Physiotherapy management of complex regional pain syndrome

Catherine Pollard BSc (Honours)
Physiotherapy, Diploma Orthopaedic Medicine
Senior Physiotherapist, The Auckland Regional Pain Service, Auckland District Health Board

ABSTRACT

Complex Regional Pain Syndrome is a painful debilitating condition characterised by sensory, vasomotor, sudomotor, and trophic changes. Traditionally, physiotherapy treatments have been directed at peripheral symptoms, often with limited efficacy. In light of the growing scientific evidence promoting the major role of the central nervous system in the pathogenesis of Complex Regional Pain Syndrome, there has been a shift towards interventions considered to modulate central processing. A systematic review performed in 2009 aimed to assess the evidence regarding the physiotherapy management of Complex Regional Pain Syndrome. Techniques showing some promise include mirror therapy, Graded Motor Imagery, tactile discrimination training, and exposure therapy. This paper aims to elaborate on the scientific framework for these techniques and explore the current research regarding treatment efficacy. Hopefully, further wide dissemination of these ideas will spark more interest from clinical practitioners and clinicians alike in the quest to more completely understand and manage this complex condition.

Pollard C (2013) Physiotherapy management of complex regional pain syndrome New Zealand Journal of Physiotherapy 41(2): 65-72.

Key Words: Body perception disturbance, Graded Motor Imagery, mirror therapy, tactile discrimination training, exposure therapy.

INTRODUCTION

Most physiotherapists either have encountered, or will encounter, a challenging case of Complex Regional Pain Syndrome (CRPS), often, but not necessarily following a patient's injury, myocardial infarction, or stroke (De Mos 2007, Veldman 1993). Traditionally, physiotherapy treatments have focussed mostly on attempted modification or management of peripheral symptoms, often with limited efficacy. More recently, spurred by scientific advances identifying the significant role of the central nervous system in the pathogenesis of CRPS, techniques which focus on central processes have been developed (Moseley 2010). Treatment strategies including mirror therapy, Graded Motor Imagery, tactile discrimination training and exposure therapy have been explored in one guise or another. However, there is little in the literature as to how these worlds of scientific evidence and best clinical practice come together. This paper addresses and attempts to bridge this divide, reviewing the scientific research that informs our adoption of these novel treatment techniques.

Diagnostic Criteria and Pathophysiology

The clinical features of CRPS include burning pain, allodynia (pain from a non-painful stimulus) and hyperalgesia (increased response to a painful stimulus); motor disturbances ranging from decreased range, speed, co-ordination of movement, tremor and muscle spasms; changes in vascular tone, temperature, skin colour, sweating and oedema; trophic changes to skin, hair, nails and perceptual disturbances with distortions to the body-self (Harden and Bruehl 2006, Lewis and McCabe 2010).

There are two types of CRPS described: CRPS-1 can occur spontaneously or following trauma, with the symptoms unrelated to the region of a single nerve, and disproportionate to the inciting event. CRPS-2 occurs in association with nerve damage (Merskey and Bogduk 1994). The management of these are similar; however, it is important to identify the presence of nerve injury in case further intervention is warranted.

The exact cause of CRPS is still not fully understood, however there are a number of proposed pathophysiological mechanisms which contribute to the overall symptoms. Neurogenic inflammation, which involves the amplification of cytokines, bradykinins, endothelin, neuropeptide CGRP and Substance P, has been demonstrated in people who developed CRPS after injury (Birklein and Schmelz 2008, Guo et al 2004). It is postulated the elevation of these inflammatory mediators occurs as a result of inadequate inactivation after their release, so they continue to promote inflammation (Birklein and Kingery 2009). Another suggestion is that more receptors are available to receive these inflammatory mediators (Birklein and Kingery 2009). The overall effect is increased temperature, skin reddening, protein extravasation, oedema and augmented nociceptive stimulation.

