Psychometric Properties of Pressure Pain Thresholds Measured in 2 Positions for Adults With and Without Neck-Shoulder Pain and Tenderness

Sharon Wang-Price, PT, PhD,[a] Jason Zafereo, PT, PhD,[b] Kelli Brizzolara, PT, PhD,[a] Brendan Mackin, PT, DPT,[a] Larry Lawson, PT, DPT,[a] Dayna Seeger, PT, DPT,[a] and Shannon Lawson, PT, DPT[a]

Abstract

Objective: The purpose of this study was to determine the psychometric properties of pressure pain threshold (PPT) testing in adults with and without neck-shoulder pain and tenderness and to compare the differences in PPT measurements between the seated and prone positions.

Methods: Thirty asymptomatic adults and 30 symptomatic patients with intermittent neck-shoulder pain and tenderness completed the study. A pressure algometer was used to assess PPTs at specific points on the middle deltoid, levator scapulae, and upper trapezius muscles of the dominant side of the asymptomatic individuals and the painful side of the patients. Four trials were performed on each muscle in both the seated and prone positions. To determine between-day reliability, a subset of the participants returned to repeat the testing.

Results: The intraclass correlation coefficients showed good to excellent within-session reliability and fair to excellent between-day reliability of PPT measurements in both the seated and prone positions for both groups. There were significant differences between groups for all muscles in both positions ($P < .05$) except for the upper trapezius muscle in the prone position. In addition, significant differences were found between the 2 testing positions for the middle deltoid and upper trapezius muscles in the symptomatic group and for the middle deltoid muscle in the asymptomatic group.

Conclusion: The results of the study suggest that PPT testing could be useful for distinguishing individuals with and without neck-shoulder pain and tenderness. Further, the patient's position should be considered when testing PPT, specifically at the middle deltoid or upper trapezius muscles. (J Manipulative Physiol Ther 2019;42:416-424)

Key Indexing Terms: *Reproducibility of Results; Spine; Hyperalgesia; Nociception; Pain Measurement*

Introduction

In the past 2 decades, neck-shoulder pain has become more prevalent owing to an increased use of computers.[1-3] The 12-month prevalence of neck-shoulder pain was found to be 55% in workers using computer monitors for more than 6 hours.[3,4] Although most neck-shoulder pain in computer users is intermittent, of low intensity, and not serious enough to interfere with normal activities, 18% to 30% of workers report severe tenderness to palpation, particularly in the upper trapezius and levator scapulae muscles.[1,5] Central facilitation phenomenon originating from an underlying pathology at the cervical spine has been attributed to the manifestation of neck-shoulder tenderness or hyperalgesia along the upper trapezius and levator scapulae muscles.[2,6-8] In patients with central facilitation, there is an increased excitability of the neurons in the central nervous system, resulting in hypersensitivity to both noxious and nonnoxious stimuli, including mechanical stimuli.[9,10]

The pressure pain threshold (PPT), defined as the minimal amount of pressure that produces pain, has been used extensively to quantify the amount of hyperalgesia and to examine pain behavior and treatment effects for patients

[a] School of Physical Therapy, Texas Woman's University, Dallas, Texas.
[b] Department of Physical Therapy, University of Texas Southwestern Medical Center, Dallas, Texas.
Corresponding author: Sharon Wang-Price, PT, PhD, School of Physical Therapy, Texas Woman's University, 5500 Southwestern Medical Avenue, Dallas, TX 75235. Tel.: +1 214 689 7715.
(e-mail: *swang@twu.edu*).
Paper submitted February 17, 2018; in revised form June 11, 2018; accepted November 2, 2018.
0161-4754

https://doi.org/10.1016/j.jmpt.2018.11.021

with neck-shoulder pain.[8,11] In particular, PPT testing of the upper trapezius muscle has been the focus of much research because its reliability and responsiveness were found to be good for patients with neck-shoulder pain of traumatic or nontraumatic onset.[7,8,12] In addition, the PPT of the upper trapezius muscle has been reported to decrease by approximately 11% to 12% after 30 minutes of computer use[13] and was significantly correlated to self-reported pain intensity.[14] Although the PPT of the upper trapezius muscle of patients with neck-shoulder pain was reportedly lower than that of asymptomatic individuals in 1 study,[7] no difference was found in other studies between asymptomatic and symptomatic groups.[2,3] These conflicting findings raise concern over the clinical use of PPT testing to distinguish people with and without neck-shoulder pain.

