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ORIGINAL RESEARCH

Test–Retest Reliability of Pain Sensitivity Measures in Individuals with Shoulder Pain

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Background: Central sensitization (CS) has been proposed as a possible contributor to persistent shoulder pain. Measures of sensitivity, such as quantitative sensory tests (QSTs) and sensitivity to movements evoked pain (SMEP), have been increasingly used to investigate CS in a wide range of painful conditions. However, there is a lack of data on whether QST and SMEP are reliable among individuals with shoulder pain. Therefore, the present study aimed to investigate the intra-rater test–retest reliability of QST and SMEP in individuals with chronic shoulder pain.

Materials and Methods: Forty-seven individuals with chronic shoulder pain were enrolled in the study. The QST measures, including pressure pain threshold (PPT) and mechanical temporal summation (MTS), were tested, and SMEP was measured with a lifting task. Relative and absolute reliability were analyzed using intraclass correlation coefficients (ICC 3,1) and standard error of the measurement (SEM), respectively.

Results: The results showed that the ICC coefficients for all sensitivity measures were moderate to good, ranging from 0.63 to 0.86. The SEM% for the QST measures at all sites ranged from 21.4% to 36%, with TS at the forearm demonstrating a high SEM% (greater than 30%). The SMEP measure also showed a high SEM% (46%).

Conclusion: The results showed that the sensitivity measures had moderate to good reliability among individuals with shoulder pain. Acceptable limits of accuracy of measurements were demonstrated for TS and PPT measures, while SMEP demonstrated high error, highlighting the need for further refinement of this measure among these populations.

Keywords: shoulder pain, quantitative sensory testing, sensitive to movement evoked pain, central sensitization, reliability

Introduction

Shoulder pain is the third most common musculoskeletal condition, with serious medical and socioeconomic consequences.[1,2] In the general population, the point prevalence of shoulder pain ranges from 6.9% to 26%, with a lifetime prevalence reaching 67%.[3,4] Almost half of patients with new episodes of shoulder pain continue to have pain after 6 months, and 40% continue to have pain after a year.[1,5] There is currently limited and contradictory evidence on the mechanisms underlying shoulder pain experience.[6,7] Central sensitization (CS) has been proposed as a possible contributor to persistent shoulder pain.[2,8,9]

CS is defined as an amplification of neural signaling within the central nervous system that elicits pain hypersensitivity.[10] CS encompasses a number of abnormal spinal and supraspinal mechanisms that result in increased nociceptive processing and decreased descending nociceptive inhibitory function.[9] Quantitative sensory testing (QST) methods have been used as proxy measures for assessing CS.[11] Several studies reported localized and widespread mechanical hyperalgesia, increased local temporal summation (TS), and a reduction in conditioned pain modulation effect in patients with persistent shoulder pain when compared to healthy individuals.[12–14] The interpretation of QST results from research or clinical settings is predicated on the assumption that the measurements are stable and reliable.[15] The reliability of QST measures has been investigated, and the results show acceptable reliability in healthy individuals.[15] However, the reliability of some QST measures such as TS has not been investigated in individuals with shoulder pain.

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Sensitivity to movement-evoked pain (SMEP) is a novel and functional form of sensitivity assessment that measures construct similar to QST outcomes.[16] SMEP has been proposed as a useful method for assessing pain summation, a key feature of central sensitization.[16] Evidence shows increasing pain levels (ie, pain summation) over repeated movements of the painful body region in a subgroup of people with chronic musculoskeletal pain including shoulder pain.[14,17,18] Assessment of SMEP may provide insights into peripheral and central mechanisms contributing to persistent pain experiences.[19] Currently, there is a lack of data on whether SMEP is reliable among individuals with shoulder pain. None of the previous studies established the test–retest reliability of SMEP among individuals with shoulder pain.

Establishing of the reliability of sensitivity measures, such as PPT, TS, and SMEP, would assist clinicians in identifying features of CS in individuals with chronic shoulder pain. These instruments are commercially available, not extremely expensive, and met measurement standards in clinical setting. Therefore, the aim of this study is to investigate the test–retest reliability of PPT, TS, and SMEP index in individuals with chronic shoulder pain.

