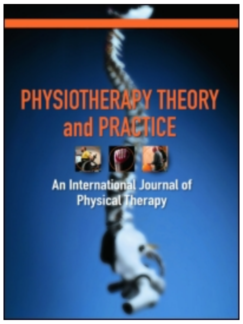

Taylor & Francis
Taylor & Francis Group

Physiotherapy Theory and Practice
An International Journal of Physical Therapy

ISSN: 0959-3985 (Print) 1532-5040 (Online) Journal homepage: http://www.tandfonline.com/loi/iptp20

Reconciling movement and exercise with pain neuroscience education: A case for consistent education

Cory Blickenstaff, PT, MS, OCS & Neil Pearson, PT, MSc (RHBS), BA-BPHE

PHYSIOTHERAPY THEORY AND PRACTICE
http://dx.doi.org/10.1080/09593985.2016.1194653

Taylor & Francis
Taylor & Francis Group

PERSPECTIVE

Reconciling movement and exercise with pain neuroscience education: A case for consistent education

Cory Blickenstaff, PT, MS, OCS[a] and Neil Pearson, PT, MSc (RHBS), BA-BPHE[b]

[a]Forward Motion Physical Therapy, Vancouver, WA, USA; [b]Department of Physical Therapy, University of British Columbia, Penticton, BC, Canada

ABSTRACT
This article will introduce a conceptual framework of kinesthetic education that is consistent with and reinforces pain neuroscience education. This article will also provide some specific guidance for integrating pain neuroscience education with exercise and movement in a more congruent manner. Our belief is that this will enhance the effectiveness of specific movement approaches such as graded exposure techniques. Over the past decade, a new paradigm of pain education has been explored in an effort to improve patient outcomes. Using advances in pain neuroscience, patients are educated in the biological and physiological processes involved in their pain experience. Growing evidence supports the ability of pain neuroscience education (PNE) to positively impact a person's pain ratings, disability, pain catastrophization, and movement limitations. What is often overlooked, however, is the consistency between the messages of PNE and those of other therapeutic interventions, including movement therapies. This article proposes the following: education provided in isolation will be limited in its impact, the addition of guided purposeful movement performed in a manner consistent with PNE may be vital to the desired behavioral changes, and when inconsistent messages are delivered between education and movement interventions, outcomes may be adversely impacted.

ARTICLE HISTORY
Received 12 November 2015
Revised 3 January 2016
Accepted 25 February 2016

KEYWORDS
Exercise; graded exposure; guidance; movement; neuroscience; pacing; pain

Introduction

Growing interest and support for pain education and neuroscience-based interventions for people in pain have pushed these approaches toward the mainstream (Moseley and Butler, 2015; Nijs et al, 2011). Both pain neuroscience education and exercise have demonstrated impact on factors known to be associated with the physiology, development, progression, persistence, and recovery from pain and disability (Moseley, 2002; Nijs et al, 2011). Physical therapists, who are traditionally well versed in approaches to movement and exercise, may grow frustrated when attempting to reconcile these approaches and incorporate them into practice. Re-conceptualizing movement intervention as a form of education, one that is communicated kinesthetically, can assist in reconciling these treatment approaches (O'Sullivan, Dankaerts, O'Sullivan, and O'Sullivan, 2015). Alterations in the meaning of the experience of pain and the physiology associated with pain occur together (Moseley, 2004). We should acknowledge the importance of kinesthetic education as a means to alter both the experience of pain and pain physiology. This paper will introduce a conceptual framework of kinesthetic education that is consistent with and reinforces pain neuroscience education. This paper will also provide some specific guidance for integrating pain neuroscience education with exercise and movement in a more congruent manner. Our belief is that this will enhance the effectiveness of specific movement approaches such as graded exposure techniques.

Movement/exercise as an approach to pain

Since Richard Deyo's landmark publication in 1986 regarding active care versus bed rest for patients with acute low back pain (Deyo, Diehl, and Rosenthal, 1986), guidelines for management of painful conditions have increasingly advised movement and activity (Waddell, Feder, and Lewis, 1997) to the point of being nearly ubiquitous. It is clear that movement is commonly effective for painful conditions. In the case of chronic pain, effectiveness of exercise programs have been demonstrated in populations of: chronic neck pain (Childs et al, 2008; Cuesta-Vargas, González-Sánchez, and Casuso-Holgado, 2013; Stewart et al, 2007; Teasell et al, 2010); osteoarthritis (Cuesta-Vargas, González-Sánchez, and Casuso-Holgado, 2013;

CONTACT Cory Blickenstaff, PT, MS, OCS cory@forwardmotionpt.com Forward Motion Physical Therapy, 13023 NE Hwy 99, Ste 7 #109, Vancouver, WA 98686, USA.

Jansen et al, 2011); headache (Darling, 1991); fibromyalgia (Brosseau et al, 2008); and chronic low back pain (Cuesta-Vargas, González-Sánchez, and Casuso-Holgado, 2013; van Middelkoop et al, 2010). What is often less clear, clinically, is how these various intervention approaches should contribute to a comprehensive episode of care. A key contributor to this difficulty is the indication that in some chronic pain populations the magnitude and direction of the effect sizes are highly variable in response to exercise as compared to acute and subacute populations (Daenen, Varkey, Kellmann, and Nijs, 2015).

Graded exposure and graded activity programs have been shown to be particularly promising approaches for chronic pain problems (Boersma et al, 2004; de Jong et al, 2005; Leeuw et al, 2008; Linton et al, 2008; Vlaeyen et al, 2001; Woods and Asmundson, 2008). However, when compared against each other and other exercise interventions, the results tend to be equivocal (George, Wittmer, Fillingim, and Robinson, 2010; López-de-Uralde-Villanueva et al, 2015; Macedo, 2010; Rasmussen-Barr, Äng, Arvidsson, and Nilsson-Wikmar, 2009). Graded activity programs work on quota based systems in which a set amount of increase at a predetermined rate is employed in an operant conditioning model, while exposure based models attempt to extinguish the response to feared activities through desensitization under controlled conditions (Lindström et al, 1992; Main et al, 2015; Riecke, Holzapfel, Rief, and Glombiewski, 2013; Vlaeyen et al, 2012) . It is clear that neither approach is effective for all chronic pain patients and that factors such as catastrophizing can predict a poorer outcome to these methods (Flink, Boersma, and Linton, 2010; Leeuw et al, 2006; Zale, Lange, Fields, and Ditre, 2013). These research findings suggest that the success of exercise approaches is in-part dependent upon how the approach is integrated with psychosocial targets.