The role of the sympathetic nervous system (SNS) in CRPS has remained controversial. It was originally proposed that the SNS was the main driver for CRPS symptoms, hence its previous name Reflex Sympathetic Dystrophy. Under normal circumstances sympathetic activity does not impact on the discharge of nociceptors; however in the case of CRPS, nociceptors appear to be under the influence of the SNS. This is referred to as sympathetically maintained pain (Raja et al 2010). In people with CRPS the epidermis of the skin within the region of hyperalgesia has been shown to contain a greater density of the receptors involved in sympathetically maintained pain compared to pain free skin and normal controls (Raja et al 2010). It was agreed however, that the SNS was not the sole cause of CRPS, as sympathetic nerve blocks did not provide significant relief for a number of patients (Galer et al 2001).

Based on physiological and functional imaging studies there is substantial evidence that in persistent pain states, reorganisation of the primary somatosensory cortex (the Penfield 'homunculus') (Flor 2003, Flor et al 2009), the secondary somatosensory cortex

(Pleger et al 2006), and the motor cortex can occur (Cohen et al 1991). It has been demonstrated that the degree of cortical reorganisation is directly related to the intensity of CRPS pain and the extent of hyperalgesia (Pleger et al 2005).

In the case of CRPS the cortical representation of the affected limb is smaller than that of the unaffected limb, with digit representations moving closer together (Juttonen et al 2002, Maihofner et al 2003, Pleger et al 2004). This can produce affects such as body perception disturbance, whereby people with CRPS describe their limb as feeling abnormal in terms of shape and size (Moseley 2005b), temperature (Lewis et al 2007), position (Lewis et al 2010) and orientation (Schwoebel et al 2001). It can produce feelings so intense that the limb no longer feels like the participant's own (Lewis et al 2007). It is postulated that this reorganisation can alter cortical processing, instating a conflict between sensory feedback and motor output. It has been shown that inducing a sensorimotor incongruence in normal participants can provoke sensations of spontaneous pain and feelings of peculiarity (McCabe et al 2005) and exacerbate pain in people with fibromyalgia (McCabe et al 2007). It is therefore credible that cortical reorganisation contributes to the pain experienced within CRPS. Cortical reorganisation can also produce motor dysfunction, leading to abnormal movement patterns during reaching and grasping tasks (Maihofner et al 2007).

In summary, these various mechanisms contribute to the multitude of symptoms that can develop in a person with CRPS.

Physiotherapy Management

Over the years many different treatment modalities have been utilised for the management of CRPS, including medical management (analgesics, steroids, supplements) and interventional treatments (sympathetic nerve blocks, sympathectomy, amputation and spinal cord stimulator insertion). It is well recognised however, that physiotherapy plays an important role in the standard treatment of CRPS.

Physiotherapy encompasses a large array of different treatment techniques and modalities. In order to gain a clearer insight into the efficacy of the varied physiotherapy interventions for the treatment of adult CRPS-1 a systematic review of the literature was performed (Daly and Bialocerkowski 2009). An electronic search was conducted for the period 1987-2007 using various databases and searches of textbooks on pain. Each study was appraised by the Australian National Health and Medicine Research Council (NHMRC) hierarchy of evidence and the Critical Review form for Qualitative Studies: 180 articles were found, of which 166 were excluded as they did not meet the inclusion criteria. There were 11 articles included in the systematic review. After analysing and comparing the data regarding the effectiveness of the different treatments, the authors concluded that Graded Motor Imagery (GMI) produced the greatest benefit in terms of reducing pain when compared to conventional physiotherapy and medical management. There was reasonable evidence for modalities such as mirror therapy, desensitisation training, and graded exposure; however, there was no evidence to support the effectiveness of transcutaneous nerve stimulation or stress loading exercise. The study highlighted a distinct lack of high quality research on physiotherapy management of CRPS.

This review aims to expand this systematic review by exploring the latest scientific and clinical based research developments pertaining to these techniques and discuss how they may be applied in a therapeutic setting. In addition, it explores the current research utilising recent modalities such as prism glasses and virtual reality for managing CRPS.