Neck-shoulder pain is often described as tightness or tenderness in many muscles, including the levator scapulae or deltoids; however, only a few studies have examined the PPT of sites other than the upper trapezius muscle.[1,3] In addition, the PPTs of the neck-shoulder muscles were investigated in the prone position or in the seated position, but it is unclear if the PPTs of neck-shoulder muscles are position dependent. Therefore, the primary purpose of this study was to determine the psychometric properties of PPT testing, including within-session reliability, between-day reliability, minimal detectable changes (MDCs), construct validity using the known-groups method, and cut-off scores for distinguishing the asymptomatic and symptomatic groups. Data were collected from adults with and without neck-shoulder pain and tenderness in both the seated and prone positions. The secondary purpose of the study was to compare the differences in PPT measurements between the seated and prone position for both groups.

Methods

Participants

This study was approved by the institutional review board of the Texas Woman's University in Dallas, Texas. Participants were recruited either from the physical therapy clinic, at which 1 investigator was employed, or from local communities. To estimate an adequate sample size for reliability analysis, an a priori power analysis was performed using G*Power 3.1.3, specifically an analysis of variance with repeated measures within factors.[15] Using a medium effect size (f) of 0.25,[7] a minimum of 28 participants for each group and 56 participants in total were required to obtain a power of 0.80 at an α level of 0.05. Asymptomatic participants were individuals with no existing neck-shoulder pain and tenderness and no neck-shoulder pain in the previous year. Participants in the symptomatic group were individuals who had existing neck-shoulder pain with an average pain intensity score ≥2 of 10 on the Numeric Pain Rating Scale (NPRS) within the past 72 hours and tenderness with palpation. In addition, the eligible participants in the symptomatic group had a history of intermittent neck-shoulder pain for a minimum of 3 months. Exclusion criteria for all participants included a history of neck or shoulder surgery, systemic joint disease (eg, rheumatoid arthritis), cancer of the upper quadrant, neurologic disorders, or inability to obtain the testing position (ie, seated and prone lying). Each participant was informed of the risks and procedures of the study and then signed a written informed consent form before data collection.

Instrumentation

A handheld computerized pressure algometer (Medoc Ltd, Ramat Yishai, Israel) was used to determine the PPT of each muscle site being tested. The algometer consists of a 1-cm^2 round tip that is pressed vertically on the target location of the muscle being assessed. To provoke the patient's pain or discomfort, pressure was increased gradually at a rate of 40 kPa/s until the participant felt the sensation of pressure change to a sensation of pain, at which time the participant pressed the response button to stop testing.[3,7,16] The PPT registered at the time of shutoff was operationally defined as the patient's PPT for the tested muscle site. In addition, the algometer's pressure limit was set at 600 kPa, meaning that testing stopped automatically at a pressure of 600 kPa to minimize tissue damage. If the participant did not push the response button before 600 kPa was reached, a value of 600 was recorded as the threshold value. Three testers administered the PPT testing depending on their availability; however, the same tester performed the PPT on the same participant throughout the study. A sloping line at 40 kPa/s of PPT with the starting point at 0 kPa and the highest point at 600 kPa was displayed on the computer screen so that the tester could follow the line during the testing to maintain consistency of the PPT tests. The PPT testing protocol was standardized, and each tester practiced the protocol for approximately 5 hours before performing data collection on participants.

Procedure

Before the pressure algometric measurements, eligible participants were asked about their demographic information and past medical history. The Neck Disability Index Questionnaire (NDI) was administered to all participants to determine their perceived disability and functional limitations owing to their neck-shoulder pain.[17,18] In addition, symptomatic participants were asked about the onset and duration of their neck-shoulder pain and to rate their pain severity on a scale of 0 to 10, with 0 indicating no pain and 10 indicating unbearable pain, in 3 different conditions: current, worst, and least in the past 72 hours.