Methodology

Study Design

A test–retest reliability study design was used to explore the reliability of the QST measures (ie, PPT and TS) and SMEP among individuals with shoulder pain. Demographic data (sex, age, height, weight, and race) and pain characteristics were collected at baseline. The study was approved via The Human Research Ethics Committee at King Abdulaziz University's Faculty of Medical Rehabilitation Sciences (Reference No. FMRS-EC2023-020). This study complies with the Declaration of Helsinki, and all patients provided written informed consent prior to enrolment.

Study Population

This study included adults between 18 and 65 years, who subjectively complaining of chronic shoulder pain primarily limited to the anterior, lateral, or posterior shoulder for at least 3 months, with a current pain intensity of at least 3 on an 11-point numeric pain rating scale (NPRS).

Exclusion Criteria

Shoulder pain associated with the following conditions/situations was excluded from participating in this study: (1) trauma; (2) inflammatory arthritis and infectious diseases; (3) neurological disorders (4) neck pain with pain referred to the shoulder regions or with radicular pain/radiculopathy; (5) underwent any surgery in the previous six months; (6) pregnancy; (7) fibromyalgia.

Sampling and Study Procedures

A convenience sampling strategy was used to recruit participants for this study. Participants from the wider community were invited to participate. Study advertisements (flyers/posters) in the public media, including public notice boards and social networking sites, sports clubs and gyms, and around the university were executed. A snowball sampling technique as a chain referral was also followed to facilitate the recruitment.

Volunteers interested in participating in the study were requested to contact the research team (via telephone or e-mail) at the King Abdulaziz University, Faculty of Medical Rehabilitation Sciences, Physiotherapy department. A member of the research team screened volunteers for the eligibility criteria. Volunteers were provided with the information sheet to familiarize themselves with the study protocol. Eligible volunteers were then provided with an appointment at the Physiotherapy department. Participants were instructed to refrain from taking any analgesics or anti-inflammatory medications 24 hours before the examination session to avoid variability in responses to the QST measures. Written informed consent was obtained from all participants on the day of assessment.

Examination Session

Following the signing of the consent form and completion of the demographic questionnaires, all participants were requested to complete a series of sensory testing conducted by the outcome assessor administered QST and recorded the outcomes in a private examination room. The outcome assessor measured the following measures: static and dynamic QST measures (eg, PPT, TS) and SMEP (ie, repeated lifting task). All participants who completed the baseline assessment were asked to attend a follow-up assessment. Participants were provided with an appointment one week after the baseline assessment. During the follow-up assessment, the same outcome assessor measured the PPT, TS, and SMEP.

Pain Intensity

Shoulder pain intensity was assessed with the Brief Pain Inventory (BPI).[20] The BPI includes an 11-point numerical rating scale, through which participants rate their pain using 0–10 rating anchored at zero "no pain" and 10 "pain as bad as you can imagine". Participants rated their current pain intensity, and the average pain intensity.

Measures of Sensitization

Quantitative Sensory Testing (QST)

Pressure Pain Threshold (PPT)

PPT is a static QST measure defined as the least amount of force required to cause pain.[21,22] PPT was measured using a handheld algometer (Wagner Force One™ FDIX) with a probe area of 5cm (Figure 1). The algometer was positioned vertically on the anatomical testing site, with pressure gradually increasing from 0 at a ramp rate of 50kPa/s to a maximum pressure of 1000kPa.[23,24] The subject reported when the sensation of pressure alone changes to the first pain. At this point, the test was terminated, and the value of pressure applied was recorded and defined as the PPT. PPT was described as the mean of the three trials with a lower score indicates high pressure pain sensitivity.

Mechanical Temporal Summation (TS)

TS is a dynamic psychophysical measure that reflects the wind-up process within the dorsal horn wide-dynamic range neuron.[22] The mechanical TS was measured using a Von Frey filament (no. 6.65) tapping within a small area of 1cm^2 to the dorsum of the distal forearm (unaffected side) and at the mid-deltoid muscle on the affected side (Figure 2).[2,14] The procedure was repeated three times with a one-minute rest period between trials. Participants were asked to rate their pain intensity (11-point NPRS) after a single (first) stimulus and after a train of ten stimuli delivered at a rate of 1Hz. The mechanical TS of pain was defined as the absolute difference in scores between the mean pain ratings of ten series and