Mirror Therapy

Mirror therapy aims to create an illusion of normality in the affected limb. It was introduced by Ramachandran in 1992, for use with phantom limb pain and has since been adapted to aid in the management of numerous conditions, including stroke and pain after wrist fracture and hand surgery (Ramachandran and Alschuler 2009). When used for CRPS, mirror therapy involves concealing the affected limb behind the mirror, while the non-affected limb is positioned so that its reflection is superimposed to where the affected limb should be. The brain has been shown to prioritise visual input over proprioceptive input (Rock and Victor 1964), so when the unaffected limb moves it appears as though the affected limb is functioning normally.

The mechanisms of action for mirror therapy are still not fully understood. There are a number of theories described in the literature including increased attention to the limb, improved ownership of the limb (McCabe 2011), activation of the mirror neurone system (Matthys et al 2009, Rothgangel et al 2011), and a reduction of sensorimotor incongruence (Ramachandran et al 1995).

Mirror therapy has been shown to have positive and negative effects on the symptoms of CRPS (McCabe 2011). It is postulated that the discrepancies in results are due to differing methods of execution. According to McCabe (2011) mirror therapy should be performed with both limbs moving in a bilateral synchronous manner, so the person can feel the movement at the same time as observing the reflection of the normal limb moving. If movement of the affected limb is not performed in synchrony with the observed reflection, conflicting sensory feedback and motor output will be exaggerated and CRPS pain can be increased (McCabe 2011). Acerra and Moseley (2004) demonstrated that pain could be evoked in the affected limb of CRPS participants when the unaffected limb was stimulated in front of a mirror (via light touch, sharp touch and the application of cold). Interestingly, only participants with CRPS experienced pain, it did not occur in participants with similar pain symptoms (but no signs of CRPS-1) or control participants.

Mirror therapy also appears to have differing effects in the acute and chronic phases of CRPS. McCabe et al (2003) performed a pilot study which involved eight participants with CRPS-1 practicing mirror therapy for six weeks. It was demonstrated that visual feedback from the mirror significantly lowered pain intensity in acute CRPS-1 (less than eight weeks). These analgesic effects were prolonged with increasing duration of mirror therapy. In the intermediate stages of the disease (less than one year) mirror therapy reduced stiffness. Unfortunately, there was no beneficial outcome for the three chronic cases. These findings concur with other studies. In acute CRPS, Cacchio et al (2009) demonstrated an improvement to CRPS symptoms, whereas for chronic CRPS Tichelaar et al (2007) reported a poor response to mirror therapy.

When CRPS symptoms persist, patients can experience more physical impairments with changes in muscle strength, contractures, joint stiffness, or motor control. This can place more restrictions on the movement of the affected limb and further increase the incongruence between the affected limb and the mirror image. In these instances it is proposed that mirror therapy may overwhelm the sensitised system therefore exacerbating pain to a greater extent (Moseley 2005a). It has been suggested that a graded approach to cortical activation utilising techniques to activate cortical regions affiliated with movement preparation but not movement execution may be more suitable, as suggested to occur in Graded Motor Imagery (described in more detail in the following section) (Moseley 2005a). This theory was supported when it was demonstrated that during GMI, mirror therapy only imparted an effect when it followed imagery (Moseley 2005a).

In summary, the research indicates that mirror therapy can assist with pain reduction and improve function in the early stages of CRPS. Considering that it is an inexpensive and accessible form of treatment that can be performed within the clinic and continued at the patient's home, there is a basis for its use in early rehabilitation. In regards to chronic CRPS, there is limited efficacy when used as a first line treatment and in some instance it can exacerbate CRPS symptoms. Caution should be made to ensure patients are instructed on the appropriate technique, to minimise potential side-effects.

Graded Motor Imagery

GMI follows a progressive three-stage motor imagery programme. In stage 1, participants see a series of photographic flash cards, and are asked to identify (as quickly as possible) whether the depiction is of a left or right limb. In stage 2, participants imagine moving the affected limb into the position demonstrated on the photograph, while the affected hand rests comfortably. Stage 3 involves mirror therapy, whereby both limbs are moved to adopt simple postures as demonstrated on the photograph (Mosley 2004).