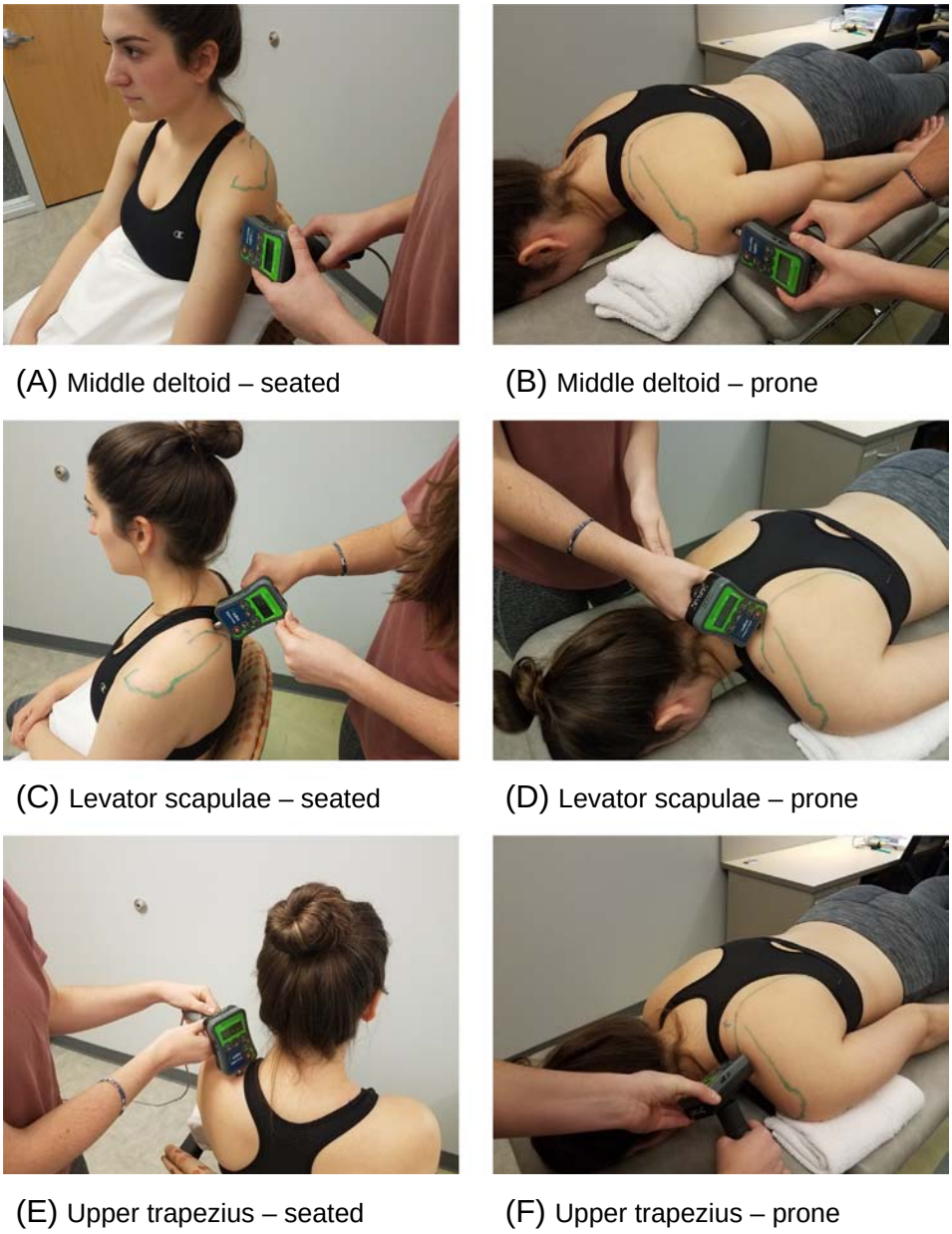

Fig 1. *Pressure pain threshold testing for the middle deltoid, levator scapulae, and upper trapezius muscles in the seated and prone positions. Middle deltoid—seated (A). Middle deltoid—prone (B). Levator scapulae—seated (C). Levator scapulae—prone (D). Upper trapezius—seated (E). Upper trapezius—prone (F).*

At the start of testing, a patient response unit with a red button was given to each participant. The participant was instructed to hold the response unit in the nontesting hand and press the button once the sensation of pressure changed to a sensation of pain. The PPT measurements were taken from the 3 muscles (middle deltoid, levator scapulae, and upper trapezius) on the dominant side of asymptomatic participants and from the painful side of symptomatic participants with the participants in a supported seated position and in a prone position (Fig 1). The upper trapezius and levator scapulae muscles are common sites that are often tender or tight to deep palpation. Although the middle deltoid muscle is rarely identified as a painful site, the PPT could be changed as a result of central or segmental facilitation.[1]

The order of the testing position was randomized. However, the muscle sites were always tested in the following order: middle deltoid, levator scapulae, and upper trapezius. The precise testing location for each muscle has been described previously.[8,16,19] For the middle deltoid

Table 1. *Characteristics of Participants With and Without Neck-Shoulder Pain and Tenderness*

