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Validity and Feasibility of the Seated Medicine Ball Throw and Unilateral Shot-Put Tests in Assessing Upper Extremity Function in Rotator-Cuff-Related Shoulder Pain

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Featured Application: The ULSPT, in particular, shows promise as a functional power test for adults with RCRSP. It provides a continuous measure of shoulder function that correlates with established clinical measures. Further research with larger samples is needed to fully elucidate the clinical utility of both tests and determine if one test may suffice for comprehensive assessment.

Abstract: Background: Rotator cuff-related shoulder pain (RCRSP) is a common musculoskeletal condition characterized by pain, functional disability, reduced mobility, and weakness. There is a need for valid functional tests that can measure shoulder strength and power without exacerbating pain. The Seated Medicine Ball Throw (SMBT) and Unilateral Shot-Put Test (ULSPT) are throwing tests that use a weighted ball in a seated position, measuring throwing distance (m). This study aimed to evaluate the feasibility, discriminative validity, and convergent validity of these tests in individuals with RCRSP. **Methods:** This cross-sectional study included 64 participants: 30 with RCRSP and 34 asymptomatic controls. Participants completed the QuickDASH and Fear-Avoidance Beliefs Questionnaire (FABQ). Pain was assessed using a 10 cm visual analog scale (VAS) at multiple time points. The SMBT and ULSPT were performed using a 2 kg ball, with throwing distance calculated as the average of three trials. Active shoulder range of motion (AROM) and grip strength were also measured. A two-way mixed-model repeated-measures ANOVA was conducted to examine group effects, with post hoc analyses performed where relevant. Pearson correlations explored associations among outcome measures. **Results:** The RCRSP group presented with persistent moderate shoulder pain (mean duration = 6.33 ± 5.7 months, VAS = 5.03 ± 1.99 cm, QuickDASH = 26.2 ± 10.54). Pain did not significantly increase after throwing (VAS change = 0.5 ± 1.6 cm, $P = 0.4$), supporting the tests' feasibility. ULSPT demonstrated significant differences between the RCRSP and control groups for both symptomatic (2.03 ± 0.81 m) and asymptomatic shoulders (2.04 ± 0.8 m) compared with controls (2.51 ± 0.93 m, $P < 0.01$). SMBT showed a trend toward group differences ($P = 0.05$). RCRSP participants showed reduced AROM (166.2 ± 10° vs. 175.1 ± 8.2°) but similar grip strength compared to controls. ULSPT strongly correlated with SMBT (r = 0.92–0.94, $P < 0.0001$). Both throwing tests correlated moderately with grip strength (r = 0.61–0.81, $P < 0.05$) and showed mild to moderate correlations with disability, pain, and fear-avoidance measures (r = 0.26–0.48, $P < 0.05$). **Conclusions:** The ULSPT demonstrated good discriminative validity in differentiating individuals with RCRSP from controls, while the SMBT showed a trend toward discrimination. Both tests were feasible to administer without significantly exacerbating pain. The strong correlation between ULSPT and SMBT, along with their associations with established measures, supports their potential as functional assessments of upper extremity performance in RCRSP.

Keywords: seated medicine ball throw; unilateral shot-put test; rotator cuff-related shoulder pain; functional shoulder test; upper extremity function

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1. Introduction

Throwing ability, once crucial for human survival through protection and predation [1], has evolved into a skill primarily utilized in sports and recreational activities. Despite its reduced survival importance, throwing remains a significant human function, albeit one not commonly assessed in clinical practice.

Rotator cuff-related shoulder pain (RCRSP) is a comprehensive term encompassing involvement of the rotator cuff muscles, tendons, and surrounding tissues, including the bursae, bone, ligament, capsule, nerve, and associated vascular structures [2,3]. This terminology acknowledges the complexity of pain science and recognizes that the precise source of symptoms is often indeterminate. RCRSP represents the most prevalent musculoskeletal shoulder condition, typically manifesting as shoulder pain and weakness, particularly during shoulder elevation and external rotation [2].

A characteristic feature of RCRSP is reduced upper-body muscle performance [4–6], which can adversely impact valued activities involving lifting, carrying, pulling, pushing, and throwing [2]. Consequently, evaluating shoulder muscle performance in a functional manner may hold clinical significance [7]. The clinical implementation of functional tests that assess shoulder muscle performance holds particular relevance in several contexts. First, these tests can provide objective measures of functional capacity that complement traditional clinical examinations. Unlike isolated muscle testing or range of motion assessment, functional tests can evaluate the integrated performance of the upper extremity, offering insights into how RCRSP affects daily activities and occupational tasks. Second, when selecting appropriate interventions and monitoring progress, clinicians need reliable tools that can quantify functional improvements without exacerbating symptoms [7].

