ERIC E. SAWYER, PT, DPT[1,2] • **AMY W. MCDEVITT,** PT, DPT[1,3] • **ADRIAAN LOUW,** PT, PhD[4]
EMILIO J. PUENTEDURA, PT, DPT, PhD[5] • **PAUL E. MINTKEN,** PT, DPT[1,6]

Use of Pain Neuroscience Education, Tactile Discrimination, and Graded Motor Imagery in an Individual With Frozen Shoulder

The reported prevalence of frozen shoulder is 2% to 5%,[46] with diagnosis being made after ruling out other pathologies and noting equal limitations in passive and active range of motion (ROM), most notably with external rotation.[20] Frozen shoulder has been reported as generally having 4 primary stages that reflect a continuum in its course.[20] Stage 1 is characterized by sharp pain at the end of ROM, achy pain at rest, and sleep disturbance. This stage lasts up to 3 months. Stage 2, described as the "painful" or "freezing" stage, presents as a gradual loss of ROM in all directions due to pain, and can last up to 9 months after onset. Stage 3, known as the "frozen" stage, is present from 9 to 15 months after onset and includes both pain and stiffness. The final stage, known as the "thawing" stage, is characterized by less pain and prevailing stiffness that becomes a more limiting factor. This last stage occurs from 15 to 24 months after onset of symptoms.[16,20]

STUDY DESIGN: Case report.

BACKGROUND: Aggressive physical therapy in the freezing stage of frozen shoulder may prolong the course of recovery. Central sensitization may play a role in the early stages of frozen shoulder. Pain neuroscience education, tactile discrimination, and graded motor imagery have been used in a number of conditions with central sensitization. The purpose of this case report was to describe the examination and treatment of a patient in the freezing stage of frozen shoulder using pain neuroscience education, tactile discrimination, and graded motor imagery.

CASE DESCRIPTION: A 54-year-old woman with a diagnosis of frozen shoulder was referred by an orthopaedic surgeon following lack of progress after 4 weeks of intensive daily physical therapy. Pain at rest was 7/10, and her Shoulder Pain and Disability Index score was 64%. She had painful and limited active range of motion and elevated fear-avoidance beliefs. Tactile discrimination and limb laterality were impaired, with signs of central sensitization. A "top-down" approach using pain neuroscience education, tactile discrimination, and graded motor imagery was used for the first 6 weeks, followed by a "bottom-up" impairment-based approach.

OUTCOMES: The patient was seen for 20 sessions over 12 weeks. At discharge, her Shoulder Pain and Disability Index score was 22%, resting pain was 0/10, and fear-avoidance beliefs improved. Improvements in active range of motion, laterality, and tactile discrimination were also noted.

DISCUSSION: Intensive physical therapy in the freezing stage of frozen shoulder may be detrimental to long-term outcomes. This case report suggests that a top-down approach may allow a quicker transition through the freezing stage of frozen shoulder.

LEVEL OF EVIDENCE: Therapy, level 5. *J Orthop Sports Phys Ther 2018;48(3):174-184. Epub 19 Dec 2017. doi:10.2519/jospt.2018.7716*

KEY WORDS: *adhesive capsulitis, central sensitization, top-down*

Nonsurgical treatment of frozen shoulder has varied over time and had mixed outcomes. A systematic review by Wong et al[78] reported finding no evidence of complete resolution without treatment, and low-quality evidence suggests that patients do not regain full ROM as long as 4 years after onset. Most improvement occurs in the early stages, suggesting that appropriate treatment strategies in the freezing/painful stage of frozen shoulder may result in better outcomes.[78] While a systematic review by Jain and Sharma[18] reported that exercise and joint mobilization were strongly recommended for reducing pain and improving function and ROM in patients with stages 2 and 3

[1]Department of Physical Therapy, University of Colorado School of Medicine, Aurora, CO. [2]Fit Physical Therapy, Westminster, CO. [3]Sports Physical Therapy and Rehabilitation, University of Colorado Health at the University of Colorado Hospital, Denver, CO. [4]International Spine and Pain Institute, Story City, IA. [5]Department of Physical Therapy, School of Allied Health Sciences, University of Nevada-Las Vegas, Las Vegas, NV. [6]Wardenburg Health Center at the University of Colorado-Boulder, Boulder, CO. The patient in this case gave consent to use her medical information and images as part of this publication. The authors certify that they have no affiliations with or financial involvement in any organization or entity with a direct financial interest in the subject matter or materials discussed in the article. Address correspondence to Dr Paul Mintken, University of Colorado School of Medicine, Mail Stop C-244, 13121 East 17th Avenue, Aurora, CO 80045. E-mail: paul.mintken@ucdenver.edu

of frozen shoulder, Diercks and Stevens[12] demonstrated that intensive physical therapy interventions produced worse outcomes at 2 years compared to supervised neglect.

Central sensitization, defined as an "amplification of neural signaling within the central nervous system that elicits pain hypersensitivity,"[79] may play a role in frozen shoulder.[2,9,54,61] It has been proposed that central sensitization may be present in the early stages of frozen shoulder, because cytokines, which signal inflammation, may provide prolonged stimulation of neurons in the dorsal horn as well as the glial cells of the spinal cord.[65] Central sensitization may hinder descending pathways for pain inhibition, altering the processing of sensory information and increasing nociceptive signaling mechanisms.[79] This can lead to nonnoxious stimuli being interpreted as threatening and painful.[61] Central sensitization has been reported to produce hypersensitivity to cold and heat, as well as decreases in pressure pain threshold.[9] In the absence of a diagnostic gold standard to diagnose central sensitization, Smart et al[62] suggested that the best alternative "reference standard" may be expert clinical judgment. Classification criteria for central sensitization are based on determining which signs and symptoms match the impression of an experienced clinician. Smart et al[63] described a symptom-and-sign cluster for central sensitization, with a reported sensitivity of 91.8% and specificity of 97.7% in individuals with low back pain. The cluster included "disproportionate, nonmechanical, unpredictable pattern of pain provocation in response to multiple/nonspecific aggravating/easing factors," "pain disproportionate to the nature and extent of injury or pathology," "strong association with maladaptive psychosocial factors," and "diffuse/nonanatomic areas of pain/tenderness on palpation."[63]

Pain neuroscience education and graded motor imagery have been used successfully in a number of conditions with suspected central sensitization.[24,29,37,38,41] Pain neuroscience education is used to educate individuals on how pain is processed by the nervous system.[24] The goal of pain neuroscience education is to increase movement and function while decreasing pain, fear avoidance, and disability.[29] Graded motor imagery is a 3-stage process that aims to facilitate sensory cortex reorganization.[15,37,38] Graded motor imagery has been used in conjunction with tactile discrimination training to produce clinically meaningful changes in pain.[14,41] The primary sensory cortex receptive fields can reportedly be modified by tactile discrimination training.[13] According to Flor et al,[14] 2 weeks of sensory discrimination training resulted in normalization of cortical organization and a clinically important reduction of pain in individuals with limb amputations. The first stage of graded motor imagery includes laterality reconstruction, in which patients view various images of body parts to determine whether the image portrays the right or left side.[72] The second stage targets activation of the primary motor cortex, requiring the patient to imagine moving the involved body part. This has been shown to activate the same areas of the cortex associated with movement of the body part.[11] The final stage involves having the patient watch the unaffected body part moving in a mirror to "trick" the brain into thinking the affected body part is actually moving in a pain-free manner.[30] Graded motor imagery has been reported to decrease pain intensity and result in marked changes on functional magnetic resonance imaging in areas of discriminative pain processing.[75] The sequence of graded motor imagery training may be important in systematically activating cortical systems and assisting in reorganization.[39] Moseley[37] described graded motor imagery as a treatment approach to "train the brain," reorganizing the cortex to decrease pain in the presence of central sensitization.