Further bolstering the relevance of psychosocial factors is the fact that despite the clear presence of physical impairments, such as specific strength and mobility changes, nothing appears to be gained by providing exercises to specifically address them. As a case in point, a program aimed at stabilization of the low back was no more effective than a general exercise approach despite specific impairments of the stabilizer muscle groups (Smith, Littlewood, and May, 2014). This may also be evident in the case of deconditioning. It would be logical to assume that those in chronic pain display high levels of deconditioning due to reduced tolerance to activity and progression of physical impairments. However, Bousema et al. (2007) found this not to be the case, again pointing toward the conclusion that something beyond physical impairment is being addressed when individuals respond positively to exercise and movement. While psychosocial targets are a clear target for intervention, they also pose as significant barriers to recovery.

Barriers to movement as an education intervention

Pain research includes numerous theories and studies of the barriers that limit the recovery of people with chronic pain. Yet, because pain is a biopsychosocial phenomenon, the search for those factors that limit recovery should include a more integrated view of barriers. Biological and physiological factors related to chronic pain may be as important as cognitive, emotional and vocational factors. Alterations in nervous system sensitization, changes in interoception, and physiological arousal (Loggia, Juneau, and Bushnell, 2011) are among the biological processes that should be considered in an expanded biopsychosocial perspective on barriers to recovery. This section presents several specific examples of barriers that exist within these realms.

Those with chronic pain often display an impaired endogenous pain inhibitory system and a hyperalgesic response to exercise

Several chronic pain populations have demonstrated impaired pain inhibition (Lewis, Rice, and McNair, 2012) which is typically evaluated through measurements of conditioned pain modulation (Yarnitsky et al, 2015) and exercise induced hypoalgesia (Lannersten and Kosek, 2010). These groups often respond to exercise with hyperalgesia while those without the impairment respond with hypoalgesia (Vaegter, Handberg, Graven-Nielsen, and Edwards, 2016). To date, we lack sufficient normative values for neural sensitization to make measurement of sensitization clinically useful, even though considerable research shows that persisting pain increases the responsiveness and reactivity of many aspects of the nervous system (Coombes, Bisset, and Vicenzino, 2012; Jull, Sterling, Kenardy, and Beller, 2007; Paul, Soo Hoo, Chae, and Wilson, 2012; Roussel et al, 2013; Suokas et al, 2012; van Wilgen et al, 2013).

The impaired endogenous pain inhibitory system is associated with catastrophic beliefs, a heightened sensitivity to pain, a lower threshold to pain, and facilitation of temporal summation of pain

In chronic pain, those with high sensitivities have been found to have associated catastrophic beliefs and are within the sub-group who demonstrate an impaired endogenous inhibitory pain modulation (Lewis, Rice, and McNair, 2012; Naugle, Fillingim, and Riley, 2012). Additionally, they display an increase in temporal summation of pain, where repeated exposure to a stimulus increases the amount of pain. People with low pain sensitivity tend to show the opposite effect. Catastrophic beliefs, having three elements; helplessness, magnification, and rumination have been shown to be involved in numerous poor prognostic indicators (Peters, Vlaeyen, and Weber, 2005; Sullivan, Lynch, and Clark, 2005; Turner, Mancl, and Aaron, 2004). These have been found to mediate changes seen in both physical and cognitive behavioral treatments (Smeets, Vlaeyen, Kester, and Knottnerus, 2006), and impact involvement in exercise participation (Goodin et al, 2009). The graded exposure approach mentioned above more predictably demonstrates effectiveness in populations with low to moderate catastrophizing scores. Those with high catastrophizing scores, typically identified through the pain catastrophizing scale (PCS) (Sullivan, Bishop, and Pivik, 1995), appear to be the specific group who do not respond to graded exposure (Flink, Boersma, and Linton, 2010). Therefore, both identification using the PCS and interventions related to this finding, possibly including referral to a behavioral health specialist, are keys to working with this population.

Chronic pain patients demonstrate cortical reorganization and imprecise neural coding of proprioceptive and exteroceptive sensory events

Spatial and proprioceptive acuity is impaired in people with chronic pain as they demonstrate disruptions in the perceived size, location, and ability to mentally maneuver body parts (Wand et al, 2011). They also demonstrate altered tactile acuity (Catley et al, 2014), a test of exteroception. These sensory events are encoded in cortical representations less precisely in people with chronic pain than they are in people with acute pain or in healthy controls (Moseley and Vlaeyen, 2015). Tactile acuity training has shown changes in pain that were positively associated with cortical re-organization (Flor, Denke, Schaefer, and Grüsser, 2001).

Low sensitivity of interoception is associated with reduced self-regulation

Sensation of the internal states or physiologic conditions of our body is known as interoception. One's homeostatic state, although normally controlled automatically below our awareness, can be consciously self-monitored (Tsay, Allen, Proske, and Giummarra, 2015). It has been suggested that the perception of one's status of homeostasis (the level of threat to one's well-being) contributes to the overall stress response implicated in chronic widespread pain (Lyon, Cohen, and Quintner, 2011). Individuals who demonstrate higher interoceptive sensitivity also demonstrate a higher capacity for self-regulation (Weiss, Sack, Henningsen, and Pollatos, 2014). This apparently enables them to override and alter their responses (Vohs et al, 2008) via self-monitoring, appraisal, and subsequent conscious reactions (Maes and Karoly, 2005). For example, interoceptive sensitivity may allow one to become aware of the increased heart rate of a stress response and subsequently react to self-regulate breathing and thoughts.

The benefit of heightened interoceptive sensitivity seems at odds with findings of hypervigilance, a compulsive monitoring for painful sensation, which is associated with a poorer prognosis. However, it has been suggested that interoception is a multifaceted concept with two realms relevant in the case of hypervigilance; interoceptive sensitivity and the interpretation of the sensations (Yoris et al, 2015). It appears that they are those with a combination of high interoceptive vigilance and catastrophic beliefs with passive coping strategies which have poorer prognoses (Meredith, Rappel, Strong, and Bailey, 2015). Additionally, the narrow intense focus of individuals on pain sensation at the expense of experiencing subtle non-pain sensations of the body may contribute to a lack of self-regulating activity. For example, while a person with low interoceptive sensitivity may have difficulty recognizing the presence of a stress response, a hypervigilant person would not only recognize the sensation as a sign of a stress response, but may also attribute the sensation to a worst case scenario such as having a heart attack (catastrophizing), the thought of which would worsen the stress response, facilitating maladaptive responses, and further worry them about their situation. This inability to self-assess and to regulate physiological arousal may also be significant barriers to recovery. Pain alters the hypothalamus-pituitary-adrenal (HPA) axis (McBeth et al, 2005) and is associated with increased sympathetic activity (Loggia, Juneau, and Bushnell, 2011). With disrupted interoception, people in pain may not self-assess the need for regulation, and may also lack skill in self-regulation of physiological arousal.

Pain, disability, and their change over time relate to recovery expectations and coping behavior

Poor recovery expectations have been demonstrated as predictive of those who will have a poor outcome in chronic low back pain populations (Iles, Davidson, Taylor, and O'Halloran, 2009). They have also been shown to be quite changeable and in fact are often cited as a target of the placebo response. When an individual's beliefs are altered to include the possibility of improvement, greater improvements are seen (Vase, Petersen, Riley, and Price, 2009).