While functional upper extremity tests exist, including the push-up, pull-up, Y-Balance Test-Upper Quarter, and Closed Kinetic Chain Upper Extremity Test, these are performed in closed kinetic chain positions (where the distal segment is fixed and the proximal segment moves, typically with the hand or forearm fixed against a surface) [8,9]. Many daily shoulder activities, however, occur in an open kinetic chain, where the distal segment moves freely through space while the proximal segment remains relatively fixed, such as reaching, lifting, or throwing movements.

The Shoulder Performance Activity Test (SPAT) evaluates open kinetic chain shoulder tasks but does not assess strength or power [10]. There is thus a need for a functional test that is clinically feasible, measures the strength and power performance of the shoulder girdle, and is conducted in an open kinematic chain.

The seated medicine ball throw (SMBT) and unilateral shot-put test (ULSPT) are open-chain throwing tests designed to measure functional muscle performance [8,9,11,12]. These tests have primarily been utilized in overhead and upper extremity sports populations to quantify the distance of a chest pass or shot-put throw performed in a seated position, minimizing energy transfer from the lower body [11,13] (Figures 1 and 2).

Previous research has demonstrated good test–retest reliability of the SMBT in asymptomatic older adults (mean age = 72.24 $\pm$ 5.2 years; ICC = 0.994, r = 0.73–0.77) [14]. The SMBT has also shown moderate to strong correlations with 'gold standard' isokinetic shoulder and elbow strength in young overhead athletes (age = 21.6 $\pm$ 2.5 years; r = 0.595–0.803) [8]. Normative throwing distance data has been reported for three age groups in volleyball, handball, and tennis [11].

The ULSPT has demonstrated excellent reliability (ICC = 0.988 dominant, 0.971 non-dominant side) in asymptomatic recreationally active adults [9]. Moderate to high associations have been reported between ULSPT and isokinetic pushing peak forces (r = 0.75–0.87) [15]. Additionally, the ULSPT has shown reliability in active participants with persistent shoulder pain (Intra-rater ICC = 0.93, inter-rater ICC = 0.96) [13] (Figure 2).

Before clinical implementation in the assessment of RCRSP, it is essential to evaluate the measurement properties of these tests in this specific population.

Figure 1. Seated medicine ball throw test (SMBT—The SMBT assesses bilateral upper body power, measured by throwing distance (cm))—starting position (**left**), throw (**right**).

Figure 2. Unilateral shot put test (ULSP—The ULSP test assesses unilateral upper body power, measured by throwing distance (cm)).

2. Aims

The primary aims of this study were to:

1. Evaluate the feasibility of the SMBT and ULSPT in non-athletic individuals with RCRSP, specifically:
   (a) Assess the ability of individuals with RCRSP to perform the tests without significant pain interference.
   (b) Quantify the pre–post throwing change in shoulder pain and compare it to the minimal clinically important difference in the VAS (pain) (1.4 cm).
2. Assess the discriminative validity of the SMBT and ULSPT by determining their ability to distinguish between individuals with RCRSP and asymptomatic controls.
3. Examine the convergent validity of the SMBT and ULSPT by analyzing the association between throwing distance and established measures of upper limb function, including:
   (a) Grip strength;
   (b) Visual analog scale (VAS) for pain;
   (c) Disability of the arm, shoulder, and hand questionnaire (QuickDASH).

We hypothesized that individuals with RCRSP would be able to throw a 2 kg ball in both tests without significant pain provocation and that the throwing tests would discriminate between individuals with RCRSP and healthy controls.

3. Methods

3.1. Study Design and Participants

This cross-sectional study recruited participants via social media and subsequent snowballing from two private healthcare clinics: Sportopedia, Tel Aviv, and Physio for you, Haifa, Israel. Initial screening was conducted via telephone, and eligible individuals were invited for in-person evaluation.

The inclusion criterion for the RCRSP group was non-traumatic RCRSP for at least one month, which was diagnosed/confirmed by a shoulder orthopedic specialist or physiotherapist.

The exclusion criteria for both groups were upper limb fracture or surgery; shoulder dislocation; severe shoulder pain with a VAS of 9–10/10; upper limb nerve injury; cervical radiculopathy; and systemic metabolic, neurological, and/or rheumatic disorders. Diagnosis of RCRSP was established through a clinical examination performed by a shoulder orthopedic specialist. While imaging is not required for diagnosing RCRSP, participants who had undergone imaging (MRI, ultrasound) had findings that did not meet the exclusion criteria. Physical activity levels were collected through a single self-report of weekly PA hours, documenting the type and duration of physical activity per week.

Informed consent was obtained from all subjects involved in the study prior to assessment. The study was approved by the Ethics Committee at the University of Haifa (082/21).