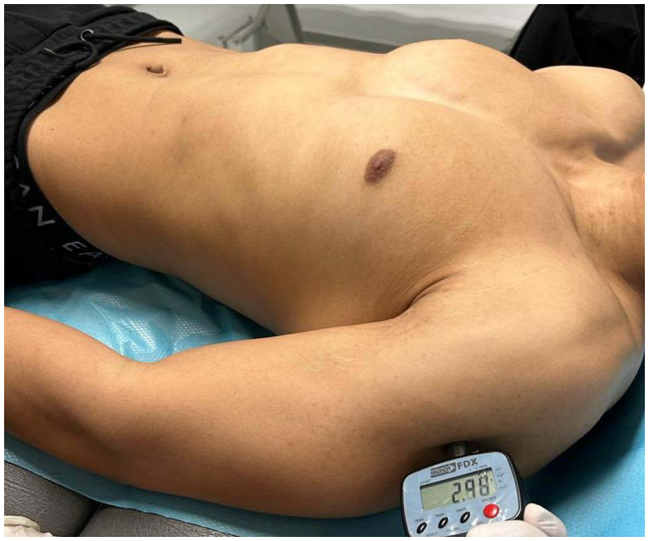

Figure 1 PPT test using a handheld algometer at the affected side.

Figure 2 TS test using Von Frey filament at the affected side and contralateral forearm.

the mean pain ratings of single stimuli. Higher change scores indicate facilitation of TS, an index of central nervous system sensitization.

Sensitivity to Movement-Evoked Pain (SMEP)

After completing QST testing procedures, all participants performed the canister-lifting task using the symptomatic shoulder.[14,25] The chosen task has been validated in people suffering from shoulder pain.[14,25,26] The canister-lifting task was completed by all participants. Participants were instructed to stand in front of a height-adjustable table and lift 18 weighted canisters. The canisters weighed 2.9, 3.4, or 3.9 kg and were arranged in three rows of six columns on the table Because all the canisters are identical, the participants are unable to predict the weight of the canisters. The table height was adjusted for each participant, so the canisters' grip in the front row (closest to the participants) is at standing elbow height. Each canister's top was labeled with a letter ranging from A to R. Participants were told to lift the canisters in alphabetical order. They were instructed to vertically lift the canister off the table for about 5 cm and hold it for about 3 seconds. As they lifted each canister, participants were asked to rate their pain on an 11-point numerical pain rating scale. Participants were also advised to complete the task at their own pace. The SMEP index was calculated by subtracting the mean pain ratings for the first three lifts from the mean pain ratings for the final three lifts of the 18 canisters.[14,25,26] Higher change scores indicate greater sensitivity to functional task, a feature of central nervous system sensitization. In addition, the average pain rating across the 18 lifts was calculated, representing the average pain elicited by a physical task (ie, movement-evoked pain).

Sample Size

Based on previous research on the reliability of QST testing measures in people with neck pain and the COSMIN Checklist for assessing the methodological quality of studies on measurement properties, a reliability study requires at least 30 participants.[27,28]

Statistical Analysis

All statistical analysis was performed using IBM SPSS Statistics (version 26). Descriptive analysis was generated for all variables, including demographic, and sensitization measures. Reliability estimates were calculated using both relative (ICC) and absolute (SEM, MDD) estimates. The relative reliability across the 2-time points was calculated to obtain the Interclass Correlation Coefficient (ICC). The ICC was obtained using a single measure, consistency, 2-way mixed-effect model (ICC3,1) described by Shrout and Fleiss (1979).[29] ICC values >0.90 are interpreted as excellent reliability, values between 0.75 and 0.90 indicate good reliability, values between 0.50 and 0.75 indicate moderate reliability, and values less than 0.50 indicate poor reliability.[30]

To facilitate the interpretation of PPT, TS, and SMEP values and identify true differences, a measure of absolute reliability (ie, measurement error) quantified using the standard error of measurement (SEM) was calculated in the current study. The SEM is a statistical indicator of the precision of repeated individual measurements, and it provides the range of measurements that might occur in a subject on repeated testing.[31] The SEM was calculated as the square root of the mean square error term from the repeated measures of variance (ANOVA) and expressed in actual SEM values and their percentages (SEM%). Since there is no formal classification for the SEM%, previous reliability studies classified their SEM% as excellent (≤10%) and acceptable (11–30%).[32–34] For this study, a similar classification of SEM% was used to interpret the results. The minimum detectable difference (MDD) was calculated using the SEM index and the formula SEM × 1.96 × $2^{½}$. This represents the smallest change that can be considered a true change beyond measurement error.[15,35] Bland-Altman plots were utilized to visually examine possible discrepancies between the measurements. The mean difference between the two repeated measures and 95% limits of agreement was calculated.

