperative time points. As such, we cannot examine how the demonstrated relationships change at postoperative time points. This is particularly important in that we are unable to track the significant

differences in preoperative PRO scores stated between WC and non-WC cohorts over time, to examine whether the cohorts experienced differential achievement of clinically significant outcomes such as the MCID or patient acceptable symptomatic state.[33] Lastly, we use published MCID values to provide necessary context to the significant differences observed between WC and non-WC patients in our cohort. Although the MCID values used for ASES were studied in an arthroscopic RCR population, the MCID values cited for QuickDASH were studied in a general upper extremity population that may be less generalizable to our isolated RCR cohort.[29,30]

Conclusions

Compared with a non-WC cohort, WC patients have significantly lower preoperative PROMIS UE CAT scores, are more likely to report the absolute minimum and maximum scores for various PROMs, and demonstrated relative floor and ceiling effects for PROMs assessing mental health. The absence of significant floor/ceiling effects for the PROMIS UE CAT may suggest improved outcome discrimination and may support the adoption of PROMIS UE for the assessment of functional status in WC patients with RTC tears.

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