3.2. Experimental Procedure

Following eligibility confirmation, participants underwent the following procedure:

1. Collection of anthropometric and demographic data.
2. Completion of QuickDASH and FABQ questionnaires.
3. VAS pain measurements:
   (a) Mean pain during the past week;
   (b) Current pain at the beginning of the session (VAS start);
   (c) Pain after SMBT, AROM, and grip measurement, pre-ULSP (VAS pre);
   (d) Pain after ULSPT (VAS post).
4. Physical tests in the following sequence: (a) SMBT, (b) AROM, (c) grip strength, (d) ULSPT.

Unilateral tests were conducted on both sides, with the non-symptomatic or non-dominant side tested first. While self-reported measures (QuickDASH, FABQ, VAS) formed a significant component of our assessment, these were complemented by objective physical

measures including grip strength and active range of motion. Grip strength serves as a validated strength measure for upper extremity function and has shown strong correlations with shoulder strength in previous research [16,17]. Active range of motion provides an objective measure of functional mobility that directly impacts daily activities. Participants were informed of their right to withdraw from the study at any stage without explanation.

3.3. Primary Outcome Measures

3.3.1. Seated Medicine Ball Throw (SMBT) (Figure 1)

The SMBT measures bilateral upper body power [8,11,14]. A 10 m measuring tape was secured to the floor. Participants sat on the floor with their head, shoulders, and back against a wall, knees bent to 90°, and feet flat on the floor [8,11,14,18]. A 2 kg medicine ball (13 cm diameter) coated with magnesium carbonate powder was used.

Upper limb length was measured with participants in the test position, holding the ball at chest level with extended elbows. The ball was dropped straight down onto the tape measure, and the distance between the wall and the farthest edge of the ball's chalk mark was subtracted from the total throwing distance [8,11,14].

Participants were instructed to push the ball as far as possible away from their chest using a chest pass technique [14,19]. After three practice throws and a 3 min rest, three recorded repetitions were performed with 90 s rests between each [8,11,14]. The throwing distance was measured from the wall to the farthest edge of the chalk mark, and the mean of three trials was calculated [8,11,14].

3.3.2. Unilateral Shot-Put Test (ULSPT) (Figure 2)

The ULSPT protocol was identical to the SMBT, except throwing was performed with one hand and measured on both sides [13,18]. The throwing order was dominant side first for controls and non-painful side first for the RCRSP group.

3.4. Secondary Outcome Measures

1. QuickDASH: A self-reported questionnaire measuring physical function in individuals with upper limb disorders [20,21]. Valid and reliable for individuals with shoulder pain [20–23].
2. Fear-Avoidance Beliefs Questionnaire (FABQ): An 11-item psychological questionnaire evaluating the influence of fear on behavior, including work (FABQ-W) and physical activity (FABQ-PA) sections. Valid and reliable for RCRSP [24,25].
3. Shoulder pain intensity was measured using a 10 cm VAS for each shoulder, ranging from no pain (0) to worst imaginable pain (10). The VAS was found to be valid and reliable for shoulder pain intensity measurement [26]. The VAS minimal clinical importance difference for people with RCRSP was found to be 1.4 [27,28].
4. Grip strength: Measured using the "JAMAR" Hydraulic Hand Dynamometer (5030J1, Preston Corporation, NJ, USA) to estimate upper extremity strength [16]. Measurements were taken in a seated position with a neutral shoulder, 90° elbow flexion, and a neutral wrist [17]. The average of three 5 s hold repetitions was used in the analysis [17].
5. Active shoulder flexion range of motion (AROM) was measured using the smartphone application 'Clinometer-level and slope finder' (version 2.0, Plaincode Software Solutions, Stephanskirchen, Germany) [29]. This application has been found to be reliable compared to a double-armed goniometer (ICC = 1–0.98) [30].

Statistical Analysis

Sample size was calculated a priori using G*power software version 3.1.9.4 [31], with a medium-large effect size of 0.75, power of 0.8, and alpha of 0.05, using a *t*-test between means [32]. This resulted in a required sample size of 58 participants.

Data normality was assessed using the Shapiro–Wilk test. Abnormally distributed measures underwent monotonic transformation. Univariate analysis was conducted to

identify demographic differences between the RCRSP and control groups. BMI was found to be significantly different and was controlled for in further analyses. Due to known strength differences, dominance was also used as a covariate [18].

Pearson correlations were calculated between all measures within each group. For the RCRSP group, correlations with unilateral measures were investigated within the painful side.

For unilateral measures (ULSP, grip, and ROM), two control groups were used: control group 1 (the asymptomatic side of participants with unilateral RCRSP) and control group 2 (participants with no shoulder symptoms). This allowed for the comparison of symptomatic and asymptomatic sides in participants with unilateral RCRSP and the generation of normative data.