The manner in which one copes with pain also has a large impact on the outcome. Both avoidance behavior and endurance behavior (where the symptoms are ignored) are poor prognostic indicators (Hasenbring and Verbunt, 2010; Linton, Buer, Vlaeyen, and Hellsing, 2000). A well-studied example of avoidance behavior relates to kinesiophobia or fear of movement. Fear of movement has been shown to mediate the disability and pain intensity at onset of chronic pain (Costa and Maher, 2011). Conversely, there are findings to suggest that, in the context of a painful experience, the active coping behavior of sensation seeking may constitute a protective factor (Meredith, Rappel, Strong, and Bailey, 2015).

Related to both recovery expectations and coping strategies is self-efficacy, which indicates the degree to which a person believes that they can: 1) get through a problem; and 2) do so of their own accord, have been found to mediate catastrophizing (McKnight et al, 2010). In a study by Costa and Maher (2011), self-efficacy was shown to mediate the changes in pain intensity and disability during the course of care and disability and pain intensity at onset of chronic pain (Table 1).

Generally, barriers to recovery are those factors that are associated temporally with a condition, that the presence of the finding predicts poorer outcomes, and that there is a negative correlation between severity of the barrier and likelihood of treatment success. Many of these clinical findings listed in Table 1 may also have potential associations with nervous system sensitization, altered interoception, and physiological arousal. Physiotherapists have the ability to assess whether their interventions have an influence on the majority of these, and should consider that like many barriers to recovery, when we are able to address the barrier, this is associated with clinical improvements.

Table 1. Clinical observation.

Clinicians often report these subjective and objective findings in people in pain. Each may be correlated with pain, but few studies are available to assess the impact of altering these on pain or movement.

- rapid shallow breathing
- increased muscle tension
- allodynia to touch, cold and/or movement
- altered proprioception
- altered interoception (often unaware of breath pattern and body tension)
- difficulty in performing refined movements
- difficulty in experiencing non-pain sensations
- breath holding, and further increases in muscle tension when moving toward the pain
- it hurts to move
- belief that pain equals tissue damage
- external locus of control in relation to pain
- external locus of control in relation to movement
- fear or movement or losing competence
- grief, including loss of self-efficacy
- high sympathetic arousal, that is difficult to change
- belief that a movement is safe, yet difficulty regulating physiological arousal with specific movements

Pain neuroscience education is an effective way to alter beliefs related to pain, which interfere with the success of exercise interventions

Pain neuroscience education has been shown to be effective in changing pain beliefs including catastrophizing (Meeus et al, 2010; Moseley, 2004) and kinesiophobia (Van Oosterwijck et al, 2011); improving health status and reducing healthcare expenditure in adult patients with various chronic pain disorders (Louw, Diener, Butler, and Puentedura, 2011; Louw, Diener, Landers, and Puentedura, 2014; Meeus et al, 2010; Moseley, 2002; Moseley, 2003; Moseley, 2004; Moseley, 2005; Moseley, Nicholas, and Hodges, 2004; Van Oosterwijck et al, 2011; Van Oosterwijck et al, 2013). Additionally, it has been shown to impact impaired endogenous pain inhibitory responses (Van Oosterwijck et al, 2013) and therefore impacts factors important for those who often prove resistant to care. Pain neuroscience education is a cognitive approach as it seeks to change beliefs and cognitions related to pain. When cognitive experiences are introduced that are inconsistent with the belief that pain equates with the state of the tissues, the threat value of pain and injury are potentially decreased. This opens the door for individuals to consider the influence they have over regaining movement and function while decreasing pain. It appears that when individuals understand more about pain physiology they will alter the manner in which they approach movement, exercise and activity. Pain with movement is no longer seen as an experience to endure or as an experience from which to flee. Thus, individuals are able to repeat movements with greater ease and frequency to create adaptive improvements in pain physiology.

In an excellent summary, Nijs and Meejus (2015) indicated several factors need be present for a cognitive approach to have effect. They specify that: 1) Only patients dissatisfied with their current perceptions about pain are prone to reconceptualization of pain (Siemonsma, Schröder, Roorda, and Lettinga, 2010; Siemonsma et al, 2008; Siemonsma et al, 2013); 2) any new explanation must be intelligible to the patient (Siemonsma, Schröder, Roorda, and Lettinga, 2010;

Siemonsma et al, 2008; Siemonsma et al, 2013); 3) a new explanation must appear plausible and beneficial to the patient; 4) the new explanation should be shared and confirmed by the direct environment of the patient; and 5) interaction with a therapist is necessary. Additionally, there is some evidence that individual education provides better outcomes than small group education (Moseley, 2003). This individualization is also important in exercise prescription for people in pain. Additionally, there may be a minimum baseline of problem solving, discussion, and/or verbal skills needed in order for cognitive approaches to be effective (Siemonsma et al, 2011).

Both movement and cognitive approaches serve as education and need to be consistent

Aligning exercise prescription and instructions with the key messages of pain education may be critical to success (Ryan, Gray, Newton, and Granat, 2010) indicating that the manner in which other interventions are prescribed to a person with chronic pain should be consistent with the messages of pain neuroscience education. For example, a new more optimistic view of pain could be nullified if the instructions for exercise indicate that pain is to be avoided and indicative of tissue damage. Confusion may ensue if exercise instructions after pain education do not include any focus on the individual's sense of safety or threat related to the exercise. Pain neuroscience education intends to provide compelling experiences convincing the individual that there is less threat than they previously considered, while also providing optimism for improved pain and function. This task becomes difficult for the educator when the messages of PNE are contrary to what the learner has been taught by others about pain. The final section of this paper provides examples of movement instruction informed by pain science.

It has also been suggested that for change to occur, exploration and experimentation need to happen in both the mental and physical realms (Siemonsma et al, 2008). Both pain neuroscience education and exercise/movement potentially provide these experiences, and should both be considered as educational opportunities. Pain neuroscience education alters the threat value of movement, while subsequent movement confirms or refutes this new belief while providing repeated sensory inputs required for creating enduring shifts in the automatic movement and stress response. The sensory and experience-rich environment of movement and exercise is kinesthetic education. A combination of verbal and kinesthetic education may be the best approach to bring about change, however highly experiential learners may be best suited to a kinesthetic dominant approach (Alkhasawneh et al, 2008; Murphy, Gray, Straja, and Bogert, 2004). As Nijs and Meeus (2015) pointed out, the new explanation of pain should be confirmed by the patient's environment. The experiences of movement should be used to fortify pain education, and vice versa. Should the experiences of movement and exercise prescription be negative then there is potential for negative effects on new pain beliefs and recovery attitudes. As an example, movement and exercise are opportunities to experience direct proof that movement is not so dangerous. When we move in a way that feels safe and does not worsen the pain, we learn that ease of movement and pain can be changed. Additionally, repeated positive movement experiences may assist in extinguishing persistent pain neurotags, and restoring body awareness and body schema. Based on these concepts, how should we guide our patients to approach movement, based on pain science?