The purpose of this case report was to describe the examination and treatment of a patient with frozen shoulder using pain neuroscience education, tactile discrimination, and graded motor imagery.

CASE DESCRIPTION

History

The patient was a 54-year-old, right hand–dominant woman with a 2-month history of gradual onset of right shoulder pain. She reported difficulty sleeping on her involved side and denied any history of trauma. This pain worsened over 4 weeks, so she consulted an orthopaedic surgeon. Radiographs were normal, and she was diagnosed with frozen shoulder. She received a corticosteroid injection and was referred for intensive physical therapy. After 4 weeks, with her pain and disability worsening, she stopped attending. She returned to the orthopaedist, requesting alternative treatment options. The patient was subsequently referred to a physical therapist for a second opinion. During the patient interview, the patient reported that her pain had started insidiously, without a specific mechanism of injury. She stated she was comfortable with her arm by her side, but elevating it would lead to sudden, excruciating pain. It continued to worsen and began to disrupt her sleep, and this motivated her to seek a medical evaluation. The previous episode of physical therapy, which she described as "aggressive," included ROM exercises and manual techniques to her pain tolerance. She reported that this made her symptoms worse, and stated that now everything hurt and she was afraid to move. She complained of hypersensitivity to touch and temperature in both upper extremities. Her functional limitations included sleeping, reaching overhead, reaching behind the back, and washing her hair. She stated, "It now hurts for me to even watch someone else move their shoulder." She also requested that the therapist not touch her shoulder.

Examination

A review of systems was used to screen for serious pathology. She was healthy

and didn't take medications or have any significant health problems. Pain ratings were collected using the numeric pain-rating scale, an 11-point scale with 0 indicating no pain and 10 the worst imaginable pain.[31] The numeric pain-rating scale has good test-retest reliability in patients with shoulder pain (intraclass correlation coefficient [ICC] = 0.74), with a minimal clinically important difference (MCID) of 1.1 to 2.17 points.[31,34] Her resting pain was 7/10 and her worst pain was 10/10. A pain diagram was also completed (**FIGURE 1**) to assess for body-mapping issues.[25] Body maps may expand or contract with cortical restructuring, in essence increasing or decreasing the body map representation in the brain.[28] Evidence suggests a correlation between the changes in shape and size of body maps and increased pain and disability.[13,23]

The Shoulder Pain and Disability Index (SPADI) was utilized to capture a baseline measure for her perceived level of disability. It contains 13 items that assess 2 domains: a 5-item subscale that measures pain and an 8-item subscale that measures disability. A mean is taken of the 2 subscales to give a total score out of 100, with higher scores indicating greater disability.[56,58] The SPADI has good test-retest reliability, with an ICC of 0.89 in patients with frozen shoulder, and is more responsive to change in this population than shoulder ROM measures.[70] The patient's SPADI score was 64%, indicating a high level of disability.[58]

A modified Fear-Avoidance Beliefs Questionnaire (FABQ) was administered to assess the patient's beliefs related to her shoulder pain (the term *back* was replaced with *shoulder*). The FABQ has 16 questions comprising 2 subscales, one related to physical activity (FABQ-PA) and the other to work (FABQ-W).[73] Each item is scored from 0 to 6 on a Likert scale, with 0 meaning "completely disagree" and 6 meaning "completely agree," with 24 possible points on the physical activity subscale and 42 on the work subscale. Lower scores indicate lower fear-avoidance behaviors. The modified FABQ has excellent reliability in patients with shoulder pain (ICC = 0.88).[33] It has also demonstrated concurrent validity with the SPADI for pain and disability in patients with shoulder pain.[33] Wertli et al[76,77] proposed cutoff values for elevated fear avoidance beliefs in individuals with low back pain of greater than 16 points on the FABQ-PA and greater than 25 points on the FABQ-W. The patient's scores were 22 for the FABQ-PA and 34 for the FABQ-W, suggesting elevated levels of fear-avoidance beliefs.

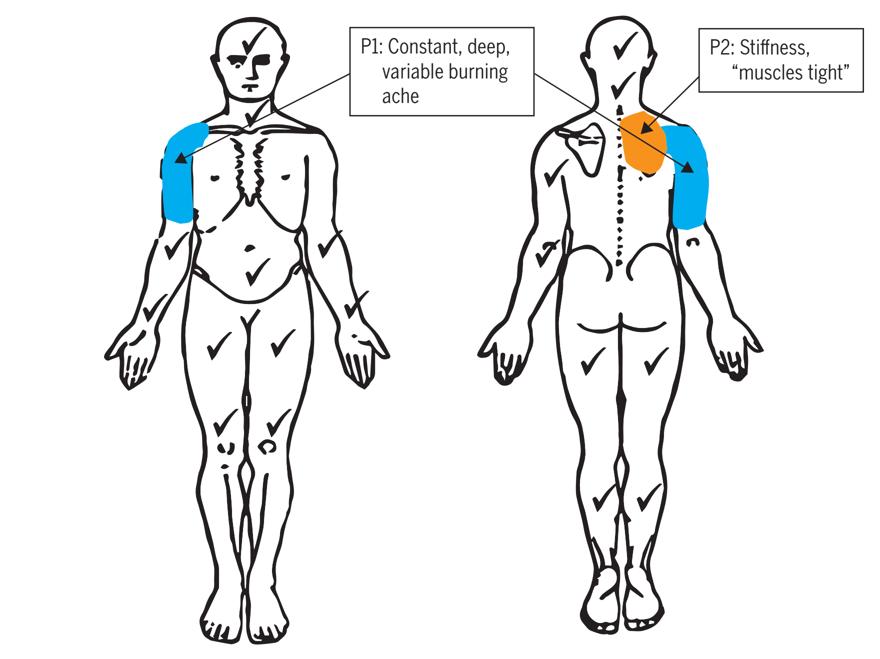

FIGURE 1. Pain diagram.