A two-way 3 (painful side groups: control, RCRSP-non painful side, RCRSP-painful side) * 2 (dominance: yes, no) mixed-model repeated-measures analysis of variance (ANOVA) was conducted to examine the effect of painful side and dominance on the outcome measures. All models were controlled for BMI and considered the same subject measurements autocorrelation. When an interaction was established, simple mean analysis was used to reveal the source of significance. The Studentized Maximum Modulus post hoc adjustment method was used to reveal significance between pairs of painful side groups.

A p-value of $\leq$0.05 was considered significant. Statistical analysis was performed using SAS for Windows version 9.4.

4. Results

4.1. Participant Characteristics

Of 72 potential participants, eight were excluded: two upper-body athletes, two due to physical loads associated with employment, two over 65 years of age, and two with systemic illnesses. The final sample consisted of 64 participants (33 females, 31 males) aged 25–64 years, including 30 people with RCRSP (15 females, 15 males) and 34 controls (18 females, 16 males).

Table 1 details the anthropometric and demographic data. There were no significant group differences in age, gender, or other characteristics, except for BMI (P = 0.007), which was higher in the RCRSP group. Therefore, BMI was defined as a co-variant in the statistical analysis model.

Table 1. Characteristics of the study's population (N = 66).

		Control (n = 34)		RCRSP (n = 30)	
		Mean	**SD**	**Mean**	**SD**
Age (years)		38.8	9.2	40.1	11.5
BMI (kg/m^2)		22.8	3.0	25.8	5.0 *
Self-reported physical activity (Hrs/wk)		2.6	2.0	3.4	2.4
Duration of shoulder pain (months)		N.R.	N.R.	6.3	5.7
		Frequency	Percent	Frequency	Percent
Gender	Female	18	52.9%	15	50.0%
	Male	16	47.1%	15	50.0%
Dominance	Right	29	85.3%	27	90.0%
	Left	5	14.7%	3	10.5%

* $p \leq 0.05$, RCRSP—Rotator cuff-related shoulder pain, SD—standard deviation, BMI—body mass index. N.R.—Not relevant.

Table 2 presents the self-reported clinical measures of pain intensity, disability, and fear avoidance for the RCRSP group.

Table 2. Self-reported results for disability (QuickDASH), fear avoidance (FABQ), pain intensity (VAS), and VAS change throughout the procedure.

Outcome Measure	Control (n = 34)		RCRSP (n = 30)	
	Mean	SD	Mean	SD
QuickDASH (11–55)	0.38	1.50	26.20	10.54
FABQ PA (0–24)	0.29	1.20	12.40	6.20
FABQ work (0–42)	0	0	8.80	9.03
FABQ total (0–66)	0.29	1.20	21.2	11.10
VAS start (/10 cm)	0	0	3.57	2.50
VAS pre ULSPT (/10 cm)	0	0	3.77	2.60
VAS post ULSPT (/10 cm)	0	0	4.60	2.43
VAS pre-post ULSPT difference	0	0	−0.35	2.43

Controls reported no pain before, during, and after the procedure, and reported minimal level of disability and FABQ. RCRSP—rotator cuff-related shoulder pain, SD—standard deviation, QuickDASH—disability arm shoulder hand, FABQ—fear-avoidance beliefs questionnaire, PA—physical activity, VAS—visual analog scale.

The mean duration of shoulder pain in the RCRSP group was 6 months. The distribution of the symptomatic side was nearly equal, with 14 (46.7%) having dominant-side pain and 16 (56.3%) having non-dominant side pain. The mean QuickDASH score was 26.2 ± 10.54, indicating moderate disability [23]. The mean FABQ score was 21.2 ± 11.1, and the mean FABQ PA was 12.4 ± 6.2, results associated with poorer recovery in upper shoulder function with physiotherapy [33].

4.1.1. Feasibility of SMBT and ULSPT

All participants with RCRSP were able to complete both the SMBT and ULSPT. The mean increase in pain pre–post throws was 0.5 ± 1.6 cm (P = 0.4), which is smaller than the reported minimal clinically important difference (MCID = 1.4 cm) [28]. This supports the hypothesis regarding the feasibility of the tests for individuals with RCRSP.

4.1.2. Discriminative Validity

Table 3 demonstrates the results of unilateral testing: (1) AROM, (2) grip, and (3) ULSPT divided into three groups—control, RCRSP painful side, and RCRSP non-painful side.

Table 3. Result of physical outcome measures by three groups: control, RCRSP painful side, and RCRSP non-painful side.