Results

Figure 3 shows the flow chart of the recruitment and screening process of study participants. A total of 47 participants with chronic shoulder pain were enrolled in this study and included in the current analysis.

Participant Characteristics

Table 1 presents a summary of the descriptive statistics of the demographic features of the study participants. The clinical participants with shoulder pain comprise 40 men and seven women with age ranging from 20 to 62 years. The majority of these participants (n = 27, 57%) report experiencing pain in their right shoulder. The reported pain severity falls within a mild-to-moderate level of pain severity (mean of 3.91; SD 1.10) on a 11-point NPRS.

A summary of participant scores for sensitivity measures (ie, TS, PPT, and SMEP) is presented in Table 2. At baseline, the mean (±SD) of TS at the painful shoulder was 1.54 (±1.09), exceeding that of the remote site, which recorded a mean (±SD) TS of 1.32 (±0.90). Conversely, the mean (±SD) of SMEP score was 1.00 (±0.75), indicating a smaller magnitude compared to the TS at both sites.

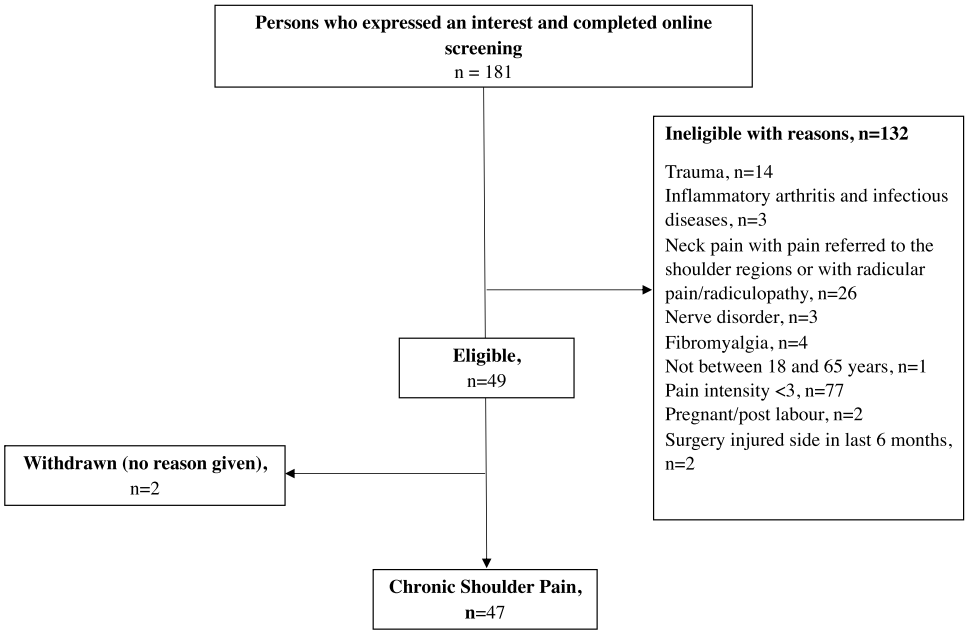

Figure 3 Flow chart of recruitment and screening process.

Table 1 Participant's Characteristics

Characteristic	Shoulder Pain (N= 47)
Duration of pain in month: Mean (SD)	25.33 (26.67)
Sex	
Male, *n* (%) Female, *n* (%)	40 (85.1%) 7 (14.9%)
Chronicity	
Acute, *n* (%) Chronic, *n* (%)	4 (8.5%) 43 (91.5%)
Ethnic group	
Saudi, *n* (%) Non-Saudi, *n* (%)	45 (95.7%) 2 (4.3%)
Marital status	
Single, *n* (%) Married, *n* (%)	41 (87.2%) 6 (12.8%)
Occupation	
Employed full-time, *n* (%) Self-employed, *n* (%) Retired, *n* (%) Homemaker, *n* (%) Student, *n* (%)	8 (17.0%) 1 (2.1%) 1 (2.1%) 1 (2.1%) 36 (76.6%)
Dominant side	
Right, *n* (%) Left, *n* (%)	45 (95.7%) 2 (4.3%)
Tested shoulder	
Right, *n* (%) Left, *n* (%)	27 (57.4%) 20 (42.6%)
Age	
Range (years) Mean (SD)	20–62 25.19 (8.96)
BMI (kg/m^2)	
Range Mean (SD)	17.90–42.02 25.29 (5.76)
Pain Severity	
Average pain severity in the past 24 hours Mean (SD) Current pain (at the time of testing) Mean (SD)	3.20 (1.64) 3.91 (1.10)