GMI is considered to exert its effects through sequential activation of distinct (ordered) stages of brain function (Moseley 2005a). Parsons and Fox (1998) used positron-emitting tomography to image brain activation (through blood-flow measures) during right / left judgement tasks (stage 1). A large amount of activity was shown in the pre-motor and supplementary motor regions and the cerebellum, however there was no activity in the primary somatosensory and motor cortices. Imagery (stage 2) has been shown to activate the pre-motor, primary somatosensory and motor cortices (Lotze et al 1999). This indicates that stage 1 activates brain centres involved in higher order aspects of motor control and movement preparation without physical movement of the limb, prior to progressing to stage 2 where activation of the motor cortices occur (Moseley 2005a). This theory was supported during a clinical trial in which 20 participants with chronic CRPS-1 of one hand were randomly allocated to undertake the three components of the GMI programme in different orders (Moseley 2005a). It was demonstrated that participants who followed the sequenced GMI stages (stages 1, 2 then 3) had better outcomes with reduced pain rating and increased functional task ability (measured using the task-specific numeric rating scale) than participants who did not follow the sequence. It also showed that imagined movements were only successful in producing measurable improvement when they followed hand laterality recognition; and mirror movements were only useful when they followed imagined movements.

Early support for effective utilisation of GMI was demonstrated in a randomised controlled trial involving 13 participants with chronic CRPS-1 following non-complicated wrist fractures (Mosley 2004). Participants were randomly allocated into either a GMI group following the three stage programme or a control group who did not receive treatment. Each stage involved intensive repetition, with exercises practised three times an hour, every waking hour, for two weeks before being progressed to the next stage. On completion of the GMI programme there was a significant reduction in the neuropathic pain scale (by approximately 20 points, on a 100 point scale), an improvement in swelling and reduced limb laterality recognition time. These improvements were maintained for at least six weeks after completion of treatment. The outcome measures for the control group did not change. However, when two of the control participants crossed over to GMI, there was a significant reduction in all three variables.

This study was repeated with a larger sample size including people with phantom limb pain after amputation, brachial plexus avulsion injuries and a more heterogeneous group of CRPS-1 patients. The results showed that pain decreased and function increased for the GMI group relative to the control group; however pain reduction was about 50% less in this study than the previous one (Moseley 2006).

Based on the success of these studies, GMI has been adopted by clinics worldwide. Reports are now being published to discuss the clinical implications of this technique. Johnson et al (2012) performed an audit to assess the outcomes of GMI used within two CRPS speciality centres in the UK. For practical reasons the GMI protocol deviated from that used in the studies by Moseley, with reduced face to face contact, increased duration of the stages, and reduced frequency of practice. Although this makes comparison debateable, it provides a more realistic view of the efficacy of GMI when applied in real-life clinical situations. Unfortunately, the outcomes from this study would suggest that the clinical application of GMI may not be as promising as anticipated. When assessing pain intensity, the participants reported the 'worst' pain intensity reduced but the 'average' pain intensity remained the same following treatment. On the whole, only 3 out of the 32 patients who started GMI achieved a 50% pain reduction and in 12 out of the 32 patients, pain actually increased with treatment. Lagueux et al (2012) also utilised a modified version of GMI in a clinical trial based on 7 patients with CRPS present for less than 6 months. The results indicated a reduction in pain but no statistically or clinically significant difference to function.

It seems plausible that GMI may provide an avenue to start rehabilitation at a manageable level for a patient who complains that pain is too severe to perform any kind of limb movement. By regressing rehabilitation to a point whereby only the cortical regions involved in movement preparation are activated, pain may be provoked to a lesser extent. This could then be progressed in a steady manner to promote greater cortical activation, prior to commencing functional activation. However, as Johnson et al (2012) identified, there are some cases where pain can be intensified during its use. Further research to identify potential subgroup populations where GMI may be unsuitable, as well as clearer recommendations for the application of GMI e.g. frequency of practice, duration of stages will assist to optimise the use of GMI in clinical practice.