Characteristic	Asymptomatic Group (n = 30)	Symptomatic Group (n = 30)	*P* Value
Sex (% female)	70%	80%	.552
Age (y)	26.9 ± 5.7	29.9 ± 8.8	.341
Height (cm)	171.2 ± 7.9	167.4 ± 8.6	.666
Weight (kg)	71.0 ± 12.5	68.6 ± 17.6	.142
NDI score (%)	1.6 ± 2.3	20.3 ± 15.3	<.001 [a]
Computer use (h/d)	3.3 ± 2.3	5.0 ± 3.0	.085
Sitting (h/d)	8.6 ± 2.8	8.4 ± 2.8	.700
Onset		Trauma: n = 5 Insidious: n = 25	-
Duration of intermittent neck-shoulder pain (mo)	-	32.0 ± 37.5	-
NPRS score (0-10)			
Current	-	2.0 ± 1.7	-
Worst	-	4.3 ± 1.5	-
Best	-	1.4 ± 1.7	-

NDI, Neck Disability Index Questionnaire; *NPRS*, Numeric Pain Rating Scale.
[a] Significance level at $P < .05$.

muscle, the pressure algometer was applied at the midpoint between the insertion of deltoid and acromion. For the levator scapulae muscle, it was applied at the point 2 cm above the lower insertion of levator scapulae located in the upper medial border of the scapula. Last, for the upper trapezius muscle, it was applied at the point halfway between the midline and lateral border of the acromion.

Four measurements were taken from each site, with a minimum of 5 seconds between measurements. The first measurement was used as a practice trial; therefore, the average of the last 3 measurements was used for data analysis.[20,21] To determine between-day test–retest reliability, the participants were asked to return for the second visit approximately 3 to 7 days later to repeat PPT testing.

Statistical Analysis

Descriptive statistics were calculated for participant characteristics and PPTs of all participants. IBM SPSS version 25.0 (IBM Corp, Armonk, New York) was used to perform statistical analysis. Intraclass correlation coefficients (ICCs) were calculated to determine reliability using a 2-way mixed-effects model and a consistency type.[22] Specifically, $ICCs_{3,1}$ were used to determine within-session reliability and $ICCs_{3,3}$ were used to determine between-day reliability, respectively. In addition, MDCs were calculated for the symptomatic group using the formula $MDC_{90\%} = SD_{pooled} \times \sqrt{1-ICC} \times \sqrt{2} \times 1.64$.[23] The 90% confidence level was used to reflect clinical practice for assessing the patient's changes over time.[7] Because the normality assumption was not met, nonparametric statistics were used for between-group and between-position comparisons. To determine construct validity using the known-groups method, Mann-Whitney *U* tests were used to compare the differences between groups. When there was a significant difference between groups, a receiver operating characteristic (ROC) analysis was performed to determine the cut-off score of the PPTs. Lastly, Wilcoxon signed rank tests were used to compare the differences between positions. The α level was set at 0.05 for all statistical analyses.

Results

Sixty-three participants were enrolled in the study from March 2015 through April 2017, and 60 participants—30 asymptomatic adults and 30 patients with neck-shoulder pain and tenderness—completed the study. Three participants were excluded from the study because they had neck-shoulder pain but did not have tenderness upon palpation. Of these 60 participants, 20 asymptomatic and 18 symptomatic participants returned for the second PPT

Table 2. *Comparison of Pressure Pain Thresholds (kPa) Between Groups for the Middle Deltoid, Levator Scapulae, and Upper Trapezius Muscles in the Seated and Prone Positions*

Position/Muscle	Asymptomatic Group (n = 30)	Symptomatic Group (n = 30)	*P* Value
Seated			
Middle deltoid	248.9 ± 97.7	194.7 ± 137.9	.006 [a]
Levator scapulae	322.0 ± 153.6	246.5 ± 158.1	.025 [a]
Upper trapezius	229.3 ± 99.8	167.6 ± 88.8	.014 [a]
Prone			
Middle deltoid	309.2 ± 134.4	228.6 ± 170.7	.003 [a]
Levator scapulae	313.7 ± 163.9	244.1 ± 169.8	.031 [a]
Upper trapezius	234.6 ± 117.2	204.1 ± 142.4	.088

[a] Significance level at $P < .05$

testing for between-day reliability. Table 1 illustrates the characteristics of the participants, including sex, age, height, weight, and NDI scores of both groups and onset and duration of neck-shoulder pain and the NPRS scores of the symptomatic group. There were no significant differences between groups in sex, age, height, and weight. The symptomatic group had longer hours of computer use, but they were not significantly different from those in the asymptomatic group ($P = .085$). The NDI score (20.3 ± 15.3) and the current NPRS score (2.0 ± 1.7) indicate that the asymptomatic participants had mild disability owing to low levels of pain. However, the long duration of their intermittent neck-shoulder pain (32.0 ± 37.5 months) indicates that their neck-shoulder pain had become chronic, with a high likelihood of central facilitation.