Presentation of guidelines for moving in the face of pain

With these concepts and findings in mind the following two sets of guidelines are presented to employ verbal and kinesthetic education to the person in pain. The first guideline is intended as a starting point, for practitioners new to integrating pain neuroscience education into exercise prescription, and without a background in employing cognitive principles into their interventions. The second guideline walks through a more complex interaction placed within a broader intervention context.

Guideline 1: The simple interaction

Guide the patient to move their body or limb to the position at which they report a slight increase in pain intensity, just perceptibly above their baseline intensity. Once there, the patient is instructed to ask two questions: "Is this (movement or position) safe for my physical body?" and "Will I be okay later (if I move this much or stay in this position)?"

With some practice and effort, the patient will find an amount of movement or postural change that feels safe, and that won't likely flare the pain. At this point the patient is directed to divide their attention between their breath, body tension and the pain. Once aware of these, the patient is instructed to do their best to keep their breath calm and their muscle tension low, while also attending to the pain, allowing self-monitoring that is unlikely to become hypervigilant or distracted.

Table 2. Steps of guideline 1.

(1)	Move to the edge of the increased pain.
(2)	Ask, "Is this safe?"
(3)	Ask, "Will I be okay later?"
(4)	Monitor and regulate breathing pattern during movement.
(5)	Monitor and regulate muscle tension during movement.
(6)	Monitor the pain during movement. Avoiding hypervigilance and full distraction (Pearson N, 2015).

Keeping one's thoughts calm, while keeping breath and body tension calm, is intended to alter sensory inputs in a manner consistent with the individual's appraisal of safety. In other words, avoiding holding one's breath, breathing shallowly, and tensing up the body are intended to alter sensory inputs in order to decrease the threat value of the movement. Monitoring the pain also decreases the threat value of movement, allowing the individual to avoid pushing through the pain into a flare up, and avoid becoming hypervigilant.

Consistent with pain neuroscience education, these guidelines provide an opportunity to experience movement that does not worsen the pain. Additionally, this guide allows the patient to individualize movement and exercise (Table 2).

Case example one

Your patient with chronic low back pain reports pain with rolling from crook lying to either side. Until he was provided pain neurophysiology education, he believed this was dangerous for his back. After the education he states that he is considering whether this might not be so dangerous, yet he is skeptical.

From a crook lying position, we ask him to roll his knees to the side that hurts less, or he feels is more safe. He is instructed to move only to a point at which there is a slight increase in pain, and then return toward center. He is asked "do you believe that was a safe movement – one that did not harm your body?". If he says it was not safe, then he is asked to move only to a spot at which he feels safe. Once he has found that amount of movement, he is asked a second question, "Will you be okay later?" If he believes he will regret moving this much, the movement is modified again. Once he finds an amount of rolling his knees to the side that he believes isn't dangerous and that he won't regret later, he is asked to repeat the movement while attending to his breath, his muscle tension, and his pain. The PT observes the patient's breathing pattern and muscle tension, helping to guide him to avoid rapid and shallow breaths, breath holding, or tensing of his muscles during the movement. The PT also guides him in the importance of attending enough to the pain to ensure he will not flare up, and not so much to become hypervigilant.

There are some key points for success with these guidelines. First, do not stop as soon as the pain increases, breath gets tight, or body tension increases. When the patient states that he cannot keep his body or breath calm, the first thing to do is ask him the same questions again, and then ask him to try harder to calm his breath and body. If doing this does not decrease the threat, then it is time to stop for now. If the movement no longer feels threatening, then he should stay longer. Second, success with these guidelines may be limited by interoception sensitivity issues and ability to self-regulate. Some individuals will require guidance and practice with maintaining longer smoother breathing patterns, and with reducing muscle or body tension, in order to perform movements in a manner that does not provide the brain with evidence that there is something dangerous happening in the body.

Guideline 2: The complex interaction

Educate in the language of physiology before that of psychology

Education is vital throughout the course of care, however, in many cases it may be the primary intervention at the outset of an episode. It is clear that many if not most patients present with the belief that their problem relates to some combination of anatomical or physiologic pathology (Nijs et al, 2015). These patients will initially be skeptical of a fear avoidance behavior approach to education (Nijs et al, 2015) as is typically used at the outset of graded exposure protocols (Vlaeyen et al, 2001). Pain neuroscience education, which approaches biopsychosocial education through the lens of physiology, is therefore well suited to the task of challenging those assumptions and laying the groundwork for the movement work ahead.

Address responses through graded exposure approaches

In graded exposure, the patient is repetitively exposed to a triggering stimulus with the goal being a gradual extinction of the response through desensitization (Main et al, 2015; Vlaeyen et al, 2012). Other cognitive behavioral therapy principles are applied during the course of care and this guideline will present some novel approaches to be used in this regard.

An important early step is determining a hierarchy of those items that the patient finds to be triggering. This may be done simply through various means of interview and examination or more systematically through use of tools such as questionnaires. Pick a low threat task or task component from the hierarchy as the first target of intervention. For example, if the patient finds bending and turning at the trunk to be a trigger, the first target could be to expose the patient to a low intensity trunk rotation. Move to the point of the trigger to find the level of tolerance of performing the motion. The patient is to monitor for the first signs of the trigger; changes in breathing, in perceived muscle tension, in pain, or a general feeling of unease. This is the point of appraisal. If the processes of reduced temporal summation and of extinction of response are active one would expect to see a reduction in the expression of these findings with repeated exposures. Slow and controlled movements up to and away from this point of appraisal are completed. However, as was noted earlier, patients with chronic pain often demonstrate the opposite effect having an increase in temporal summation (Vaegter, Handberg, Graven-Nielsen, and Edwards, 2016) with a resulting hyperalgesia and wind up of pain. Education is a key here, as this response tends to associate with beliefs such as catastrophizing (Lewis, Rice, and McNair, 2012; Naugle, Fillingim, and Riley, 2012).

Graded exposure protocols often suggest the implementation of a general "relaxation" intervention to teach skills of gaining control over reactions (Meeus et al, 2015). A more specific application would be to ask the patient to attend to their breathing and muscle tension at the point of appraisal and during the movement in question. Also, the appraisal itself is addressed through pointed questions asking the patient to consider the present and future safety for having engaged in the task this way. Attending to responses in this way has evidence of increasing the extinction response (Tsay, Allen, Proske, and Giummarra, 2015).