Outcome Measure	Control (n = 34, 68 Shoulders)		Rotator Cuff-Related Shoulder Pain (n = 30 Participants, 60 Shoulders in Total)			
			RCRSP Non-Painful Side (n = 30)		RCRSP Painful Side (n = 30)	
	Mean	SD	Mean	SD	Mean	SD
ULSPT (m)	2.51	0.93	**2.04** ^	0.80	**2.03** *	0.81
SMBT (m)	3.39	1.24	**-**	-	2.85	0.98
AROM (°)	175.10	8.20	167.90	29.70	**166.20** **,#	10.00
Grip (kg)	34.80	11.70	32.40 ^	10.70	33.50	11.70

* Significant difference between control and RCRSP painful side (* $p < 0.05$, ** $p < 0.0001$) # Significant difference between painful side and non-painful side in the RCRSP group ($p < 0.05$) ^ Significant difference between control and RCRSP non-painful side ($p < 0.05$) RCRSP—rotator cuff-related shoulder pain, SD—standard deviation, AROM—active range of motion, ULSPT—unilateral shot-put test, SMBT—seated medicine ball throw, a bilateral measure ($p = 0.05$).

The ULSPT demonstrated significant differences between the control group and both the painful and non-painful shoulders in the RCRSP group (p = 0.02). However, there was no significant difference in throwing distance between the painful and non-painful sides in the RCRSP group.

The SMBT, the only bilateral physical measure, did not show a significant group difference, although RCRSP participants threw to shorter distances.

AROM showed significant differences between the control and painful sides of the RCRSP group (p = 0.0001), with higher AROM demonstrated by controls. The RCRSP painful side had lower ROM compared with the non-painful side (p = 0.02).

4.2. Convergent Validity

Table 4 presents the correlation results between the throwing tests and other measures. Key correlations are illustrated in Figure 3.

Table 4. Correlation results (r, P): (A) between throwing tests (SMBT and ULSPT) and other physical measures (grip strength and AROM) within the control (n = 68) and RCRSP painful side (n = 30); (B) between throwing tests and self-reported measures (QuickDash, FABQ, and VAS) within the control (n = 34) and RCRSP (n = 30) group.

A	**SMBT (m) r, P**		**ULSPT (m) r, P**	
	Control	**RCRSP**	**Control**	**RCRSP**
ULSPT (m)	**0.92 <0.0001 ****	**0.94 <0.0001 ****	1	1
Grip (kgf)	**0.78 <0.0001 ****	**0.70 <0.0001 ****	**0.81 <0.0001 ****	**0.61 <0.0004 ***
AROM (°)	−0.05 0.65	−0.22 0.21	0.04 0.77	−0.2 0.30
B	**SMBT (m) r, P**		**ULSPT (m) r, P**	
	Control	**RCRSP**	**Control**	**RCRSP**
QuickDASH (11–55)	**−0.27 0.03 ***	**−0.48 0.0059 ****	−0.23 0.056	**−0.44 0.02 ***
Fear avoidance (0–66)	**0.26 0.03 ***	**−0.39 0.02 ***	**0.29 0.02 ***	**−0.42 0.02 ***
VAS (past week) (/10 cm)	N.R	**−0.37 0.04 ***	N.R	−0.29 0.12

* $p < 0.05$, ** $p < 0.005$ RCRSP—rotator cuff-related shoulder pain (only the painful shoulder), SMBT—seated medicine ball throw, AROM—active range of motion, ULSPT—unilateral shotput test, kgf—kilogram force, QuickDASH—disability of arm shoulder and neck, VAS—visual analog.

SMBT and ULSPT were highly correlated in both groups (r = 0.92, 0.94, p = 0.0001).

A good correlation was found between the throwing tests and grip strength in the control group (r = 0.78–0.81), and a moderate correlation was found in the RCRSP group (r = 0.61, 0.7). Mild significant associations were found between the throwing tests and QuickDASH in the RCRSP group (r = (−0.48)–(−0.44)). Fear avoidance was mildly associated with SMBT and ULSPT in both groups (SMBT: control r = −0.29, p = 0.03; RCRSP r = −0.39, p = 0.02; ULSPT: control r = −0.42, p = 0.02). Only a low correlation was found between SMBT and past-week VAS (r = −0.37, p = 0.05) in the RCRSP group.

AROM was correlated with fear avoidance only in the RCRSP group (r = 0.52, p = 0.002).

Mild to moderate correlations were found among QuickDASH, fear avoidance, and past-week VAS (r = 0.35–0.53, $p < 0.05$).

In summary, both SMBT and ULSPT were feasible for individuals with RCRSP to perform, with minimal pain exacerbation (mean increase in pain 0.5 ± 1.6 cm, p = 0.4). The ULSPT demonstrated the ability to discriminate between RCRSP and control groups for both painful and non-painful shoulders. The SMBT did not show significant group differences, although a trend was observed. Both throwing tests showed a strong correlation with each other and a moderate to good correlation with grip strength. Mild to moderate correlations were observed between throwing tests and self-reported measures (QuickDASH, FABQ), and weak correlations were observed with pain intensity (VAS).