Table 2 lists the means and standard deviations of PPTs measured in both the seated and prone positions for all 3 muscles. The reliability analysis revealed good-to-excellent within-session reliability of PPT measurements collected in both the seated and prone positions, with ICC values ranging from 0.849 to 0.947 for the asymptomatic group and 0.922 to 0.963 for the neck-shoulder pain group (Table 3). Although the ICC values for the between-day reliability were lower than those of the within-session reliability, the values showed good-to-excellent between-day reliability for both groups in both positions, ranging from 0.861 to 0.980 with the exception of the ones for the middle deltoids and upper trapezius muscles of the asymptomatic group in the seated position, which were fair, with ICCs of 0.731 and 0.710, respectively. The MDCs (Table 3), calculated using the between-day ICCs of the symptomatic group, were similar between the seated and prone positions, with the middle deltoids having the lowest MDCs in both positions (73.8 kPa for seated, 74.4 kPa for prone).

Mann-Whitney *U* tests revealed significant differences between the 2 groups for all muscles in both the seated and prone positions ($P < .05$) except for the upper trapezius muscle in the prone position ($P = .088$) (Table 2). Therefore, ROC analysis was not performed for the PPTs of the upper trapezius muscle in the prone position. Table 4 shows the results of ROC analysis for the PPTs of neck-shoulder pain and tenderness, including sensitivity, specificity, cut-off scores, area under the curve, and *P* values. The ROC curves suggest that the PPTs at all 5 testing sites were able to discriminate between the individuals with and without neck-shoulder pain and tenderness. Wilcoxon signed rank tests revealed a significant difference in PPTs between the seated and prone positions for the middle deltoid muscle ($P = .002$) of the asymptomatic individuals and for the middle deltoid ($P = .032$) and upper trapezius ($P = .003$) muscles of the symptomatic group. These significant differences between positions suggest that these PPT measurements are position dependent.

Discussion

The results of the study showed overall good-to-excellent with-session and between-day reliability of PPT measurements on the middle deltoids, levator scapulae, and upper trapezius muscles for patients with neck-shoulder pain (symptomatic individuals). These results are in agreement with the findings of previous studies,[7,8,12,16] suggesting that PPT testing can be used to assess a patient's change in mechanosensitivity of these 3 muscles consistently over time in clinical settings. Similar to Walton et al's study,[7] the testers in this study only had a few hours of practice on the testing protocol and had no previous

Table 3. *Within-Session and Between-Day Reliability and MDC of Pressure Pain Threshold Measurements for the Middle Deltoid, Levator Scapulae, and Upper Trapezius Muscles in the Seated and Prone Positions*

	Within-Session Reliability		
	Asymptomatic Group (n = 30)	Symptomatic Group (n = 30)	
	$ICC_{3,1}$ (95% CI)	$ICC_{3,1}$ (95% CI)	$MDC_{90\%}$ (kPa)
Seated			
Middle deltoid	0.929 (0.875-0.963)	0.963 (0.933-0.981)	62.3
Levator scapulae	0.947 (0.906-0.973)	0.952 (0.915-0.975)	81.6
Upper trapezius	0.849 (0.745-0.919)	0.931 (0.877-0.964)	55.3
Prone			
Middle deltoid	0.913 (0.848-0.954)	0.953 (0.917-0.976)	87.2
Levator scapulae	0.941 (0.895-0.969)	0.922 (0.863-0.959)	112.5
Upper trapezius	0.895 (0.818-0.945)	0.952 (0.913-0.975)	73.4
	Between-Day Reliability		
	Asymptomatic Group (n=20)	Symptomatic Group (n=18)	
	$ICC_{3,3}$ (95% CI)	$ICC_{3,3}$ (95% CI)	$MDC_{90\%}$ (kPa)
Seated			
Middle deltoid	0.731 (0.305-0.894)	0.966 (0.910-0.987)	73.8
Levator scapulae	0.908 (0.779-0.963)	0.949 (0.863-0.981)	100.5
Upper trapezius	0.710 (0.278-0.884)	0.861 (0.638-0.948)	107.9
Prone			
Middle deltoid	0.864 (0.653-0.964)	0.980 (0.946-0.992)	74.4
Levator scapulae	0.893 (0.730-0.958)	0.934 (0.827-0.975)	114.2
Upper trapezius	0.872 (0.684-0.949)	0.936 (0.822-0.976)	90.0

CI, confidence interval; *ICC*, intraclass correlation coefficient; *MDC*, minimal detectable change.

experience using the pressure algometer, indicating that clinicians without extensive training can use a pressure algometer to assess clinical outcomes consistently. Interestingly, the ICC values of the asymptomatic group were slightly lower than those of the symptomatic group, thus indicating that symptomatic individuals were more consistent in their perception of PPT.