The physical examination for the shoulder was limited due to the patient's fear of movement and of being touched. Active and passive ROM of bilateral shoulders was measured (**TABLE 1**) to assess for a capsular pattern, which, along with normal radiographs, has been suggested for clinical diagnosis of frozen shoulder.[80] Glenohumeral glides/accessory motions were assessed because limitations in multiple directions are a common impairment in frozen shoulder.[20]

Centrally mediated pain was suspected, due to the presence of the cluster predictive of central sensitization reported by Smart et al.[63] The patient complained of hypersensitivity to cold, heat, and pressure, both local to and distant from the site of symptoms.[48] These were each investigated by the treating therapist by applying a hot pack, ice cup, and digital pressure 3 times to both shoulders and volar forearms.[9,48] The patient stated that each stimulus elicited a painful response at all points tested, suggesting allodynia and possible centrally mediated pain.[54]

To further investigate suspected deficiencies in sensory processing, two-point discrimination (2PD) testing of the shoulders and laterality testing of the shoulders and hands were completed.[37,41] Norms for 2PD in the shoulders of healthy adults are reported to range between 40 and 45 mm,[3,50] and 2PD has good intrarater reliability.[6] Norms for laterality testing of the shoulder and hands have been established for both accuracy (94% to 95%[3,5] and 94%,[40] respectively) and response time (1.3 seconds[3,5] and 2.3 seconds,[40] respectively). Impairments were noted in both 2PD and laterality testing in this patient (**TABLE 2**), and, interestingly, a reduction in resting pain of 3 points was reported after laterality testing.

TABLE 1 RANGE OF MOTION*

	Flexion	Abduction	External Rotation	Internal Rotation
Active				
Left	165	148	70	T7
Right	61	32	3	Hip
Passive				
Left	170	152	74	NT
Right	65	40	8	NT

Abbreviation: NT, not tested.
**Values are degrees unless otherwise indicated.*

TABLE 2 CENTRAL SENSITIZATION TESTING AT INITIAL EVALUATION

	Left	Right
2-point discrimination, mm	40	58
Hand laterality test		
Accuracy, %	70	50
Speed, s	2.2	4.2
Shoulder laterality test		
Accuracy, %	80	60
Speed, s	2.5	4.9

Evaluation

The diagnosis of frozen shoulder was originally made by the orthopaedic physician, and the physical therapist examination corroborated this. According to the clinical practice guideline for shoulder pain and mobility deficits, the diagnosis of frozen shoulder is determined from the history and physical examination.[20] She met the clinical practice guideline criteria for frozen shoulder: 40 to 65 years of age, gradual onset and progressive worsening of pain and stiffness, and painful and limited glenohumeral active and passive ROM in multiple directions, with external rotation the most limited (**FIGURE 2**). Her glenohumeral rotation decreased as the humerus was abducted, and her accessory motions were restricted in all directions.[20] The examination findings, severity of pain, and functional limitations suggested that she was in stage 2, the freezing stage. The possibility of centrally mediated pain was reinforced by her reports of hypersensitivity away from the right shoulder, fear of movement, diminished 2PD, and impaired laterality in both the shoulders and hands (**TABLE 2**). These findings suggested that she could potentially benefit from graded motor imagery, including sensory discrimination training.[25]

Interventions

Due to her fear of movement and being touched, a "top-down," cognitive-based treatment approach was implemented to address the probable centralized pain. She was first educated about lifestyle management to expedite her recovery and manage her symptoms, including the importance of a positive outlook about her recovery. A systematic review by Mondloch et al[35] reported that positive expectations are associated with better health outcomes. Dean and Söderlund[10] suggest that addressing lifestyle behavior change in individuals with pain might improve outcomes, and should be included in first-line management of musculoskeletal pain conditions. The patient was, therefore, educated about the importance of hydration, proper nutrition, and adequate sleep. Additionally, a smartphone application (Calm; Calm.com, Inc, San Francisco, CA) was used for stress reduction/relaxation techniques to manage stress and allow her to concentrate on her recovery. Breathing exercises and stress reduction techniques have been shown to reduce pain and improve function.[7] A fitness program of moderate-intensity aerobic exercise (brisk walking) 150 minutes per week was encouraged.[55] Moderate-intensity aerobic exercise can improve chronic pain symptoms.[21,45,71]

Pain neuroscience education, also initiated in the first week, included the following key concepts: (1) pain is an output produced by our brain in response to what it perceives as danger; (2) pain is not necessarily associated with tissue damage; (3) a variable relationship exists between nociception and pain; (4) environment can influence perceived pain intensity; (5) persistent pain creates an upregulation in nociception; and (6) the nervous system is plastic and adaptable.[27] The second phase of treatment began in the second week of therapy, consisting of 4 stages, each 1 week in duration. They included tactile discrimination training[14,41] and the 3 steps of graded motor imagery: laterality training, imagined movements, and mirror therapy.[37,38] Typically, tactile discrimination training precedes graded motor imagery, but laterality training was implemented first in this case because the patient did not want her shoulder touched and laterality training had resulted in an immediate reduction in resting pain. Tactile discrimination training occurred in week 3, followed by imagined movements in week 4 and mirror therapy in week 5. Below is a brief description of each stage.

Step 1: Laterality Training Laterality training is the first step in the graded motor imagery program to improve the

FIGURE 2. Notable losses of shoulder external rotation (A), abduction (B), flexion (C), and internal rotation (D) range of motion.

accuracy of the patient's cortical representation of his or her body.[38] The patient trains by looking at left and right images of body parts in different positions. Flash cards (**FIGURE 3**) or a smartphone application, such as Recognise (Neuro Orthopaedic Institute, Adelaide, Australia), can be used. The patient downloaded the Recognise Hand and Shoulder applications onto her iPhone. The application records both accuracy and response times, and allows the user to set the difficulty of the images by modifying context and background. She was encouraged to train 1 to 2 hours per day in short sessions, using 20 images, and to look at people throughout the day and say, "That's left, that's right."[38] Additionally, she was urged to look through magazines with pictures of people and circle right shoulders. Laterality training was progressed by increasing the number and difficulty of the images (**TABLE 3**).

FIGURE 3. Recognise flash cards.

Step 2: Tactile Discrimination Training[41] Tactile discrimination training was then performed on the patient's involved shoulder. A digital photograph was taken of her shoulder, and 5 points were marked in different areas of the photograph (**FIGURE 4**). All were located in her painful area, and the distance between points was approximately the same as her 2PD results (approximately 6 cm). She was placed in a seated position with a dressing mirror positioned between her legs, enabling her to look at her unaffected shoulder while her right shoulder was behind the dressing mirror (**FIGURE 5**). Moseley and Wiech[41] reported that allowing patients to see the mirror image of the affected body part resulted in greater improvements in pain and tactile acuity compared to not seeing the reflected image. The photograph with the 5 points was taped on the mirror for reference. Her husband used the eraser of a pencil to lightly touch the painful shoulder in 1 of the 5 points depicted, and the patient was asked to identify which area was touched. The patient was instructed to perform 6-minute blocks of 24 stimuli (interstimulus interval, 15 seconds), 3 times per day, for a total of 18 minutes per day.[41] This was initially painful for her, but after 2 days she no longer had pain with light touch. At this point, 2PD was initiated, with the distance between points

TABLE 3 Treatment Progression and Outcomes

			AROM*			
Treatment Focus	**Week**	**NPRS (Rest, Worst)**	**Flexion**	**Abduction**	**ER**	**IR**
Initial exam	0	7/10, 10/10	61	32	3†	To hip
Neuroscience education	1	5/10, 7/10	82	38	12	SI joint
Laterality	2	4/10, 6/10	97	43	17	L5
Motor imagery	3	3/10, 6/10	105	55	25	L3
Mirror therapy	4	3/10, 6/10	112	62	34	L3
Tactile discrimination	5	3/10, 4/10	120	70	38	L2
CT MT	6	2/10, 3/10	125	79	42	L1
CT and shoulder MT	7	1/10, 3/10	142	90	48‡	T12
MT plus exercise	8	0/10, 3/10	154	104	52	T10

Abbreviations: AROM, active range of motion; CT, cervicothoracic; ER, external rotation; IR, internal rotation; MT, manual therapy; NPRS, numeric pain-rating scale; SI, sacroiliac.
**Values are degrees unless otherwise indicated.*
†Arm by side.
‡At 90° of abduction.