Reliability of PPT, MTS, and SMEP

The results of the reliability analysis are summarized in Table 2. The ICC was moderate to good (range from 0.63 to 0.86) for all sensitivity measures. The ICC value of TS was higher at the painful shoulder compared to the forearm. The SMEP measure had the lowest ICC value (0.63) among the sensitivity measures. The SEM% for the PPT and TS ranged

Table 2 Test–Retest Reliability of the Sensitivity Measures

Measures	Bassline Mean (SD)	One-Week Mean (SD)	Mean of 2 Trials (SD)	ICC3,1 (95% CI)	SEM (%)	MDD	Mean Difference (95% Limits of Agreement)
TS							
Painful shoulder	1.54 (1.09)	1.80 (1.12)	1.67 (1.23)	0.73 (0.57–0.84)	0.50 (29.8%)	1.39	−0.26 (−1.84–1.33)
Forearm	1.32 (0.90)	1.51 (1.04)	1.42 (0.94)	0.65 (0.45–0.79)	0.52 (36.6%)	1.44	−0.19 (−1.77–1.39)
PPT							
Painful shoulder	315.07 (180.51)	283.77 (174.98)	299.42 (171.45)	0.86 (0.76–0.92)	64.15 (21.4%)	177.81	31.30 (−152.83–215.43)
MEP							
Painful shoulder	2.05 (1.97)	1.95 (1.56)	2.00 (3.16)	0.86 (0.77–0.92)	0.60 (30.0%)	1.66	_
SMEP							
Painful shoulder	1.00 (0.75)	1.22 (1.10)	1.11 (0.89)	0.63 (0.42–0.78)	0.52 (46.8%)	1.44	−0.22 (−1.81–1.38)

Abbreviations: TS, temporal pain summation; PPT, pressure pain threshold; SMEP, sensitivity to movement-evoked pain; MEP, movement-evoked pain.

from 21.4% to 36%, with TS at the forearm demonstrating a high SEM% (ie, greater than 30%). Further, a high SEM% (46%) was observed for the SMEP test. Table 2 additionally presents the MDD for all sensitivity measures.

The Bland-Altman plots for reliability are shown in Figure 4. The data show that all mean differences were close to zero. Visual inspection of the plots revealed that the overall measurement error was small, with proportional increases at the higher ends of the scale.

Discussion

This study aimed to investigate the test–retest reliability of pain sensitivity measures including PPT, MTS, and SMEP among individuals with chronic shoulder pain. The reliability analysis indicated that the ICC ranged from moderate to good for all sensitivity measures. The TS was found to be more precise at the painful shoulder than at the forearm. The