At the point of appraisal, specific interventions may be applied in an attempt to reduce the perceived threat level of the movement or situation. This may take the form of a "cognitive challenge" in which the patient is asked to consider alternative ways of thinking about the problem and thereby alter the cognitive response (Vlaeyen et al, 2012). Pain neuroscience education is well suited to this task. However, an additional approach is to alter sensory input at the point of appraisal. This can be done in any number of ways, such as alterations in the position, addition of an isometric muscle contraction, or even the addition of manual contact. But, a simple example is to start with altered breathing and muscle tension, to which the patient has at this point already learned to attend. Simply having the patient actively breathing slowly and fully and actively attempting to reduce the muscle tension at this point may serve as an alteration of sensory input sufficient to reduce the perceived level of threat. Thus the patient has learned an active coping strategy that can be applied to their response to movement and pain. This is consistent with Zusman's concept of "exposure without danger (Zusman, 2004)."

A common graded exposure practice is that of pacing, in which a patient "paces" their activities throughout the day based on a quota or amount of activity (Nielson, Jensen, Karsdorp, and Vlaeyen, 2013). Pacing has little support of effectiveness (Nielson, Jensen, Karsdorp, and Vlaeyen, 2013). Alternatively, what may be done is to educate the patient to utilize the skills that they have learned of attending to the movements and activities of their life. Thus, instead of pacing based on an amount of movement, they have attended activity, based on the manner and response to movement which is a more active coping behavior.

Address pain behavior through graded activity

Graded activity typically consists of establishing an amount of activity that the patient feels safe participating in, and then the patient and therapist agree on a set amount of increase in activity over a given time. This is a quota based system. Importantly throughout the graded activity process, the patient re-establishes "well behavior". A graded exercise program is often used for this process and Fordyce claimed that exercise is always a well behavior (Main et al, 2015). As mentioned earlier, forms of graded exercise have been shown to be as effective as other programs focused on graded functional activities (Rasmussen-Barr, Äng, Arvidsson, and Nilsson-Wikmar, 2009). However, graded activity presents an opportunity to provide education within the context of relevant functional activities.

As exercise programs are commonly explained using the language of strain, recovery, and tissue response, these explanations could very easily provide an inconsistency with the pain neuroscience education. It is vital that all forms of education have consistency. Otherwise, the various forms of intervention will devalue each other, perhaps rendering a portion or the entirety of the program ineffective. Clear language, consistent with pain education, asserts that the initial intention of movement and exercise is to impact the nervous system. As such, improvements are expected to occur following timelines more akin to motor learning than to tissue responses.

Case example two

This case highlights some specific examples of use of these guidelines at the point of the beginning of exposure movements. As a part of the initial encounter it is identified that the patient has most difficulty and pain with lifting and has expressed fear that this may indicate a more significant problem that has not yet been identified. As time has gone by, all of his motions and positions of the back have become increasingly limited and painful. Based upon the interview and examination, including the patient specific functional scale, it is determined that motions and activities involving rotational motions are lower on the hierarchy of threatening movement, while bending forward, and ultimately lifting are higher.

A discussion ensues regarding the patient's beliefs about their pain and the therapist facilitates the discussion taking place in terms of the impact that they have on the valued activities. Examination findings are discussed and as appropriate reassurance and recovery expectations are addressed using open ended questioning. Pain neuroscience education is used to create a reasonable context for the presence and nature of their pain and the patient is invited to begin exploring motion.

With the patient in crook lying, they are asked to let both of their knees lower slowly to one side as far as they feel that they can safely go, return to the starting position and repeat to the other side. They are questioned about what they felt during the movement and why they stopped where they did. They are then asked to repeat the motion, but this time they are to stop at the first sign of anything that they would consider to be a protective response. They are advised that this is the point of appraisal, the "edge" (Blickenstaff, 2015), and it could be an alteration in muscle tension, breathing, pain, or even a general feeling of unease. If breath holding or preparatory muscle tension is noted they are actively encouraged to keep their breathing calm and muscles relaxed. Once they have demonstrated the skill of finding this point of appraisal, they are taken through a series of approaches.

(1) They move up to the point of appraisal and then immediately back to the starting point repetitively. They are encouraged to attend to and find that point each time instead of trying to match a particular position. They are actively questioned as to any changes in response, quality, or amount of motion and if any changes are observed they are pointed out to the patient.
(2) Next they move up to the point of appraisal again, and while staying at that position take 3 full breaths and then return to the starting point. Then they immediately move to the point of appraisal again while actively looking for change. This is then repeated numerous times, always attending to the motion and any changes.
(3) They are again asked to move to the point of appraisal with their knees, and while staying at that position, they push their palms together in an isometric contraction holding for three breaths, and then relaxing the arms and returning the knees to the starting point. Again they immediately return to the point of appraisal while actively looking for change.

Many other forms of sensory input may be applied at the point of reappraisal, such as altering the position of a body part or even applying manual therapy. Caution in the selection of the altered sensory input should be taken with the purpose of encouraging active coping behaviors. This is also a point with the "cognitive challenge" process may be completed. For example, if the patient had expressed concerns about a spinal degeneration, a discussion could ensue about how simply breathing could have no impact on the presence of degenerative findings which could lead into a productive pain neuroscience discussion. At subsequent sessions, the complexity and level of prior stress of the chosen movement is increased. For example, the process could next be applied to a rotational movement done in sitting or standing or in a functional context such as rolling in bed. This progression continues toward those motions that were indicated as being more stressful, namely forward bending and lifting.

The patient describes some familiarity and enjoyment in the past with resistance training. While standing in their most comfortable position they demonstrate the ability to perform multiple sets of isometric exercises of the shoulders, knees, and ankles without increasing their symptoms. Patient and therapist agree on a set amount of increase per week in the repetitions and duration of holds performed of the exercises. This is to be the start of the graded activity program. The effect of isometrics to elicit exercise induced hypoalgesia is discussed as is the effectiveness of exercise in painful populations. The purpose of the exercise is clearly explained as being aimed at well behaviors and not strength, per se. Additionally, the patient is reminded of how they learned to respond to their symptoms during the crook lying movement and taught how this could be applied during the graded activity process as well.

Conclusion

Clinical pain science provides guidance for innovations in exercise and movement prescription as well as instruction for people with persistent pain. Inconsistencies derived from differing historical philosophies of care are pervasive in common practice. Equally important, previous guidelines have not considered exercise and movement as an educational modality. The guidelines in this paper were created in attempt to reconcile these issues based upon the available evidence. However, the reader is cautioned that these guidelines themselves have not been subjected to specific scrutiny through scientific enquiry at this point.

References

Alkhasawneh IM, Mrayyan MT, Docherty C, Alashram S, Yousef HY 2008 Problem-based learning (PBL): Assessing students' learning preferences using vark. Nurse Education Today 28: 572–579.

Blickenstaff C 2015 Novel Movement Opportunities Using the Edgework Approach. San Diego Pain Summit, San Diego, CA.

Boersma K, Linton S, Overmeer T, Jansson M, Vlaeyen J, de Jong J 2004 Lowering fear-avoidance and enhancing function through exposure in vivo: A multiple baseline study across six patients with back pain. Pain 108: 8–16.

Bousema EJ, Verbunt JA, Seelen HA, Vlaeyen JW, Knottnerus JA 2007 Disuse and physical deconditioning in the first year after the onset of back pain. Pain 130: 279–286.