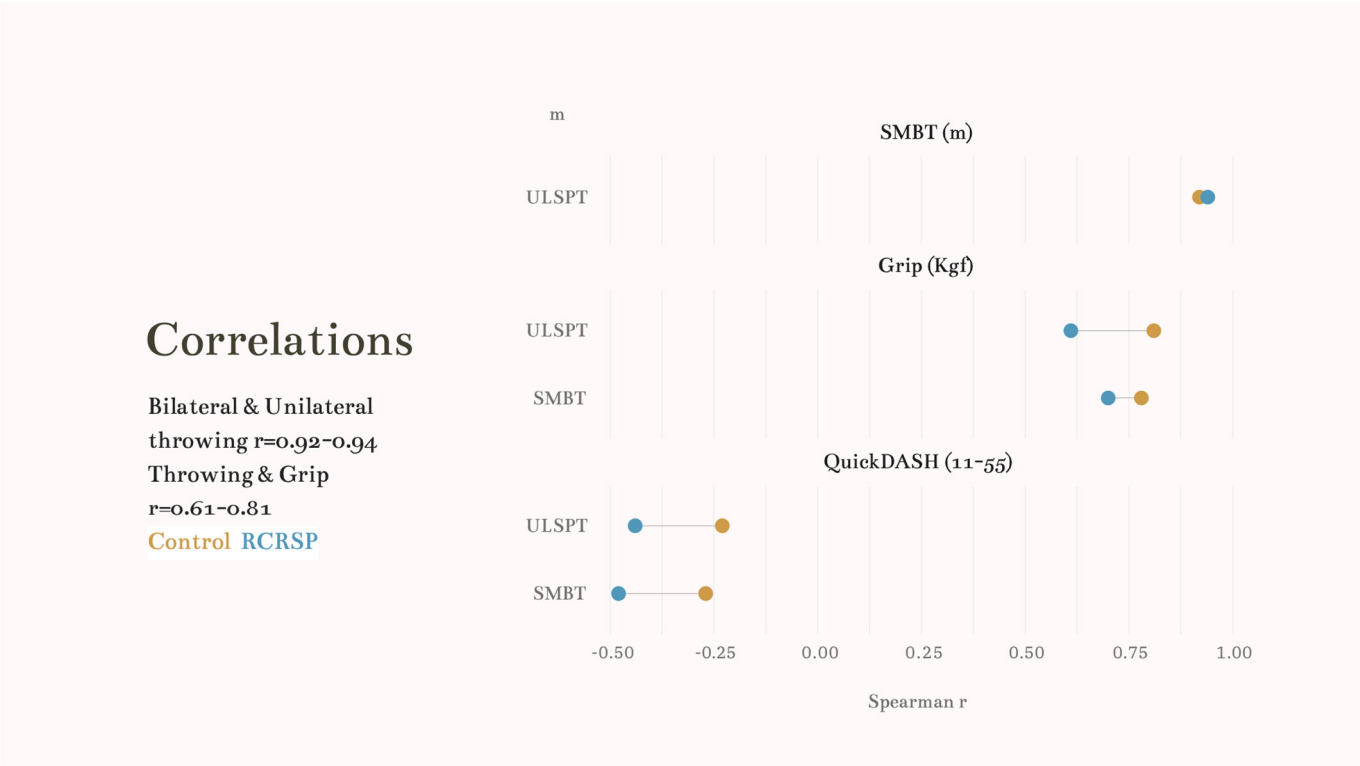

Figure 3. Key Correlations in RCRSP and control Groups. Spearman r correlation results are presented for the 2 throwing tests (ULSPT, SMBT) within them, and with the other measurements—Grip dynamometry for upper limb isometric strength, and QuickDASH for self-reported shoulder disability (See Table 4 for the full correlation results).

Both painful and non-painful shoulders in the RCRSP group showed reduced performance in the ULSPT compared with controls, suggesting potential bilateral effects of unilateral shoulder pain.

These findings provide initial support for the use of the ULSPT as a functional assessment tool in individuals with RCRSP while suggesting that further investigation may be needed for the SMBT in this population.

5. Discussion

This study aimed to evaluate the feasibility and discriminative convergent validity of the Seated Medicine Ball Throw (SMBT) and Unilateral Shot-Put Test (ULSPT) in individuals with rotator cuff-related shoulder pain (RCRSP). This preliminary investigation into the measurement properties of the SMBT and ULSPT provides initial evidence supporting their potential utility, particularly the ULSPT, in RCRSP assessment. While the findings are promising, they should be considered a foundation for further research rather than definitive validation.