TABLE 4 Outcomes Measures

	Initial Exam	**Discharge**	**13 mo Post Discharge**
Pain (right shoulder)			
Best	7/10	0/10	
Worst	10/10	3/10	
AROM (right shoulder), deg			
Flexion	61	162	
Abduction	32	111	
External rotation	3	65	
SPADI, %	64	22	7
FABQ-W	34	14	6
FABQ-PA	22	6	2
2PD (right shoulder), mm	58	48	
Hand laterality test (right hand)			
Accuracy, %	50	80	
Speed, s	4.2	2.5	
Shoulder laterality test (right shoulder)			
Accuracy, %	60	80	
Speed, s	4.9	2.3	

Abbreviations: 2PD, two-point discrimination; AROM, active range of motion, FABQ-PA, Fear-Avoidance Beliefs Questionnaire physical activity subscale; FABQ-W, Fear-Avoidance Beliefs Questionnaire work subscale; SPADI, Shoulder Pain and Disability Index.

FIGURE 4. Tactile discrimination.


FIGURE 5. Use of mirror for tactile discrimination.

set to the normal distance for the shoulder (approximately 40 mm). The patient was instructed to localize which area was touched and determine whether she was touched at 1 or 2 points. She continued this training for the rest of the week, and her accuracy and tactile acuity improved (**TABLE 4**).

Step 3: Imagined Movements During the fourth week, the treatment progressed by having the patient imagine moving her painful shoulder. Moseley[38] describes this stage of graded motor imagery as preparing the patient to move. A picture with 8 different shoulder postures was used for this training (**FIGURE 6**). The cues were as follows: "Imagine your involved shoulder in the pictured postures without actually moving. Imagine each posture twice, and repeat the entire process 3 times per day." Imagined body movements are reported to activate the cortex in a manner similar to executed movements.[22] This intervention was utilized due to her report of pain with watching other people move. The patient continued to make improvements in pain and ROM with this intervention (**TABLE 3**).

Step 4: Mirror Therapy In week 5, we introduced the final step of graded motor

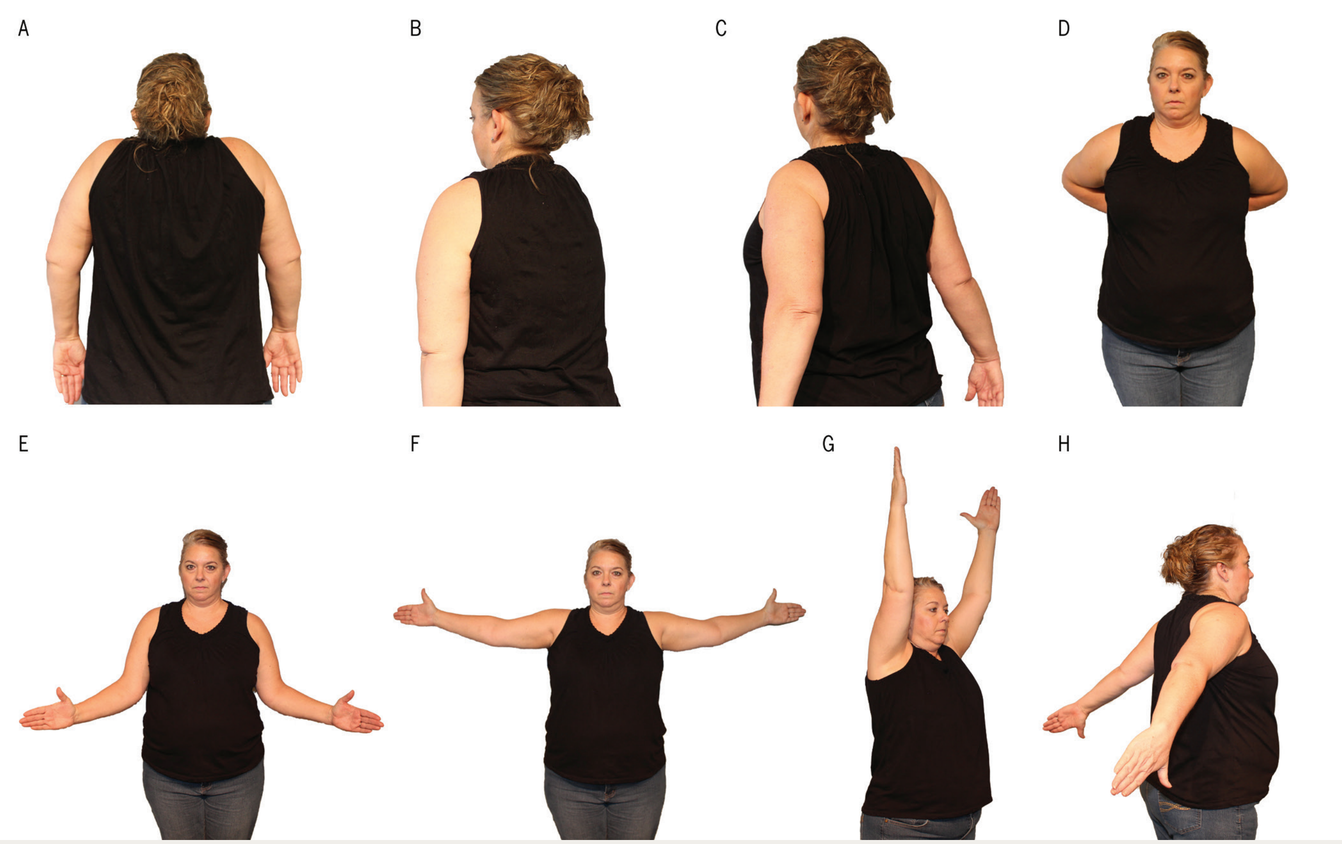

FIGURE 6. Shoulder movements for graded motor imagery and mirror therapy. (A) Shrug, (B) protraction, (C) retraction, (D) internal rotation, (E) external rotation, (F) abduction, (G) flexion, (H) extension.

imagery: mirror therapy. Mirror therapy involves using a mirror to observe movement of the unaffected body part.[4,38] This creates the illusion that the painful body part is moving in a pain-free fashion. She was instructed to look at the mirror image of the unaffected shoulder and move that shoulder into the 8 positions used for imagined movement training (**FIGURE 7**). She did this twice per session, 3 times per day. She was instructed that once she was able to view the mirrored movement without pain, she could begin to simultaneously perform the movements with the affected shoulder. Mirror therapy provides strong positive sensory cortical feedback that movement does not have to be painful, and may disprove cognitions of the mind, allowing the patient to believe pain-free movement is possible. After 1 week of mirror therapy, the patient was able to actively move her involved shoulder through all of the movements with a level of pain of 3/10 or lower.