Tactile Discrimination

Tactile discrimination is slower in a CRPS-affected limb than in an unaffected limb (Moseley et al 2009) and in some cases, mislocalisation of sensory stimulation is present in the affected limb. Maihöfner et al (2006) demonstrated that when touching the digits of an affected CRPS hand, the sensation was felt to be in another place within the same hand in 8 out of 24 participants tested. It was also noted that the presence of mechanical hyperalgesia was a significant predictor for the incidence of sensory mislocalisation. These occurrences are considered to be related to cortical reorganisation. Flor et al (2001) demonstrated that the extent of reorganisation correlates with the magnitude of pain, and the degree of tactile acuity of the affected region. It has been suggested that tactile information processing is 'spatially' related (where the body is in space) rather than somatotopically defined (the body position in accordance to its location within the homunculus). Moseley et al (2009) studied ten participants with CRPS in a single arm. Participants received pairs of vibro-tactile stimuli, one delivered to each hand, at various asynchronies. They were asked to identify which hand had been stimulated first by releasing a foot switch to indicate left or right. This was performed with the arms held each side of the midline and then with the arms crossed over midline. The point at which participants were equally likely to select either hand was compared between conditions and between those with left and right-sided symptoms. The results showed that when arms were not crossed, the participants prioritised stimuli from the unaffected limb over those from the affected limb. In other words, it took participants longer to recognise and/or respond to the stimulus applied to the affected arm. When the arms were crossed the effect was reversed, requiring earlier delivery of the stimulus to the unaffected limb in order for it to be recognised as simultaneous to the affected limb. The study also discovered a strong correlation between the time to recognise stimulus to the affected arm and skin temperature. The earlier the affected limb needed to be stimulated in order for the two stimuli to be perceived as simultaneous, the cooler the affected limb was in relation to the unaffected limb. When the arms were crossed the temperature of the affected limb increased. It was postulated that this warming effect may indicate improved ownership of the limb. These results indicate that CRPS is associated with a deficit in tactile processing that is defined by the space in which the affected limb normally resides, not by the limb itself.

In order to normalise tactile acuity, techniques such as sensory discrimination training have been employed. Sensory discrimination training has been shown to be effective in improving pain and two-point discrimination for people with phantom limb pain. These changes were accompanied by normalisation of the somatosensory cortical organisation (Flor et al 2001). Similar results have been shown for people with CRPS (Pleger et al 2005) however it appears that the technique for delivering sensory training is paramount. Approaches which involve active participation from the participant, such as distinguishing the location and type of stimuli applied to the affected area, have been shown to be more effective at reducing pain and improving tactile acuity than passive stimulation (touching the affected region with no conscious thought to the stimuli) (Moseley et al 2008a).

In summary, tactile discrimination training techniques which encourage patients to concentrate on the delivered stimuli can improve tactile acuity and reduce pain. Following such training, functional imaging studies have demonstrated improvements in cortical re-organisation (Pleger et al 2005).

Exposure Therapy

It is well documented that pain-related anxiety and fear are strong predictors of pain disability in people with various chronic musculoskeletal conditions (De Jong et al 2011). This can lead to a vicious cycle of pain, fear, and disability. In some cases people living with pain can develop activity avoidance or hypervigilance. In the acute phase of tissue injury these behaviours may be useful for healing but as pain persists they become detrimental. For people with CRPS these behaviours may lead to fear avoidance of using their limb, guarding and protecting it, and developing maladaptive coping strategies. This can lead to secondary changes associated with non-use, which can result in a further decline in function. De Jong et al (2011) explored the concept of fear avoidance of movement in terms of functional limitation in people with CRPS-1. In people with acute CRPS the severity of pain determined functional limitation, not fear. Conversely, in people with chronic CRPS perceived harmfulness of activity correlated stronger with functional limitation than the impact of pain intensity. Moseley et al (2008b) demonstrated that fear of movement and catastrophic thoughts can have a negative impact on swelling and pain in the affected limb when performing imagined movements. It is therefore important that fear-avoidance is addressed early.