The PPT values taken from the upper trapezius and levator scapulae muscles of the asymptomatic individuals in the prone position were similar to those found in Ge et al's study,[2] but the PPTs taken from the symptomatic group were approximately 20% lower in our study. Similarly, the PPTs of the upper trapezius muscles measured in 2 other studies were approximately 20% to 25% higher than those found in our study.[7,8] The lower PPTs could be attributed to the chronicity of the symptoms in our patient population, which had a history of intermittent of neck-shoulder pain of 30 months. In addition, sex, but not age, has been shown to have effects on PPT.[24,25] Specifically, women have been shown to have approximately 28% lower PPTs than do men.[24] A higher percentage of the symptomatic participants were women (80%) in our study, thus possibly contributing to the lower PPT results.

Interestingly, the PPTs for the middle deltoid found in this study were lower than those of the upper trapezius and levator scapulae muscles. However, the deltoid muscle has been shown to be less prevalent for severe tenderness as compared with the levator scapulae, and patients rarely

Table 4. *Results of Receiver Operating Curve Analysis for the Pressure Pain Thresholds of Neck-Shoulder Pain and Tenderness*

Position/Muscle	Sensitivity	Specificity	Cut-off Score	AUC	*P* Value
Seated position					
Middle deltoid	0.767	0.733	203.2	0.709	.005
Levator scapulae	0.700	0.667	252.2	0.669	.024
Trapezius	0.633	0.733	191.8	0.704	.007
Prone position					
Middle deltoid	0.600	0.833	200.6	0.716	.004
Levator scapulae	0.667	0.667	242.1	0.662	.031

AUC, area under the curve.

complain of pain or tenderness in the deltoid area.[1] The low PPTs of the middle deltoid suggest that the extent of the middle deltoid muscle affected by central facilitation could be more than originally speculated. Furthermore, the MDCs of PPTs measured from the middle deltoid muscle in both positions were the lowest. Therefore, the PPT of the deltoid muscle might be more useful than those of the upper trapezius and levator scapulae to detect clinical changes for this patient population.

With the exception of the upper trapezius tested in the prone position, the comparison analysis demonstrated good construct validity for the PPTs measured from all 3 muscles in both the seated and prone positions because these measurements were able to discriminate between the individuals with and without neck-shoulder pain and tenderness. However, this finding is in disagreement with the finding of Walton et al,[7] in which PPTs of the upper trapezius muscle tested in the seated position were not different between individuals with and without acute neck pain. The main differences between the 2 studies are that the patients in Walton et al's study had an average symptom duration of 38 days and the injury mechanisms of those patients were of traumatic onset, whereas in the current study, the neck-shoulder pain was chronic and of insidious onset. We speculate that the patients in the Walton et al study may not have developed central facilitation owing to a short duration of symptoms, whereas some of the participants in our study may have had central facilitation, as evidenced by changes in PPT of a remote muscle, such as the middle deltoid. Further, the comparison finding of PPTs of the upper trapezius tested in the prone position were in agreement with Ge et al's study,[2] in which PPTs of the upper trapezius muscle were not different between computer users with and without chronic musculoskeletal pain. These comparison findings for the upper trapezius muscle suggest that the seated position should be used rather than the prone position for PPT testing of the upper trapezius muscle to distinguish those with and without neck-shoulder pain.

The comparison results also showed significant differences between the 2 positions for the middle deltoid muscle of asymptomatic individuals and for the middle deltoid and upper trapezius muscles of symptomatic individuals, with lower PPTs measured in the seated position than in the prone position. Therefore, the testing position should be specified and kept the same for assessing changes, in particular for the middle trapezius and upper trapezius muscles. A neurophysiological change (eg, increased central sensitization from increased loading on the diseased cervical spine) could have occurred in the seated position, thus resulting in lower PPTs. As demonstrated in an electromyographic study,[26] a decrease of PPT occurred concomitant with an unrelaxed muscle, as indicated by high electromyographic activity in patients with shoulder-neck pain. In addition, the PPT of the upper trapezius is significantly decreased after 30 minutes of computer use in a seated position.[13] These observations also could explain the lower PPT finding in the seated position as compared with the prone position. On the contrary, the PPTs of the levator scapulae muscle were almost identical for both seated and prone positions, indicating that the PPTs for the levator scapulae muscle appear to be unaffected by position change.