By the sixth week of treatment, the treating therapist postulated that the patient's pain and fear of movement had decreased to where she would tolerate manual therapy and exercise in the plan of care. The patient was amenable to trying hands-on treatments. Treatment commenced with a regional interdependence[74] manual therapy approach directed to areas with impaired mobility adjacent to her shoulder, specifically, thoracic manipulation and cervical mobilizations.[32,57,66] These were applied for 1 week, with continued improvements in pain and ROM (**TABLE 3**). At this time, the patient gave consent to use manual therapy directed at the shoulder along with the cervicothoracic manual techniques.[8] The final addition to the treatment regimen was to add stretching and progressive resistive exercises in the eighth week of treatment. The final 4 weeks focused on stretching exercises and neuromuscular re-education, per the clinical practice guideline.[20] Stretches were progressed into tissue resistance as long as they did not produce posttreatment pain, and neuromuscular re-education focused on integrating gains in mobility into normal movement during functional activities.

OUTCOMES

The patient was seen for 20 visits over 12 weeks. She demonstrated consistent improvements in her pain ratings and active ROM measurements throughout the episode of care (**TABLE 3**). At discharge, her pain ratings had dropped from 7/10 at rest to 0/10 and from 10/10 at worst to 3/10 (**TABLE 4**). Michener et al[31] reported the MCID for the numeric pain-rating scale to be 2.17 points in patients with shoulder pain. The patient's active ROM in the painful shoulder also demonstrated

FIGURE 7. Mirror therapy.

clinically meaningful improvements during the episode of care (**TABLE 4**). Muir et al[44] reported that the minimal detectable change (MDC) for flexion, abduction, and external rotation ranged from 11° to 16°. Tveitå et al[68] reported that the ICC for test-retest differences ranged from 0.61 to 0.93 for all measurements.

The SPADI and the modified FABQ were readministered at week 6 and at discharge to determine changes in function and fear of movement (**FIGURE 8**). The patient also completed the SPADI and FABQ by e-mail 13 months after discharge. Her SPADI score dropped from 64% to 22% at discharge, which surpassed the MDC of 17% for individuals with frozen shoulder and the MCID of 8% to 13% in individuals with shoulder pain (**TABLE 4**).[59,69] Thirteen months after discharge, her SPADI score was 7%. Her FABQ-PA score dropped 16 points (22 to 6), while her FABQ-W score decreased by 20 points (34 to 14) at discharge, which exceeded the MDC of 8 points for the FABQ-PA and 13 points for the FABQ-W in people with upper extremity injuries.[17] This suggests a potentially meaningful change in her fear-related behaviors. At 13 months post discharge, her FABQ-PA score was 2 and her FABQ-W score was 6 (**TABLE 4**, **FIGURE 8**).

DISCUSSION

This case report describes the examination and treatment of a patient with a highly irritable frozen shoulder and suspected central sensitization, using a top-down approach for the first 6 weeks. This treatment approach was adopted early on due to the patient's request that her shoulder not be touched. Although this approach is commonly used in conditions with central sensitization,[4,37] to our knowledge, this is the first description of its use in a patient with frozen shoulder. Recent reports[2,9,61,65] have suggested the presence of central sensitization in some individuals with shoulder pain, and the treating therapist suspected centrally mediated pain in this case. Therefore, tests and measures were performed to test this hypothesis, specifically, tactile discrimination and laterality. As noted earlier, conventional physical therapy approaches have not proven efficacious in the treatment of frozen shoulder, and this patient had already failed a previous bout of therapy.

Because pain neuroscience education and graded motor imagery have been shown to reduce pain and disability in some chronic pain conditions,[4,24,29] these interventions were implemented to address suspected changes in pain processing. Pain neuroscience education may be an important component of a graded motor imagery program because it helps the patient to understand the upregulation of neural processing and helps to decrease pain by explaining the biological processes involved in pain.[49,60] Utilization of pain neuroscience education has demonstrated effectiveness in decreasing pain, fear, and pain perception, as well as increasing patient compliance with the graded motor imagery program.[24,29,36,43] A recent systematic review and meta-analysis by Thieme et al[67] concluded that graded motor imagery was effective in reducing pain and disability in patients with limb pain and suggested that graded motor imagery techniques should be considered in the treatment of acute pain

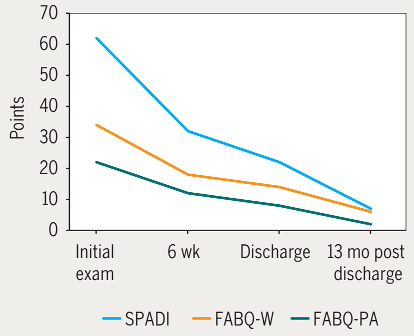

FIGURE 8. Outcome measures. Abbreviations: FABQ-PA, Fear-Avoidance Beliefs Questionnaire physical activity subscale; FABQ-W, Fear-Avoidance Beliefs Questionnaire work subscale; SPADI, Shoulder Pain and Disability Index.

after trauma and surgery.[67] Another recent systematic review by Bowering et al[4] concluded that graded motor imagery and mirror therapy alone may be effective for the treatment of chronic pain. Finally, Louw et al[26] reported that a brief mirror therapy intervention resulted in statistically significant improvements in pain, pain catastrophization, fear avoidance, and shoulder flexion active ROM in patients presenting with shoulder pain. Each element of graded motor imagery was utilized in this case, with dosage as described by Moseley,[38] over the first 6 weeks of care. In addition, tactile discrimination training was added because it has been shown to be effective at improving tactile acuity and decreasing pain in individuals with chronic limb pain, phantom-limb pain, and complex regional pain syndrome.[14,41,42]

During the first 6 weeks using this top-down approach, positive changes were seen in the patient's pain, function, and ROM (**TABLE 3**). She was then open to transitioning to an approach utilizing manual therapy and exercise. This approach is supported by a retrospective cohort study by Jewell et al[19] that included 2370 patients with frozen shoulder, concluding that these interventions were more effective than passive modalities in improving pain and function. As the patient was apprehensive about hands-on shoulder interventions, a regional interdependence approach[74] was initiated, targeting impairments in the cervicothoracic spine.[1,32,51-53,57,64] These interventions helped to instill confidence in the patient that manual therapy would not be harmful, and the following week she allowed the treating therapist to use manual therapy to address impairments in her shoulder. Pain, ROM, and disability continued to improve until discharge at 12 weeks after the evaluation. At that time, her hand and shoulder laterality accuracy and speed were within normal ranges, and 2PD had improved by 10 mm (**TABLE 4**). She returned to all her desired activities and, in a 13-month follow-up e-mail, she characterized herself as "recovered."