Brosseau L, Wells GA, Tugwell P, Egan M, Wilson KG, Dubouloz CJ, Casimiro L, Robinson VA, McGowan J, Busch A, Poitras S, Moldofsky H, Harth M, Finestone HM, Nielson W, Haines-Wangda A, Russell-Doreleyers M, Lambert K, Marshall AD, Veilleux L; Ottawa Panel Members 2008 Ottawa Panel evidence-based clinical practice guidelines for aerobic fitness exercises in the management of fibromyalgia: Part 1. Physical Therapy 88: 857–871.

Catley MJ, O'Connell NE, Berryman C, Ayhan FF, Moseley GL 2014 Is tactile acuity altered in people with chronic pain? A systematic review and meta-analysis. Journal of Pain 15: 985–1000.

Childs JD, Cleland JA, Elliott JM, Teyhen DS, Wainner RS, Whitman JM, Sopky BJ, Godges JJ, Flynn TW;American Physical Therapy Association 2008 Neck pain: Clinical practice guidelines linked to the International Classification of Functioning, Disability, and Health from the Orthopedic Section of the American Physical Therapy Association. Journal of Orthopaedic and Sports Physical Therapy 38: a1–a34.

Coombes BK, Bisset L, Vicenzino B 2012 Thermal hyperalgesia distinguishes those with severe pain and disability in unilateral lateral epicondylalgia. Clinical Journal of Pain 28: 595–601.

Costa L, Maher CG 2011 Self-efficacy is more important than fear of movement in mediating the relationship between pain and disability in chronic low back pain. European Journal of Pain 15: 213–219.

Cuesta-Vargas AI, González-Sánchez M, Casuso-Holgado MJ 2013 Effect on health-related quality of life of a multimodal physiotherapy program in patients with chronic musculoskeletal disorders. Health and Quality of Life Outcomes 11: 19.

Daenen L, Varkey E, Kellmann M, Nijs J 2015 Exercise, not to exercise, or how to exercise in patients with chronic pain? Applying science to practice. Clinical Journal of Pain 31: 108–114.

Darling M 1991 Exercise and migraine. A critical review. Journal of Sports medicine and Physical Fitness 31: 294–302.

de Jong JR., Vlaeyen JW, Onghena P, Cuypers C, Hollander M den, Ruijgrok J 2005 Reduction of pain-related fear in complex regional pain syndrome type I: The application of graded exposure in vivo. Pain 116: 264–275.

Deyo RA, Diehl AK, Rosenthal M 1986 How many days of bed rest for acute low back pain? A randomized clinical trial. New England Journal of Medicine 315: 1064–1070.

Flink IK, Boersma K, Linton SJ 2010 Catastrophizing moderates the effect of exposure in vivo for back pain patients with pain -related fear. European Journal of Pain 14: 887–892.

Flor H, Denke C, Schaefer M, Grüsser S 2001 Effect of sensory discrimination training on cortical reorganisation and phantom limb pain. Lancet 357(9270): 1763–1764.

George SZ, Wittmer VT, Fillingim RB, Robinson ME 2010 Comparison of graded exercise and graded exposure clinical outcomes for patients with chronic low back pain. Journal of Orthopaedic and Sports Physical Therapy 40: 694–704.

Goodin BR, McGuire LM, Stapleton LM, Quinn NB, Fabian LA, Haythornthwaite JA, Edwards RR 2009 Pain catastrophizing mediates the relation between self-reported strenuous exercise involvement and pain ratings: The moderating role of anxiety sensitivity. Psychosomatic Medicine 71: 1018–1025.

Hasenbring MI, Verbunt JA 2010 Fear-avoidance and endurance-related responses to pain: New models of behavior and their consequences for clinical practice. Clinical Journal of Pain 26: 747–753.

Iles RA, Davidson M, Taylor NF, O'Halloran P 2009 Systematic review of the ability of recovery expectations to predict outcomes in non-chronic non-specific low back pain. Journal of Occupational Rehabilitation 19: 25–40.

Jansen MJ, Viechtbauer W, Lenssen AF, Hendriks EJM, de Bie RA 2011 Strength training alone, exercise therapy alone, and exercise therapy with passive manual mobilisation each reduce pain and disability in people with knee osteoarthritis: a systematic review. Journal of Physiotherapy 57: 11–20.

Jull G, Sterling M, Kenardy J, Beller E 2007 Does the presence of sensory hypersensitivity influence outcomes of physical rehabilitation for chronic whiplash? – A preliminary RCT. Pain 129: 28–34.

Lannersten L, Kosek E 2010 Dysfunction of endogenous pain inhibition during exercise with painful muscles in patients with shoulder myalgia and fibromyalgia. Pain 151: 77–86.

Leeuw M, Goossens ME, Linton SJ, Crombez G, Boersma K, Vlaeyen JW 2006 The fear-avoidance model of musculoskeletal pain: Current state of scientific evidence. Journal of Behavioral Medicine 30: 77–94.

Leeuw M, Goossens ME, van Breukelen GJ, de Jong JR, Heuts PH, Smeets RJ, Köke AJ, Vlaeyen JW 2008 Exposure in vivo versus operant graded activity in chronic low back pain patients: Results of a randomized controlled trial. Pain 138: 192–207.

Lewis GN, Rice DA, McNair PJ 2012 Conditioned pain modulation in populations with chronic pain: A systematic review and meta-Analysis. Journal of Pain 13: 936–944.

Lindström I, Öhlund C, Lindström I, Ohlund C, Eek C, Wallin L, Peterson LE, Fordyce WE, Nachemson AL 1992 The effect of graded activity on patients with subacute low back pain: A randomized prospective clinical study with an operant-conditioning behavioral approach. Physical Therapy 72: 279–290.

Linton SJ, Boersma K, Jansson M, Overmeer T, Lindblom K, Vlaeyen JW 2008 A randomized controlled trial of exposure in vivo for patients with spinal pain reporting fear of work-related activities. European Journal of Pain 12: 722–730.

Linton SJ, Buer N, Vlaeyen J, Hellsing AL 2000 Are fear-avoidance beliefs related to the inception of an episode of back pain? A prospective study. Psychology and Health 14: 1051–1059.

Loggia ML, Juneau M, Bushnell MC 2011 Autonomic responses to heat pain: Heart rate, skin conductance, and their relation to verbal ratings and stimulus intensity. Pain 152: 592–598.

López-de-Uralde-Villanueva I, Muñoz-García D, Gil-Martínez A, Pardo-Montero J, Muñoz-Plata R, Angulo-Díaz-Parreño S, Gómez-Martínez M, La Touche R 2015 A systematic review and meta-analysis on the effectiveness of graded activity and graded exposure for chronic nonspecific low back pain. Pain Medicine: Aug 3 [Epub ahead of print]

Louw A, Diener I, Butler DS, Puentedura EJ 2011 The effect of neuroscience education on pain, disability, anxiety, and stress in chronic musculoskeletal pain. Archives of Physical Medicine and Rehabilitation 92: 2041–2056.