5.1. Feasibility

The primary concern in implementing new assessment tools for individuals with shoulder pain is the potential for pain exacerbation. Our results demonstrated that participants with RCRSP were able to complete both the SMBT and ULSPT without a significant increase in pain. The mean increase in pain pre–post throws (0.5 $\pm$ 1.6 cm) was below the minimal clinically important difference (MCID) of 1.4 cm [28]. This suggests that these tests can be safely administered in a clinical setting for individuals with RCRSP, addressing a key gap in functional open kinetic chain assessment procedures for shoulder evaluation.

5.2. Discriminative Validity

The ULSPT demonstrated the ability to differentiate individuals with RCRSP from healthy controls, with both the symptomatic and asymptomatic shoulders of RCRSP participants showing reduced throwing distances compared to controls. This finding aligns with previous research indicating bilateral deficits in muscle performance in individuals with unilateral shoulder pain [34]. The bilateral nature of these deficits suggests that RCRSP may involve more complex, possibly neural or even central changes in pain processing rather than localized impairments [35–37].

Interestingly, the SMBT did not show significant group differences, despite being highly correlated with the ULSPT. This discrepancy may be due to the bilateral nature of the SMBT, which could potentially mask unilateral deficits. Further research with larger sample sizes may be needed to fully elucidate the discriminative capabilities of the SMBT in this population.

5.3. Convergent Validity

Both throwing tests showed moderate to strong correlations with grip strength, supporting their validity as measures of upper extremity function. The correlation between throwing distance and grip strength (r = 0.78–0.81 in controls, r = 0.61–0.7 in RCRSP) is consistent with previous findings in healthy populations [38], suggesting that these relationships persist in the presence of shoulder pain. The mild to moderate correlations observed between the throwing tests and self-reported measures (QuickDASH, FABQ) indicate that these tests capture aspects of function that are relevant to patients' perceived disability and fear-avoidance behaviors. However, the relatively weak correlation with pain intensity (VAS) suggests that throwing performance may be influenced by factors beyond pain alone, such as strength, motor control, or psychological factors.

Comparison with Previous Studies

Our findings for both the SMBT and ULSPT are consistent with previous research, supporting the validity of our results (Table 5). For the SMBT, our results for the control group (3.39 ± 1.24 m) align closely with those reported by Gokalp and Kirmizigil (3.21 ± 0.77 m) in a sedentary population [39]. Similarly, our female results (2.53 ± 0.49 m) are comparable to those reported by Borms and Cools (2.34 ± 0.39 m) in overhead athletes [11].

Table 5. Comparison of current study results with previous research, normalized for ball weight (m/kg).

Study	Population	Test	Ball Mass	Throwing Distance (m)	Distance per kg (m/kg)	Key Findings/Relevance
Current study	Sedentary, RCRSP (n = 30) Control (n = 34), 39 ± 10.4 years	SMBT	2 kg	RCRSP: 2.85 ± 0.98; Control: 3.39 ± 1.24	RCRSP: 1.43 ± 0.49; Control: 1.70 ± 0.62	Current results for comparison
Current study		ULSPT	2 kg	RCRSP: 2.03 ± 0.8; Control: 2.51 ± 0.93	RCRSP: 1.02 ± 0.4; Control: 1.26 ± 0.47	
Gokalp and Kirmizigil 2020 [39]	Sedentary (n = 36), 24.08 ± 4.27 years	SMBT	2 kg	3.21 ± 0.77	1.61 ± 0.39	Similar results for sedentary population
Pinheiro et al. 2020 [13]	Upper extremity athletes, chronic shoulder pain (n = 30), 23.7 ± 4.47 years	ULSPT	3 kg	3.49 ± 0.67	1.16 ± 0.22	Similar results for RCRSP, despite different population
Negrete et al. 2010 [12]	Active adults (n = 180), 38–42 years	ULSPT	2.72 kg	3.34 ± 1.3	1.22 ± 0.48	Similar results for control group
Borms and Cools 2018 [11]	Overhead athletes, tennis subgroup (n = 16), 34–50 years	SMBT	2 kg	F: 2.34 ± 0.39; M: 3.17 ± 0.5	F: 1.17 ± 0.19; M: 1.59 ± 0.25	Similar results for female participants

SMBT—seated medicine ball throw test; ULSPT—unilateral shot-put test, RCRSP—rotator cuff-related shoulder pain, F—female, M—male.

For the ULSPT, our normalized results for the RCRSP group (1.01 ± 0.4 m) are similar to those reported by Pinheiro et al. (1.16 ± 0.22 m) [13], which is the only other study

we identified using ULSPT in a similar clinical population. Our control group results (1.3 ± 0.46 m) are comparable to those reported by Negrete et al. (1.2 ± 0.48 m) [9].

Interestingly, despite assessing a general population compared to the athletic population in Pinheiro et al.'s study [13], our throwing distances are similar. This may be explained by the more persistent nature of symptoms reported in their athletic sample (40.96 ± 36.32 months, compared to 6.33 ± 5.7 months in our study).