CONCLUSION

Current evidence suggests that pain is a top-down and a bottom-up phenomenon.[47] The treating therapist suspected centrally mediated pain and developed a plan of care that included a hands-off, top-down approach. Pain neuroscience education, tactile discrimination, and graded motor imagery were used to decrease the patient's high level of irritability, fear of movement, and suspected centrally mediated pain. The patient made consistent and meaningful improvements throughout the episode of care, particularly at a time when she had signs of high irritability. One cannot infer cause and effect from a single case, and it is possible that the improvements she experienced would have occurred with no treatment at all. Additional research should investigate the effectiveness of pain neuroscience education, tactile discrimination, and graded motor imagery, both alone and in combination, in the treatment of individuals with frozen shoulder. ◉

REFERENCES

1. Bergman GJ, Winters JC, Groenier KH, et al. Manipulative therapy in addition to usual medical care for patients with shoulder dysfunction and pain: a randomized, controlled trial. *Ann Intern Med*. 2004;141:432-439. https://doi.org/10.7326/0003-4819-141-6-200409210-00008
2. Borstad J, Woeste C. The role of sensitization in musculoskeletal shoulder pain. *Braz J Phys Ther*. 2015;19:251-257. https://doi.org/10.1590/bjpt-rbf.2014.0100
3. Botnmark I, Tumilty S, Mani R. Tactile acuity, body schema integrity and physical performance of the shoulder: a cross-sectional study. *Man Ther*. 2016;23:9-16. https://doi.org/10.1016/j.math.2016.02.001
4. Bowering KJ, O'Connell NE, Tabor A, et al. The effects of graded motor imagery and its components on chronic pain: a systematic review and meta-analysis. *J Pain*. 2013;14:3-13. https://doi.org/10.1016/j.jpain.2012.09.007
5. Breckenridge JD, McAuley JH, Butler DS, Stewart H, Moseley GL, Ginn KA. Shoulder left/right judgement task: development and establishment of a normative dataset [abstract]. *Physiotherapy*. 2015;101:e169-e170. https://doi.org/10.1016/j.physio.2015.03.323
6. Catley MJ, Tabor A, Wand BM, Moseley GL. Assessing tactile acuity in rheumatology and musculoskeletal medicine—how reliable are 2PD tests at the neck, hand, back and foot? *Rheumatology (Oxford)*. 2013;52:1454-1461. https://doi.org/10.1093/rheumatology/ket140
7. Chang KL, Fillingim R, Hurley RW, Schmidt S. Chronic pain management: nonpharmacological therapies for chronic pain. *FP Essent*. 2015;432:21-26.
8. Conroy DE, Hayes KW. The effect of joint mobilization as a component of comprehensive treatment for primary shoulder impingement syndrome. *J Orthop Sports Phys Ther*. 1998;28:3-14. https://doi.org/10.2519/jospt.1998.28.1.3
9. Coronado RA, Simon CB, Valencia C, George SZ. Experimental pain responses support peripheral and central sensitization in patients with unilateral shoulder pain. *Clin J Pain*. 2014;30:143-151.
10. Dean E, Söderlund A. What is the role of lifestyle behaviour change associated with non-communicable disease risk in managing musculoskeletal health conditions with special reference to chronic pain? *BMC Musculoskelet Disord*. 2015;16:87. https://doi.org/10.1186/s12891-015-0545-y
11. Decety J. The neurophysiological basis of motor imagery. *Behav Brain Res*. 1996;77:45-52. https://doi.org/10.1016/0166-4328(95)00225-1
12. Diercks RL, Stevens M. Gentle thawing of the frozen shoulder: a prospective study of supervised neglect versus intensive physical therapy in seventy-seven patients with frozen shoulder syndrome followed up for two years. *J Shoulder Elbow Surg*. 2004;13:499-502. https://doi.org/10.1016/j.jse.2004.03.002
13. Flor H, Braun C, Elbert T, Birbaumer N. Extensive reorganization of primary somatosensory cortex in chronic back pain patients. *Neurosci Lett*. 1997;224:5-8. https://doi.org/10.1016/S0304-3940(97)13441-3
14. Flor H, Denke C, Schaefer M, Grüsser S. Effect of sensory discrimination training on cortical reorganisation and phantom limb pain. *Lancet*.