Limitations

A limitation of this study was that the symptomatic groups had overall low intensity but a long history of intermittent neck-shoulder pain, which is commonly seen in this patient population. Therefore, the results of the study may not be generalized to those with high levels of pain or a short history of neck-shoulder pain. In addition, the PPTs were determined by the participants' perception of change from pressure to pain. This required participants

to be able to understand the meaning of the PPT test so that they could end each PPT test properly. To ensure that each participant understood the test, a standardized instruction was given before the PPT testing and was repeated for each muscle test. Although we can never be sure of the accuracy of the PPT tests, the findings of good reliability and construct validity indicate that the participants of the study understood the instructions and meaning of the PPT testing and determined their actual PPTs. Last, temporal summation could have occurred from consecutive multiple stimuli of PPT testing, thus affecting the results of the study.[10] However, threshold, rather than pain stimulus, was tested, and only 4 PPTs were taken from 1 site at a time with 5 seconds between each stimulus; therefore, temporal summation was unlikely to have occurred.

Conclusions

The results showed overall good-to-excellent within-session and fair-to-excellent between-day reliability of PPT measurements for both groups. In addition, the results suggest that PPT testing could be a useful tool for distinguishing individuals with and without neck-shoulder pain and tenderness. Therefore, the cut-off scores and MDC values established in this study can be used to determine treatment effectiveness in clinics. The patient's position should be considered when testing PPT, specifically at the middle deltoid or upper trapezius muscle. Finally, clinicians without extensive training can use a pressure algometer to assess clinical outcomes consistently.

Funding Sources and Conflicts of Interest

No funding sources or conflicts of interest were reported for this study.

Contributorship Information

Concept development (provided idea for the research): S.W.-P., J.Z., K.B.
Design (planned the methods to generate the results): S.W.-P., J.Z., K.B.
Supervision (provided oversight, responsible for organization and implementation, writing of the manuscript): S.W.-P.
Data collection/processing (responsible for experiments, patient management, organization, or reporting data): S.W.-P., B.M., L.L., D.S., S.L.
Analysis/interpretation (responsible for statistical analysis, evaluation, and presentation of the results): S.W.-P., B.M., L.L., D.S., S.L.
Literature search (performed the literature search): S.W.-P., B.M., L.L., D.S., S.L.
Writing (responsible for writing a substantive part of the manuscript): S.W.-P., J.Z.
Critical review (revised manuscript for intellectual content, this does not relate to spelling and grammar checking): S.W.-P., J.Z., K.B., B.M., L.L., D.S., S.L.

Practical Applications

- Pressure pain threshold testing could be used to monitor the progress of patients with shoulder pain and tenderness.
- Pressure pain thresholds of the middle deltoid or upper trapezius muscles should be tested in the same position (ie, seated or prone) consistently for patients with neck-shoulder pain and tenderness.
- A low PPT of the deltoid muscle could be a clinical manifestation of central facilitation.

References

1. Andersen LL, Hansen K, Mortensen OS, Zebis MK. Prevalence and anatomical location of muscle tenderness in adults with nonspecific neck/shoulder pain. *BMC Musculoskelet Disord.* 2011;12:169.
2. Ge HY, Vangsgaard S, Omland Ø, Madeleine P, Arendt-Nielsen L. Mechanistic experimental pain assessment in computer users with and without chronic musculoskeletal pain. *BMC Musculoskelet Disord.* 2014;15:412.
3. Johnston V, Jull G, Souvlis T, Jimmieson NL. Neck movement and muscle activity characteristics in female office workers with neck pain. *Spine.* 2008;33(5):555-563.
4. Klussmann A, Gebhardt H, Liebers F, Rieger MA. Musculoskeletal symptoms of the upper extremities and the neck: a cross-sectional study on prevalence and symptom-predicting factors at visual display terminal (VDT) workstations. *BMC Musculoskelet Disord.* 2008;9:96.
5. Andersen JH, Kaergaard A, Frost P, et al. Physical, psychosocial, and individual risk factors for neck/shoulder pain with pressure tenderness in the muscles among workers performing monotonous, repetitive work. *Spine.* 2002;27(6):660-667.
6. Fernández-de-Las-Peñas C, Madeleine P, Caminero AB, Cuadrado ML, Arendt-Nielsen L, Pareja JA. Generalized neck-shoulder hyperalgesia in chronic tension-type headache and unilateral migraine assessed by pressure pain sensitivity topographical maps of the trapezius muscle. *Cephalalgia.* 2009;30(1):77-86.
7. Walton DM, Macdermid JC, Nielson W, Teasell RW, Chiasson M, Brown L. Reliability, standard error, and minimum detectable change of clinical pressure pain threshold testing in people with and without acute neck pain. *J Orthop Sports Phys Ther.* 2011;41(9):644-650.