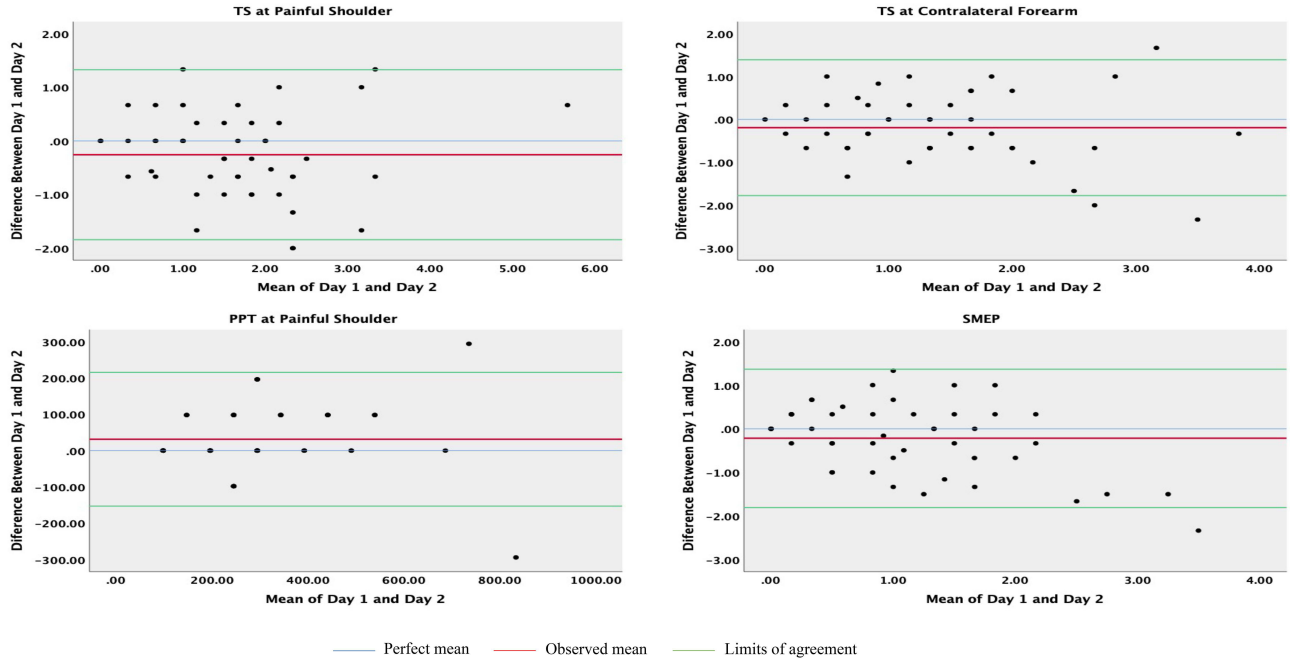

Figure 4 Bland-Altman plots for test–retest agreement.

SMEP test exhibited the lowest ICC value among the sensitivity measures. Acceptable limits of agreement of measurements (ie, SEM%) was demonstrated for TS at the painful shoulder, as well as for PPT measures, while TS at the forearm and SMEP demonstrated high error (>30%).

The current findings indicated that PPT has a good reliability with acceptable limits of accuracy (ie, SEM%) among individuals with chronic shoulder pain. This is supported by evidence from a recent study that showed PPT applied to shoulder muscles had a good to excellent intra- and inter-reliability in assessing pain sensitivity in individuals with chronic shoulder pain.[36] Findings from the present study showed that the absolute reliability (ie, SEM) of the PPT was around 64 KPa. This was consistent with a previous study reported similar values which absolute reliability of the PPT ranged from 42.17 to 73.55 KPa in the shoulder pain patients.[37] Additionally, the minimal clinically important differences of PPT were described in a prior study that included elderly participants with non-specific shoulder pain, which ranged from 1.15 to 1.17 kg/cm2.[38] The results indicated the usefulness of the PPT to assess the upper limb after interventions in older adults with non-specific shoulder pain. These data suggest that PPT would be used as a reliable tool in a clinical setting for measuring pain sensitivity.

In the present study, mechanical TS demonstrated moderate reliability among individuals with chronic shoulder pain. In agreement with our findings, fair to good long-term reliability was observed among healthy participants with ICC values ranging from 0.51 at the back to 0.61 at hand.[15,39] The absolute long-term reliability of TS has also been reported across different anatomical sites in healthy volunteers, with values ranging from 0.11 to 0.18.[15,39] Additionally, test–retest analysis in healthy subjects indicated good to excellent reliability of TS, with one study reporting acceptable within-session test–retest reliability of TS applied to healthy shoulders using pressure stimulus.[40] However, a comparison with other research was not feasible since this is the first study to assess the reliability of TS among participants with chronic shoulder pain.

It should be noted that static QST measures (ie, PPT) demonstrated acceptable limits of accuracy of measurements (ie, SEM%: 21.4%). Similar to our findings, a recent study showed that PPT applied at shoulder has a good to excellent intra- and inter-reliability to assess pain sensitivity in individuals with shoulder pain with variation generally less than 15% in most intra-day intra-rater assessments.[36] By contrast, the reliability of the dynamic QST (ie, TS) was found to be lower with high percentage error than static QST (ie, PTT) in our sample. This finding agrees with Marcuzzi et al (2017), where the reliability of TS was lower than the PPT in healthy individuals.[15] An explanation for this finding could be the differences in response to static and dynamic QST measures.[15] Static measures that determine a threshold assess the basal state of the nervous system and are considered to involve a stable and reproducible endpoint.[15,41] Whereas dynamic QST tests involve assessing of more complex mechanisms of nociceptive modulation, including multiple and combined central processing.[15,41] However, results from this study suggest that QST measures demonstrated acceptable error among individual experiencing shoulder pain.