2001;357:1763-1764. https://doi.org/10.1016/S0140-6736(00)04890-X
15. Flor H, Elbert T, Knecht S, et al. Phantom-limb pain as a perceptual correlate of cortical reorganization following arm amputation. *Nature*. 1995;375:482-484. https://doi.org/10.1038/375482a0
16. Hannafin JA, Chiaia TA. Adhesive capsulitis. A treatment approach. *Clin Orthop Relat Res*. 2000:95-109.
17. Inrig T, Amey B, Borthwick C, Beaton D. Validity and reliability of the Fear-Avoidance Beliefs Questionnaire (FABQ) in workers with upper extremity injuries. *J Occup Rehabil*. 2012;22:59-70. https://doi.org/10.1007/s10926-011-9323-3
18. Jain TK, Sharma NK. The effectiveness of physiotherapeutic interventions in treatment of frozen shoulder/adhesive capsulitis: a systematic review. *J Back Musculoskelet Rehabil*. 2014;27:247-273. https://doi.org/10.3233/BMR-130443
19. Jewell DV, Riddle DL, Thacker LR. Interventions associated with an increased or decreased likelihood of pain reduction and improved function in patients with adhesive capsulitis: a retrospective cohort study. *Phys Ther*. 2009;89:419-429. https://doi.org/10.2522/ptj.20080250
20. Kelley MJ, Shaffer MA, Kuhn JE, et al. Shoulder pain and mobility deficits: adhesive capsulitis. *J Orthop Sports Phys Ther*. 2013;43:A1-A31. https://doi.org/10.2519/jospt.2013.0302
21. Koltyn KF, Umeda M. Exercise, hypoalgesia and blood pressure. *Sports Med*. 2006;36:207-214. https://doi.org/10.2165/00007256-200636030-00003
22. Kranczioch C, Mathews S, Dean PJ, Sterr A. On the equivalence of executed and imagined movements: evidence from lateralized motor and nonmotor potentials. *Hum Brain Mapp*. 2009;30:3275-3286. https://doi.org/10.1002/hbm.20748
23. Lloyd D, Findlay G, Roberts N, Nurmikko T. Differences in low back pain behavior are reflected in the cerebral response to tactile stimulation of the lower back. *Spine (Phila Pa 1976)*. 2008;33:1372-1377. https://doi.org/10.1097/BRS.0b013e3181734a8a
24. Louw A, Diener I, Butler DS, Puentedura EJ. The effect of neuroscience education on pain, disability, anxiety, and stress in chronic musculoskeletal pain. *Arch Phys Med Rehabil*. 2011;92:2041-2056. https://doi.org/10.1016/j.apmr.2011.07.198
25. Louw A, Farrell K, Wettach L, Uhl J, Majkowski K, Welding M. Immediate effects of sensory discrimination for chronic low back pain: a case series. *NZ J Physiother*. 2015;43:58-63.
26. Louw A, Puentedura EJ, Reese D, Parker P, Miller T, Mintken PE. Immediate effects of mirror therapy in patients with shoulder pain and decreased range of motion. *Arch Phys Med Rehabil*. 2017;98:1941-1947. https://doi.org/10.1016/j.apmr.2017.03.031
27. Louw A, Puentedura EL, Mintken P. Use of an abbreviated neuroscience education approach in the treatment of chronic low back pain: a case report. *Physiother Theory Pract*. 2012;28:50-62. https://doi.org/10.3109/09593985.2011.562602
28. Louw A, Schmidt SG, Louw C, Puentedura EJ. Moving without moving: immediate management following lumbar spine surgery using a graded motor imagery approach: a case report. *Physiother Theory Pract*. 2015;31:509-517. https://doi.org/10.3109/09593985.2015.1060656
29. Louw A, Zimney K, Puentedura EJ, Diener I. The efficacy of pain neuroscience education on musculoskeletal pain: a systematic review of the literature. *Physiother Theory Pract*. 2016;32:332-355. https://doi.org/10.1080/09593985.2016.1194646
30. Matthys K, Smits M, Van der Geest JN, et al. Mirror-induced visual illusion of hand movements: a functional magnetic resonance imaging study. *Arch Phys Med Rehabil*. 2009;90:675-681. https://doi.org/10.1016/j.apmr.2008.09.571
31. Michener LA, Snyder AR, Leggin BG. Responsiveness of the Numeric Pain Rating Scale in patients with shoulder pain and the effect of surgical status. *J Sport Rehabil*. 2011;20:115-128. https://doi.org/10.1123/jsr.20.1.115
32. Mintken PE, Cleland JA, Carpenter KJ, Bieniek ML, Keirns M, Whitman JM. Some factors predict successful short-term outcomes in individuals with shoulder pain receiving cervicothoracic manipulation: a single-arm trial. *Phys Ther*. 2010;90:26-42. https://doi.org/10.2522/ptj.20090095
33. Mintken PE, Cleland JA, Whitman JM, George SZ. Psychometric properties of the Fear-Avoidance Beliefs Questionnaire and Tampa Scale of Kinesiophobia in patients with shoulder pain. *Arch Phys Med Rehabil*. 2010;91:1128-1136. https://doi.org/10.1016/j.apmr.2010.04.009
34. Mintken PE, Glynn P, Cleland JA. Psychometric properties of the Shortened Disabilities of the Arm, Shoulder, and Hand Questionnaire (QuickDASH) and Numeric Pain Rating Scale in patients with shoulder pain. *J Shoulder Elbow Surg*. 2009;18:920-926. https://doi.org/10.1016/j.jse.2008.12.015
35. Mondloch MV, Cole DC, Frank JW. Does how you do depend on how you think you'll do? A systematic review of the evidence for a relation between patients' recovery expectations and health outcomes. *CMAJ*. 2001;165:174-179.
36. Moseley GL. Evidence for a direct relationship between cognitive and physical change during an education intervention in people with chronic low back pain. *Eur J Pain*. 2004;8:39-45. https://doi.org/10.1016/S1090-3801(03)00063-6
37. Moseley GL. Graded motor imagery for pathologic pain: a randomized controlled trial. *Neurology*. 2006;67:2129-2134. https://doi.org/10.1212/01.wnl.0000249112.56935.32
38. Moseley GL. Graded motor imagery is effective for long-standing complex regional pain syndrome: a randomised controlled trial. *Pain*. 2004;108:192-198. https://doi.org/10.1016/j.pain.2004.01.006
39. Moseley GL. Is successful rehabilitation of complex regional pain syndrome due to sustained attention to the affected limb? A randomised clinical trial. *Pain*. 2005;114:54-61. https://doi.org/10.1016/j.pain.2004.11.024
40. Moseley GL. Why do people with complex regional pain syndrome take longer to recognize their affected hand? *Neurology*. 2004;62:2182-2186. https://doi.org/10.1212/01.WNL.0000130156.05828.43
41. Moseley GL, Wiech K. The effect of tactile discrimination training is enhanced when patients watch the reflected image of their unaffected limb during training. *Pain*. 2009;144:314-319. https://doi.org/10.1016/j.pain.2009.04.030
42. Moseley GL, Zalucki NM, Wiech K. Tactile discrimination, but not tactile stimulation alone, reduces chronic limb pain. *Pain*. 2008;137:600-608. https://doi.org/10.1016/j.pain.2007.10.021
43. Moseley L. Unraveling the barriers to reconceptualization of the problem in chronic pain: the actual and perceived ability of patients and health professionals to understand the neurophysiology. *J Pain*. 2003;4:184-189. https://doi.org/10.1016/S1526-5900(03)00488-7
44. Muir SW, Corea CL, Beaupre L. Evaluating change in clinical status: reliability and measures of agreement for the assessment of glenohumeral range of motion. *N Am J Sports Phys Ther*. 2010;5:98-110.
45. Naugle KM, Fillingim RB, Riley JL, 3rd. A meta-analytic review of the hypoalgesic effects of exercise. *J Pain*. 2012;13:1139-1150. https://doi.org/10.1016/j.jpain.2012.09.006
46. Neviaser AS, Hannafin JA. Adhesive capsulitis: a review of current treatment. *Am J Sports Med*. 2010;38:2346-2356. https://doi.org/10.1177/0363546509348048
47. Nijs J, Malfliet A, Ickmans K, Baert I, Meeus M. Treatment of central sensitization in patients with 'unexplained' chronic pain: an update. *Expert Opin Pharmacother*. 2014;15:1671-1683. https://doi.org/10.1517/14656566.2014.925446
48. Nijs J, Van Houdenhove B, Oostendorp RA. Recognition of central sensitization in patients with musculoskeletal pain: application of pain neurophysiology in manual therapy practice. *Man Ther*. 2010;15:135-141. https://doi.org/10.1016/j.math.2009.12.001
49. Nijs J, van Wilgen CP, Van Oosterwijck J, van Ittersum M, Meeus M. How to explain central sensitization to patients with 'unexplained' chronic musculoskeletal pain: practice guidelines. *Man Ther*. 2011;16:413-418. https://doi.org/10.1016/j.math.2011.04.005
50. Nolan MF. Two-point discrimination assessment in the upper limb in young adult men and women. *Phys Ther*. 1982;62:965-969. https://doi.org/10.1093/ptj/62.7.965
51. Norlander S, Aste-Norlander U, Nordgren B, Sahlstedt B. Mobility in the cervico-thoracic motion segment: an indicative factor of musculoskeletal neck-shoulder pain. *Scand J Rehabil Med*. 1996;28:183-192.
52. Norlander S, Gustavsson BA, Lindell J, Nordgren