8. Ylinen J, Nykänen M, Kautiainen H, Häkkinen A. Evaluation of repeatability of pressure algometry on the neck muscles for clinical use. *Man Ther.* 2007;12(2):192-197.
9. Neblett R, Cohen H, Choi Y, et al. The Central Sensitization Inventory (CSI): establishing clinically significant values for identifying central sensitivity syndromes in an outpatient chronic pain sample. *J Pain.* 2013;14(5):438-445.
10. Starkweather AR, Heineman A, Storey S, et al. Methods to measure peripheral and central sensitization using quantitative sensory testing: a focus on individuals with low back pain. *Appl Nurs Res.* 2016;29:237-241.
11. Murray M, Lange B, Nørnberg BR, Søgaard K, Sjøgaard G. Self-administered physical exercise training as treatment of neck and shoulder pain among military helicopter pilots and crew: a randomized controlled trial. *BMC Musculoskelet Disord.* 2017;18(1):147.
12. Walton DM, Levesque L, Payne M, Schick J. Clinical pressure pain threshold testing in neck pain: comparing protocols, responsiveness, and association with psychological variables. *Phys Ther.* 2014;94(6):827-837.
13. Shin S, Yoo W. Changes in cervical range of motion, flexion-relaxation ratio and pain with visual display terminal work. *Work.* 2014;47(2):261-265.
14. Uddin Z, MacDermid JC, Woodhouse LJ, Triano JJ, Galea V, Gross AR. The effect of pressure pain sensitivity and patient factors on self-reported pain-disability in patients with chronic neck pain. *Open Orthop J.* 2014;8:302-309.
15. Faul F, Erdfelder E, Lang A-G, Buchner A. G* Power 3: a flexible statistical power analysis program for the social, behavioral, and biomedical sciences. *Behav Res Methods.* 2007;39(2):175-191.
16. Persson AL, Brogårdh C, Sjölund BH. Tender or not tender: test-retest repeatability of pressure pain thresholds in the trapezius and deltoid muscles of healthy women. *J Rehabil Med.* 2004;36(1):17-27.
17. MacDermid JC, Walton DM, Avery S, et al. Measurement properties of the Neck Disability Index: a systematic review. *J Orthop Sports Phys Ther.* 2009;39(5):400-417.
18. Pietrobon R, Coeytaux RR, Carey TS, Richardson WJ, DeVellis RF. Standard scales for measurement of functional outcome for cervical pain or dysfunction: a systematic review. *Spine (Phila Pa 1976).* 2002;27(5):515-522.
19. Fischer AA. Pressure algometry over normal muscles. Standard values, validity and reproducibility of pressure threshold. *Pain.* 1987;30(1):115-126.
20. Chesterton LS, Sim J, Wright CC, Foster NE. Interrater reliability of algometry in measuring pressure pain thresholds in healthy humans, using multiple raters. *Clin J Pain.* 2007;23(9):760-766.
21. Sarrafzadeh J, Ahmadi A, Yassin M. The effects of pressure release, phonophoresis of hydrocortisone, and ultrasound on upper trapezius latent myofascial trigger point. *Arch Phys Med Rehabil.* 2012;93(1):72-77.
22. Koo TK, Li MY. A guideline of selecting and reporting intraclass correlation coefficients for reliability research. *J Chiropr Med.* 2016;15(2):155-163.
23. Portney LG, Watkins MP. *Foundations of Clinical Research: Applications to Practice*. 3rd ed. Upper Saddle River, NJ: Prentice Hall; 2009.
24. Chesterton LS, Barlas P, Foster NE, Baxter GD, Wright CC. Gender differences in pressure pain threshold in healthy humans. *Pain.* 2003;101(3):259-266.
25. Lautenbacher S, Kunz M, Strate P, Nielsen J, Arendt-Nielsen L. Age effects on pain thresholds, temporal summation and spatial summation of heat and pressure pain. *Pain.* 2005;115(3):410-418.
26. Hägg GM, Aström A. Load pattern and pressure pain threshold in the upper trapezius muscle and psychosocial factors in medical secretaries with and without shoulder/neck disorders. *Int Arch Occup Environ Health.* 1997;69(6):423-432.