Louw A, Diener I, Landers MR, Puentedura EJ 2014 Preoperative pain neuroscience education for lumbar radiculopathy: A multicenter randomized controlled trial with 1-year follow-up. Spine 39: 1449–1457.

Lyon P, Cohen M, Quintner J 2011 An evolutionary stress-response hypothesis for chronic widespread pain (fibromyalgia syndrome). Pain Medicine 12: 1167–1178.

Macedo LG, Smeets RJ Maher CG, Latimer J, McAuley JH 2010 Graded activity and graded exposure for persistent nonspecific low back pain: A systematic review. Physical Therapy 90: 860–879.

Maes S, Karoly P 2005 Self-regulation assessment and intervention in physical health and illness: A review. Applied Psychology 54: 267–299.

Main CJ, Keefe FJ, Jensen MP, Vlaeyen JW, Volwes KE 2015 Fordyce's Behavioral Methods for Chronic Pain and Illness: Republished with Invited Commentaries. Philadelphia, Lippincott Williams & Wilkins.

McBeth J, Chiu YH, Silman AJ, Ray D, Morriss R, Dickens C, Gupta A, Macfarlane GJ 2005 Hypothalamic-pituitary-adrenal stress axis function and the relationship with chronic widespread pain and its antecedents. Arthritis Research and Therapy 7: R992.

McKnight PE, Afram A, Kashdan TB, Kasle S, Zautra A 2010 Coping self-efficacy as a mediator between catastrophizing and physical functioning: treatment target selection in an osteoarthritis sample. Journal of Behavioral Medicine 33: 239–249.

Meeus M, Nijs J, Vanderheiden T, Baert I, Descheemaeker F, Struyf F 2015 The effect of relaxation therapy on autonomic functioning, symptoms and daily functioning, in patients with chronic fatigue syndrome or fibromyalgia: A systematic review. Clinical Rehabilitation 29: 221–233.

Meeus M, Nijs J, Van Oosterwijck J, Van Alsenoy V, Truijen S 2010 Pain physiology education improves pain beliefs in patients with chronic fatigue syndrome compared with pacing and self-management education: A double-blind randomized controlled trial. Archives of Physical Medicine and Rehabilitation 91: 1153–1159.

Meredith PJ, Rappel G, Strong J, Bailey KJ 2015 Sensory sensitivity and strategies for coping with pain. American Journal of Occupational Therapy 69: 6904240010.

Moseley GL 2002 Combined physiotherapy and education is efficacious for chronic low back pain. Austrailian Journal of Physiotherapy 48: 297–302.

Moseley GL 2003 Joining forces – combining cognition-targeted motor control training with group or individual pain physiology education: A Successful treatment for chronic low back pain. Journal of Manual and Manipulative Therapy 11: 88–94.

Moseley GL 2004 Evidence for a direct relationship between cognitive and physical change during an education intervention in people with chronic low back pain. European Journal of Pain 8: 39–45.

Moseley GL 2005 Widespread brain activity during an abdominal task markedly reduced after pain physiology education: fMRI evaluation of a single patient with chronic low back pain. Australian Journal of Physiotherapy 51: 49–52.

Moseley GL, Butler DS 2015 Fifteen years of explaining pain: The past, present, and future. Journal of Pain 16: 807–813.

Moseley GL, Nicholas MK, Hodges PW 2004 A randomized controlled trial of intensive neurophysiology education in chronic low back pain. Clinical Journal of Pain 20: 324–330.

Moseley GL, Vlaeyen JW 2015 Beyond nociception: The imprecision hypothesis of chronic pain. Pain 156: 35–38.

Murphy RJ, Gray SA, Straja SR, Bogert MC 2004 Student learning preferences and teaching implications. Journal of Dental Education 68: 859–866.

Naugle KM, Fillingim RB, Riley JL 2012 A meta-analytic review of the hypoalgesic effects of exercise. Journal of Pain 13: 1139–1150.

Nielson WR, Jensen MP, Karsdorp PA, Vlaeyen JWS 2013 Activity pacing in chronic pain: Concepts, evidence, and future directions. Clinical Journal of Pain 29: 461–468.

Nijs J, Lluch Girbés E, Lundberg M, Malfliet A, Sterling M 2015 Exercise therapy for chronic musculoskeletal pain: Innovation by altering pain memories. Manual Therapy 20: 216–220.

Nijs J, Meeus M 2015 Five Requirements for Effective Pain Neuroscience Education in Physiotherapy Practice, Canadian Physiotherapy Association. Pain science Division. http://www.physiotherapy.ca/Pain-Science-Division/Featured-Articles/Latest-articles/Neuroimmune-interactions-in-CRPS-Luke-Parkitny,-PT?lang=en-ca.

Nijs J, Paul van Wilgen C, Van Oosterwijck J, van Ittersum M, Meeus M 2011 How to explain central sensitization to patients with 'unexplained' chronic musculoskeletal pain: practice guidelines. Manual Therapy 16: 413–418.

O'Sullivan K, Dankaerts W, O'Sullivan L, O'Sullivan PB 2015 Cognitive functional therapy for disabling nonspecific chronic low back pain: Multiple case-cohort study. Physical Therapy 95:1478–1488.

Paul TM, Soo Hoo J, Chae J, Wilson RD 2012 Central hypersensitivity in patients with subacromial impingement syndrome. Archives of Physical Medicine and Rehabilitation 93: 2206–2209.

Pearson N 2015 Yoga therapy for people in pain. In: Thompson D, Brooks M (eds) Integrative Pain Medicine. Handspring Publishers Limited.

Peters ML, Vlaeyen JW, Weber WE 2005 The joint contribution of physical pathology, pain-related fear and catastrophizing to chronic back pain disability. Pain 113: 45–50.

Rasmussen-Barr E, Äng B, Arvidsson I, Nilsson-Wikmar L 2009 Graded exercise for recurrent low-back pain: a randomized, controlled trial with 6-, 12-, and 36-month follow-ups. Spine 34: 221–228.

Riecke J, Holzapfel S, Rief W, Glombiewski JA 2013 Evaluation and implementation of graded in vivo exposure for chronic low back pain in a German outpatient setting: A study protocol of a randomized controlled trial. Trials 14: 203.

Roussel NA, Nijs J, Meeus M, Mylius V, Fayt C, Oostendorp R 2013 Central sensitization and altered central pain processing in chronic low back pain: Fact or myth? Clinical Journal of Pain 29: 625–638.

Ryan CG, Gray HG, Newton M, Granat MH 2010 Pain biology education and exercise classes compared to pain biology education alone for individuals with chronic low back pain: A pilot randomised controlled trial. Manual Therapy 15: 382–387.