B. Reduced mobility in the cervico-thoracic motion segment--a risk factor for musculoskeletal neck-shoulder pain: a two-year prospective follow-up study. *Scand J Rehabil Med*. 1997;29:167-174.
53. Norlander S, Nordgren B. Clinical symptoms related to musculoskeletal neck-shoulder pain and mobility in the cervico-thoracic spine. *Scand J Rehabil Med*. 1998;30:243-251.
54. Noten S, Struyf F, Lluch E, D'Hoore M, Van Looveren E, Meeus M. Central pain processing in patients with shoulder pain: a review of the literature. *Pain Pract*. 2017;17:267-280. https://doi.org/10.1111/papr.12502
55. Office of Disease Prevention and Health Promotion. 2008 Physical Activity Guidelines for Americans. Washington, DC: US Department of Health and Human Services; October 2008.
56. Paul A, Lewis M, Shadforth MF, Croft PR, van der Windt DA, Hay EM. A comparison of four shoulder-specific questionnaires in primary care. *Ann Rheum Dis*. 2004;63:1293-1299. https://doi.org/10.1136/ard.2003.012088
57. Peek AL, Miller C, Heneghan NR. Thoracic manual therapy in the management of non-specific shoulder pain: a systematic review. *J Man Manip Ther*. 2015;23:176-187. https://doi.org/10.1179/2042618615Y.0000000003
58. Roach KE, Budiman-Mak E, Songsiridej N, Lertratanakul Y. Development of a shoulder pain and disability index. *Arthritis Care Res*. 1991;4:143-149. https://doi.org/10.1002/art.1790040403
59. Roy JS, MacDermid JC, Woodhouse LJ. Measuring shoulder function: a systematic review of four questionnaires. *Arthritis Rheum*. 2009;61:623-632. https://doi.org/10.1002/art.24396
60. Ryan CG, Gray HG, Newton M, Granat MH. Pain biology education and exercise classes compared to pain biology education alone for individuals with chronic low back pain: a pilot randomised controlled trial. *Man Ther*. 2010;15:382-387. https://doi.org/10.1016/j.math.2010.03.003
61. Sanchis MN, Lluch E, Nijs J, Struyf F, Kangasperko M. The role of central sensitization in shoulder pain: a systematic literature review. *Semin Arthritis Rheum*. 2015;44:710-716. https://doi.org/10.1016/j.semarthrit.2014.11.002
62. Smart KM, Blake C, Staines A, Doody C. Clinical indicators of 'nociceptive', 'peripheral neuropathic' and 'central' mechanisms of musculoskeletal pain. A Delphi survey of expert clinicians. *Man Ther*. 2010;15:80-87. https://doi.org/10.1016/j.math.2009.07.005
63. Smart KM, Blake C, Staines A, Thacker M, Doody C. Mechanisms-based classifications of musculoskeletal pain: part 1 of 3: symptoms and signs of central sensitisation in patients with low back (±leg) pain. *Man Ther*. 2012;17:336-344. https://doi.org/10.1016/j.math.2012.03.013
64. Strunce JB, Walker MJ, Boyles RE, Young BA. The immediate effects of thoracic spine and rib manipulation on subjects with primary complaints of shoulder pain. *J Man Manip Ther*. 2009;17:230-236. https://doi.org/10.1179/106698109791352102
65. Struyf F, Meeus M. Current evidence on physical therapy in patients with adhesive capsulitis: what are we missing? *Clin Rheumatol*. 2014;33:593-600. https://doi.org/10.1007/s10067-013-2464-3
66. Tate AR, McClure PW, Young IA, Salvatori R, Michener LA. Comprehensive impairment-based exercise and manual therapy intervention for patients with subacromial impingement syndrome: a case series. *J Orthop Sports Phys Ther*. 2010;40:474-493. https://doi.org/10.2519/jospt.2010.3223
67. Thieme H, Morkisch N, Rietz C, Dohle C, Borgetto B. The efficacy of movement representation techniques for treatment of limb pain—a systematic review and meta-analysis. *J Pain*. 2016;17:167-180. https://doi.org/10.1016/j.jpain.2015.10.015
68. Tveitå EK, Ekeberg OM, Juel NG, Bautz-Holter E. Range of shoulder motion in patients with adhesive capsulitis; intra-tester reproducibility is acceptable for group comparisons. *BMC Musculoskelet Disord*. 2008;9:49. https://doi.org/10.1186/1471-2474-9-49
69. Tveitå EK, Ekeberg OM, Juel NG, Bautz-Holter E. Responsiveness of the Shoulder Pain and Disability Index in patients with adhesive capsulitis. *BMC Musculoskelet Disord*. 2008;9:161. https://doi.org/10.1186/1471-2474-9-161
70. Tveitå EK, Sandvik L, Ekeberg OM, Juel NG, Bautz-Holter E. Factor structure of the Shoulder Pain and Disability Index in patients with adhesive capsulitis. *BMC Musculoskelet Disord*. 2008;9:103. https://doi.org/10.1186/1471-2474-9-103
71. Vierck CJ, Jr., Staud R, Price DD, Cannon RL, Mauderli AP, Martin AD. The effect of maximal exercise on temporal summation of second pain (windup) in patients with fibromyalgia syndrome. *J Pain*. 2001;2:334-344. https://doi.org/10.1054/jpai.2001.25533
72. Vingerhoets G, de Lange FP, Vandemaele P, Deblaere K, Achten E. Motor imagery in mental rotation: an fMRI study. *NeuroImage*. 2002;17:1623-1633. https://doi.org/10.1006/nimg.2002.1290
73. Waddell G, Newton M, Henderson I, Somerville D, Main CJ. A Fear-Avoidance Beliefs Questionnaire (FABQ) and the role of fear-avoidance beliefs in chronic low back pain and disability. *Pain*. 1993;52:157-168. https://doi.org/10.1016/0304-3959(93)90127-B
74. Wainner RS, Whitman JM, Cleland JA, Flynn TW. Regional interdependence: a musculoskeletal examination model whose time has come. *J Orthop Sports Phys Ther*. 2007;37:658-660. https://doi.org/10.2519/jospt.2007.0110
75. Walz AD, Usichenko T, Moseley GL, Lotze M. Graded motor imagery and the impact on pain processing in a case of CRPS. *Clin J Pain*. 2013;29:276-279. https://doi.org/10.1097/AJP.0b013e318250f4e8
76. Wertli MM, Rasmussen-Barr E, Held U, Weiser S, Bachmann LM, Brunner F. Fear-avoidance beliefs—a moderator of treatment efficacy in patients with low back pain: a systematic review. *Spine J*. 2014;14:2658-2678. https://doi.org/10.1016/j.spinee.2014.02.033
77. Wertli MM, Rasmussen-Barr E, Weiser S, Bachmann LM, Brunner F. The role of fear avoidance beliefs as a prognostic factor for outcome in patients with nonspecific low back pain: a systematic review. *Spine J*. 2014;14:816-836.e4. https://doi.org/10.1016/j.spinee.2013.09.036
78. Wong CK, Levine WN, Deo K, et al. Natural history of frozen shoulder: fact or fiction? A systematic review. *Physiotherapy*. 2017;103:40-47. https://doi.org/10.1016/j.physio.2016.05.009
79. Woolf CJ. Central sensitization: implications for the diagnosis and treatment of pain. *Pain*. 2011;152:S2-S15. https://doi.org/10.1016/j.pain.2010.09.030
80. Zuckerman JD, Rokito A. Frozen shoulder: a consensus definition. *J Shoulder Elbow Surg*. 2011;20:322-325. https://doi.org/10.1016/j.jse.2010.07.008