One approach to tackle fear-avoidance is to perform graded exposure to the feared stimulus. Graded exposure therapy follows a structured process involving screening, education, and graded exposure (Vlaeyen and Linton 2000). Overall, the process aims to stimulate fear, then disconfirm the fear by providing new information on the feared activity, whereby inaccurate predictions about activities causing harm, are dispelled (Philips 1987).

Graded exposure has been explored in a number of pain conditions including chronic low back pain (Macedo et al 2010); post-traumatic neck pain (De Jong et al 2008, Wicksell et al 2008); and generic pain conditions (Bliokas et al 2007, George et al 2010) with mixed results. In regard to CRPS, a small study based on eight female participants with chronic CRPS, demonstrated that graded exposure was successful in decreasing levels of pain-related fear, pain disability, and pain intensity. Participants also reported reduced signs and symptoms of CRPS-1 (such as swelling or colour changes). At a six month follow-up, the eight participants had complete resolution of their symptoms (De Jong et al 2005).

Anecdotal evidence indicates that encouraging participants to face feared activities may however provoke pain and exacerbate CRPS symptoms. Ek et al (2009) therefore assessed the safety of exposure therapy by encouraging patients to focus on functional improvement while neglecting the pain. The outcomes were positive, from 102 people who completed the functional exposure programme, 49 achieved full recovery in terms of function, 46 partial recovery, and five experienced no change. The authors also found that pain scores reduced in 76 patients, increased in 14, and did not change in 12. From those patients whose pain worsened or did not change, 10 had achieved full function. Interestingly, only four participants dropped out as they considered the interventions too strenuous and painful. The study concluded that treatment focussing on functional restoration can be applied safely and effectively for patients with chronic CRPS. This work was expanded to include assessment of specific CRPS symptoms, including oedema, skin temperature, skin colour, joint mobility, muscle strength, and pain during exposure therapy (Van de Meent et al 2011). These authors used a progressive-loading exercise programme, desensitising techniques, forced use of the affected limb in daily activities and management of pain-avoidance behaviour, without the use of specific CRPS-1 medication or analgesics. Participants were discouraged from complaining about the pain and treatment intensity was not reduced because of pain. On monitoring the symptoms of CRPS-1, two out of the 20 participants had a slight increase in oedema during treatment, whereas temperature differences and colour changes between limbs improved in some participants during treatment. Pain increased in five cases during treatment but on the whole declined following treatment. Joint mobility and arm strength increased; and following treatment, measures determining 'functional use', 'fear avoidance to activity', and 'quality of life' all showed improvement. There were no participants who withdrew from the study due to discomfort or adverse effects.

Due to the risk of initially increasing pain intensity, the studies exploring exposure therapy highlighted the importance of ensuring the patient was adequately educated and motivated to be compliant with treatment regimes, in order for it to be successfully tolerated. These studies provide reassuring evidence that treatments focussing on activity whilst ignoring pain can be safely applied with no deterioration of CRPS-1 symptoms.

Virtual Reality

With the ever growing developments in technology, the theories regarding mirror therapy have been expanded into the virtual world, with studies looking into the efficacy of virtual reality systems for managing pain. There is currently evidence to demonstrate efficacy of virtual reality for acute pain (such as during routine medical procedures) (Gold et al 2005), burns (Hoffman et al 2000), cancer pain (Sander et al 2002, Schneider and Workman 2000), and more recently, CRPS. Sato et al (2010) developed a computer-based programme linked to a glove which was embedded with sensors to detect movement of the hand. The glove is worn on the unaffected hand but produces an image on the screen of the opposite (affected) hand. Participants are instructed to focus on the motion of the virtual hand while performing motor tasks such as reaching out, grasping, transferring, and placing. The programme was tested on five participants with chronic CRPS-1 who were seen weekly for this treatment for up to eight sessions. They found that four out of the five patients showed a 50% reduction in the pre-treatment pain score. In two patients, the analgesic effect continued after cessation of the therapy and no participants described any treatment related side-effects.