It is important to note some methodological differences between studies, including variability in ball weight, number of throws, and lack of ball diameter records in some studies (Table 5) [9,13,18,39]. These differences highlight the need for standardized protocols to enable more direct comparisons between studies and populations.

5.4. Clinical Implications

Our findings support the potential use of the ULSPT as a functional assessment tool in individuals with RCRSP. The test's ability to discriminate between affected and unaffected individuals, coupled with its feasibility and correlations with strength measures, suggests that it could provide valuable information in clinical settings. The ULSPT offers a simple, cost-effective method for assessing upper extremity function that may complement existing assessment techniques.

The observation of bilateral deficits in individuals with unilateral RCRSP underscores the importance of comprehensive upper body assessment and rehabilitation approaches that address both the affected and unaffected sides. This finding aligns with the emerging understanding of the complex, multifaceted nature of RCRSP and its impacts on overall upper extremity function.

We believe the applicability of these tests should not vary significantly across different RCRSP presentations. Based on our findings and theoretical considerations, the ULSPT and SMBT may be appropriate for patients with mild to moderate shoulder symptoms who can maintain appropriate positioning and generate sufficient force for the throwing action. These tests might be less suitable for acute and severe cases or for individuals with significant shoulder stiffness, which could limit the throwing position.

5.5. Limitations

Several limitations of this study should be acknowledged:

The participants with RCRSP in our sample presented with mild to moderate disability and pain levels. Further research is needed to evaluate the applicability of these tests in individuals with more severe presentations.

The relatively young age of our study population (40 years) represents a generalization limitation. The performance characteristics and feasibility of these tests might differ in older populations due to age-related changes in muscle strength, power generation, and overall shoulder function. Future validation studies are needed in older populations to establish age-specific normative values and assess test feasibility in this demographic.

This study has potential heterogeneity within the RCRSP group. While all participants met the clinical diagnostic criteria for RCRSP, this diagnosis is a wide umbrella term. We did not further stratify participants based on specific imaging findings (e.g., tendinopathy, partial-thickness tears, or bursitis) through imaging or arthroscopic diagnosis. Future studies should consider subgroup analysis based on potential pathoanatomical observations to determine if these tests perform differently across various RCRSP presentations. However, this limitation reflects the clinical reality where RCRSP often presents as a complex, multifaceted condition rather than a homogeneous pathology.

The order of physical tests was uniform to avoid fatigue effects from throwing. While this approach ensured consistency, it may have introduced order effects. Future studies with randomized test sequences and larger sample sizes could address this limitation.

We used isometric grip strength as a comparator measure, which has been previously validated against isokinetic measures [17]. However, direct comparison with isokinetic measurements of shoulder strength in this population would further support construct validity.

While we assessed the feasibility of the tests in terms of pain provocation, we did not evaluate their responsiveness to change over time or with intervention. Longitudinal studies are needed to establish the tests' sensitivity to clinical change.

The sample size, while sufficient for our primary analyses, may have limited our ability to detect smaller effect sizes, particularly for the SMBT. Larger studies may provide more definitive conclusions about the discriminative validity of this test. Another limitation is the absence of receiver operating characteristic (ROC) analysis to determine optimal cut-off values for discriminating between individuals with and without RCRSP. Such analysis would enhance the clinical utility of these tests by providing clinicians with specific thresholds for identifying functional deficits and monitoring progress. Future research should focus on establishing these cut-off values across different age groups and activity levels, which would facilitate more precise clinical decision-making and outcome assessment.

6. Conclusions

This study provides initial evidence supporting the use of the ULSPT as a feasible, non-provocative functional assessment tool for individuals with RCRSP. The test demonstrated the ability to discriminate between affected and unaffected individuals and showed meaningful correlations with established measures of upper extremity function. Future research needs to investigate if this difference normalizes after rehabilitation. The observation of bilateral deficits in individuals with unilateral RCRSP highlights the complex nature of this condition and the potential value of comprehensive functional assessment.

While the SMBT did not demonstrate significant discriminative validity in this sample, its strong correlation with the ULSPT and established measures suggests it may still have value in certain clinical contexts. Further research is warranted to fully elucidate the clinical utility of both the ULSPT and SMBT in diverse patient populations and clinical settings.

These findings contribute to the growing body of evidence supporting the use of functional performance tests in the assessment of shoulder disorders. As we continue to refine our understanding of RCRSP and its impacts on upper extremity function, tools like the ULSPT may play an increasingly important role in comprehensive patient assessment and management. This study provides encouraging evidence for the clinical utility of these tests, particularly the ULSPT. However, larger-scale validation studies across diverse populations and clinical settings are needed to establish these tests as standard clinical tools.

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