Siemonsma PC, Schröder CD, Roorda LD, Lettinga AT 2010 Benefits of treatment theory in the design of explanatory trials: Cognitive treatment of illness perceptions in chronic low back pain rehabilitation as an illustrative example. Journal of Rehabilitation Medicine 42: 111–116.

Siemonsma PC, Schröder CD, Schroder CD, Dekker JH, Lettinga AT 2008 The benefits of theory for clinical practice: Cognitive treatment for chronic low back pain patients as an illustrative example. Disability Rehabilitation 30: 1309–1317.

Siemonsma PC, Stuive I, Roorda LD, Vollebregt JA, Lankhorst GJ, Lettinga AT 2011 Best candidates for cognitive treatment of illness perceptions in chronic low back pain: Results of a theory-driven predictor study. Journal of Rehabilitation Medicine 43: 454–460.

Siemonsma PC, Stuive I, Roorda LD, Vollebregt JA, Walker MF, Lankhorst GJ, Lettinga AT 2013 Cognitive treatment of illness perceptions in patients with chronic low back pain: A randomized controlled trial. Physical Therapy 93: 435–448.

Smeets RJ, Vlaeyen JW, Kester AD, Knottnerus JA 2006 Reduction of pain catastrophizing mediates the outcome of both physical and cognitive-behavioral treatment in chronic low back pain. Journal of Pain **7**: 261–271.

Smith BE, Littlewood C, May S 2014 An update of stabilisation exercises for low back pain: A systematic review with meta-analysis. BMC Musculoskeletal Disorders 15: 416.

Stewart MJ, Maher CG, Refshauge KM, Herbert RD, Bogduk N, Nicholas M 2007 Randomized controlled trial of exercise for chronic whiplash-associated disorders. Pain 128: 59–68.

Sullivan MJ, Bishop SR, J Pivik 1995 The pain catastrophizing scale: Development and validation. Psychological Assessment 7: 524–532.

Sullivan MJ, Lynch ME, Clark AJ 2005 Dimensions of catastrophic thinking associated with pain experience and disability in patients with neuropathic pain conditions. Pain 113: 310–315.

Suokas AK, Walsh DA, McWilliams DF, Condon L, Moreton B, Wylde V, Arendt-Nielsen L, Zhang W 2012 Quantitative sensory testing in painful osteoarthritis: A systematic review and meta-analysis. Osteoarthritis and Cartilage 20: 1075–1085.

Teasell RW, McClure JA, Walton D, Pretty J, Salter K, Meyer M, Sequeira K, Death B 2010 A research synthesis of therapeutic interventions for whiplash-associated disorder (WAD): Part 4 – Noninvasive interventions for chronic WAD. Pain Research and Management 15: 313–322.

Tsay A, Allen TJ, Proske U, Giummarra MJ 2015 Sensing the body in chronic pain: A review of psychophysical studies implicating altered body representation. Neuroscience and Biobehavioral Reviews 52: 221–232.

Turner JA, Mancl L, Aaron LA 2004 Pain-related catastrophizing: A daily process study. Pain 110: 103–111.

Vaegter HB, Handberg G, Graven-Nielsen T, Edwards R 2016 Hypoalgesia after exericse and cold pressor test are reduced in chronic musculuskeletal pain patients with high pain sensitivity. Clinical Journal of Pain 32: 58–69.

van Middelkoop M, Rubinstein SM, Verhagen AP, Ostelo RW, Koes BW, van Tulder MW 2010 Exercise therapy for chronic nonspecific low-back pain. Best Practice and Research Clinical Rheumatology 24: 193–204.

Van Oosterwijck J, Meeus M, De Schryver M, Pascal A, Lambrecht L, Nijs J 2013 Pain physiology education improves health status and endogenous pain inhibition in fibromyalgia: A double-blind randomized controlled trial. Clinical Journal of Pain 29: 873–882.

Van Oosterwijck J, Nijs J, Meeus M, Truijen S, Craps J, Van den Keybus N, Paul L 2011 Pain neurophysiology education improves cognitions, pain thresholds, and movement performance in people with chronic whiplash: A pilot study. Journal of Rehabilitation Research and Development 48: 43–58.

van Wilgen CP, Konopka KH, Keizer D, Zwerver J, Dekker R 2013 Do patients with chronic patellar tendinopathy have an altered somatosensory profile? A Quantitative Sensory Testing (QST) study. Scandanavian Journal of Medicine and Science in Sports 23: 149–155.

Vase L, Petersen GL, Riley JL 3rd, Price DD 2009 Factors contributing to large analgesic effects in placebo mechanism studies conducted between 2002 and 2007. Pain 145: 36–44.

Vlaeyen JW, de Jong J, Geilen M, Heuts PH, van Breukelen G 2001 Graded exposure in vivo in the treatment of pain-related fear: a replicated single-case experimental design in four patients with chronic low back pain. Behaviour Research and Therapy 39: 151–166.

Vlaeyen JW, Morley SJ, Linton SJ, Boersma K, de Jong J 2012 Pain-Related Fear: Exposure-Based Treatment of Chronic Pain. Seattle, IASP.

Vohs KD, Baumeister RF, Schmeichel BJ, Twenge JM, Nelson NM, Tice DM 2008 Making choices impairs subsequent self-control: A limited-resource account of decision making, self-regulation, and active initiative. Journal of Personality and Social Psychology 94: 883–898.

Waddell G, Feder G, Lewis M 1997 Systematic reviews of bed rest and advice to stay active for acute low back pain. British Journal of General Practice 47(423): 647–652.

Wand BM, Parkitny L, O'Connell NE, Luomajoki H, McAuley JH, Thacker M, Moseley GL 2011 Cortical changes in chronic low back pain: Current state of the art and implications for clinical practice. Manual Therapy 16: 15–20.

Weiss S, Sack M, Henningsen P, Pollatos O 2014 On the interaction of self-regulation, interoception and pain perception. Psychopathology 47: 377–382.

Woods MP, Asmundson GJ 2008 Evaluating the efficacy of graded in vivo exposure for the treatment of fear in patients with chronic back pain: A randomized controlled clinical trial. Pain 136: 271–280.

Yarnitsky D, Bouhassira D, Drewes AM, Fillingim RB, Granot M, Hansson P, Landau R, Marchand S, Matre D, Nilsen KB, Stubhaug A, Treede RD, Wilder-Smith OH 2015 Recommendations on practice of conditioned pain modulation (CPM) testing. European Journal of Pain 19: 805–806.

Yoris A, Esteves S, Couto B, Melloni M, Kichic R, Cetkovich M, Favaloro R,Moser J, Manes F, Ibanez A, Sedeño L 2015 The roles of interoceptive sensitivity and metacognitive interoception in panic. Behavioral and Brain Functions 11:14.

Zale EL, Lange KL, Fields SA, Ditre JW 2013 The relation between pain-related fear and disability: A meta-analysis. Journal of Pain 14: 1019–1030.

Zusman M 2004 Mechanisms of musculoskeletal physiotherapy. Physical Therapy Reviews 9: 39–49.