Virtual reality has been shown to produce analgesic effects through modulation of sensory and emotional aspects of pain processing with reduced activity demonstrated via fMRI in areas such as caudal anterior cingulate cortex which is involved in the emotional aspects of pain; the somatosensory areas, involved in registering location and intensity of pain; as well as the thalamus and insula (Hoffman et al 2004).

Unfortunately its widespread use is limited as the equipment is expensive and can only be used within the therapy clinic. With ongoing developments of next generation home gaming systems, it will be interesting to see if similar results may be achieved with accessible and cheaper alternatives. The added advantage of virtual reality and 'gaming' treatments are that they are based on activities which patients are more likely to find fun and/or interesting to do. This may improve compliance and activate the brains reward systems, leading to the release of dopamine which strengthens and consolidates learning and neurological plasticity (Harley 2004, Wise 2004).

Minimising Body Perception Disturbance

People with CRPS-1 have been described in numerous texts to exhibit 'neglect-like' behaviours similar to that which may follow neurological insult such as stroke (Galer et al 1995, Galer and Jensen 1999). Following work by Förderreuther et al (2004) and Lewis et al (2007), the term 'neglect' for CRPS has been superseded by the term 'body perception disturbance'. In order to move the affected limb, people with CRPS-1 frequently comment on their need to consciously focus their mental and visual attention to the limb, often describing the limb as "not belonging to me" (Galer and Jensen 1999, Moseley 2005b, Lewis et al 2007).

Body perception disturbance not only involves changes in the perception of the body part itself but in how that body part relates to the body and the space in which it occupies. As discussed in the section regarding tactile discrimination, Moseley et al (2009) demonstrated that crossing the affected limb over to the other side of the body influenced sensory acuity and skin temperature. Sumitani et al (2007a) demonstrated that people with CRPS showed a shift in subjective body-midline with a bias towards the affected side which is contrary to previous thoughts of CRPS neglecting the space of the affected side.

In order to normalise body perception disturbance, treatments aimed at correcting cortical remapping are considered appropriate (Lewis et al 2007). It is postulated that delivering normal stimuli to the affected limb and encouraging the patient to engage with the limb may assist to normalise sensory and motor responses. This can include utilising the techniques described in the preceding sections, which are considered to influence cortical activation and organisation (Pleger et al 2005, Maihofner 2007). A number of other gadgets and appliances have also been trialled with the intention of tricking the brain to improve body perception, such as prism glasses and minifying lenses.

Prism glasses are based on the principles of mirror therapy, but were designed to allow portable treatments which can be performed more regularly. They utilise a wedge prism to add visual displacement towards the affected side while the vision in the other eye is blocked. When the patient moves the non-affected limb the prism inverts the image to appear as though the affected limb is moving. Prism glasses have been used with success for managing hemianopia (blindness in half of the visual field in both eyes—either the left or the right field) (Bowers et al 2008, Giorgi et al 2009) and for patients with stroke and hemispatial neglect (Fujiwara et al 2011, Keane et al 2006). In terms of their use for CRPS, Sumitani et al (2007b) demonstrated that performing visual subjective body-midline judgment tasks while wearing the prism glasses with a 20° prismatic displacement of visual field toward the unaffected side for two weeks alleviated pain in five patients with CRPS. There was also an improvement in proprioception and limb position awareness. When the prism glasses were displaced 20° toward the affected side, pain increased.

Bultitude and Rafal (2010) provided a single case report of a patient with early CRPS managed with prism glasses and mirrors. Following activities involving the prism glasses, the patient noted a decrease in pain, swelling and temperature, and improvements to range of motion of the limb. After nine days of treatment, the patient was pain free.