The variability of QST measures observed in the current study may be explained by the rate of pressure increase (PPT)/stimulus delivery (TS) and the participants' reaction time when asked to stop applying pressure.[36] Furthermore, participants with shoulder pain may experience more variable pain perception as a result of peripheral sensitization caused by continuous nociceptive afferents from the clinical condition. Although training tends to mitigate this issue, it is difficult to replicate the same assessment condition because the muscles might react to the applied stimulus differently.[36]

This study further demonstrated a moderate reliability of SMEP among individuals with chronic shoulder pain. The current findings support and extend the emerging body of research showing that SMEP discriminates between healthy individuals and patients with shoulder pain.[14] Additionally, previous studies have demonstrated that SMEP exists in individuals with chronic shoulder pain.[14] This characteristic is also observed in a subset of participants with other chronic musculoskeletal pain conditions.[18,26] As this is the first study to investigate the reliability of SMEP, a comparison with other studies was not possible.

Like TS, the reliability of the SMEP was found to be lower with a high percentage error. One explanation could be that the SMEP is assessing more complex mechanisms of nociceptive modulation, such as multiple and combined central processes.[15,41] Another possibility is the role of psychological factors and their potential impact on protective motor strategies.[42] For example, inappropriate beliefs, such as catastrophic pain thoughts, may lead to avoidance behavior, resulting in different motor adaptations.[42] Additionally, it is probable that the repeated movement of the shoulder trigger increased nociceptive activity through peripheral mechanisms,[17,25] which lead to experience more variable pain perception.

Limitations

To the author's knowledge, the present study is the first to investigate the test–retest reliability of pain sensitivity measures including SMEP among individuals with chronic shoulder pain. Since there is no formal classification for the SEM%, previous reliability studies classified their SEM% as excellent (≤10%) and acceptable (11–30%). A similar classification of SEM% was used to interpret the results for this study. However, the current study has several limitations, including the inability to divide the sample by sex to assess possible differences between men and women. The substantial variations in the proportion of male participants (85.1%) versus females (14.9%) could be a critical study limitation. While effort was made to ensure that participants were tested at the same time of day for each session, this was not always possible.

Future Research

Future research should address study limitations, such as the gender imbalance and age variance, as well as conduct a long-term test–retest reliability assessment of sensitivity measures. Moreover, exploring the underlying mechanisms of SMEP and its potential as a predictor of clinical outcomes will be essential to advance our understanding of pain sensitivity in shoulder pain patients and inform more effective therapeutic approaches. Additionally, there is large evidence demonstrating the validity and reliability of employing a fully automated pupillometry approach to capture the pupil diameter in order to obtain a direct impression of the functioning of the autonomic nervous system.[43] This area requires further investigation in the future to explore the relationship between QST, SMEP, and autonomic nervous system function utilizing an automated pupillometry instrument.

Clinical Implication

The finding from this study has the potential to be of great value to health-care professionals working in the evaluation and treatment of individuals with shoulder pain. In that assessing PPT, TS, and SMEP using a bedside tool may be combined with clinical assessment of patients with shoulder pain to identify the presence of CS. Furthermore, clinicians may utilize the information in this study to determine whether the change they observe between assessment sessions is due to true change or random error.

Conclusion

The present study provides valuable insight into the short-term reliability of sensitivity measures in individuals with chronic shoulder pain. The findings demonstrate moderate to good reliability for the tested measures (ie, PPT, TS, and SMEP), with the SMEP exhibiting the lowest ICC value. In terms of measurement error (ie, SEM), TS and PPT measures demonstrated acceptable limits of accuracy, however SMEP showed a large error, highlighting the need for further refinement of this test.

Data Sharing Statement

All datasets used and analysed during the current study are available from the corresponding author upon reasonable request.

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Disclosure

The authors have no conflicts of interest to declare for this work.

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