Minifying lenses are inverted binoculars which make objects appear smaller. Their potential use was demonstrated in a study by Moseley et al (2008c) whereby 10 participants with unilateral arm pain performed various hand movements. Participants observed their arm moving under four conditions; with no visual appliance; through binoculars with no magnification; through magnified binoculars; and looking through inverted binoculars. Although movement aggravated pain in all conditions, it was intensified to a greater extent when the arm was magnified. Interestingly, the increase in pain intensity and swelling was least when the image of the arm was minified. This study adds further weight to the evidence for the link between vision and proprioception, and how central processes can be manipulated through visual input. It is possible minifying lenses create the illusion that fewer sensory neurones have been activated, distorting the afferent input and reducing cortical activation. Research to investigate this theory is still required.

CONCLUSION

Although the pathophysiological mechanisms for CRPS are still not fully understood, there is increasing evidence for the role of the central nervous system in the development and/or maintenance of CRPS. Changes to cortical processing and organisation can lead to the development of symptoms such as body perception disturbance, sensory incongruities, and motor dysfunction. Over recent years there have been advances connecting neuroscience to clinical practice, with physiotherapeutic techniques focussing on central modulation growing in popularity. There is emerging evidence for techniques including mirror therapy, tactile discrimination training, GMI, graded exposure therapy, and virtual reality. Physiotherapists are at the forefront of initiating these techniques with CRPS patients. An understanding of the mechanisms of action and clinical effectiveness will help physiotherapists use these techniques in clinical practice.

KEY POINTS

- Expanding research in the field of neuroscience is improving our understanding of CRPS.
- With advanced understanding of CRPS-related brain and spinal cord processes, treatment modalities are moving away from peripheral management to focus on central processing.
- Techniques such as mirror therapy, Graded Motor Imagery, tactile discrimination training, and graded exposure therapy show promise in the management of CRPS.
- Physiotherapists are at the forefront of initiating these techniques with CRPS patients.

ACKNOWLEDGEMENTS

No financial support.

ADDRESS FOR CORRESPONDENCE

Catherine Pollard. Email cpollard@adhb.govt.nz

REFERENCES

Acerra NE, Moseley GL (2005) Dysynchiria: Watching the mirror image of the unaffected limb elicits pain on the affected side. *Neurology* 65: 751-753.

Birklein F, Kingery WS (2009) Complex regional pain syndrome: A loss of inhibition? *Pain* 142: 177-178.

Birklein F, Schmelz M (2008) Neuropeptides, neurogenic inflammation and complex regional pain syndrome (CRPS). *Neuroscience Letters* 437: 199-202.

Bliokas V, Cartmill T, Nagy B (2007) Does systematic graded exposure in vivo enhance outcomes in multidisciplinary chronic pain management groups? *Clinical Journal of Pain* 23: 361-374.

Bowers AR, Keeney K, Peli E (2008) Community-based trial of peripheral prism visual field expansion device for hemianopia. *Archives of Ophthalmology* 126: 657-664.

Bultitude JH, Rafal RD (2010) Derangement of body representation in complex regional pain syndrome: report of a case treated with mirror and prisms. *Experimental Brain Research* 204: 2107-2108.

Cacchio A, De Blasis E, De Blasis V et al (2009) Mirror therapy in complex regional pain syndrome type 1 of the upper limb in stroke patients. *Neurorehabilitation and Neural Repair* 23: 792–799.

Chae J (2010) Poststroke Complex Regional Pain Syndrome. *Topics in Stroke Rehabilitation* 17: 151-162.

Cohen LG, Bandinelli TW, Findlay TW, Hallett M (1991) Motor reorganization after upper limb amputation in man. *Brain* 114: 615-627.

Daly AE, Bialocerkowski AE (2009) Review: Does evidence support physiotherapy management of adult Complex Regional Pain Syndrome Type One? A systematic review. *European Journal of Pain* 13: 339-353.

De Jong JR, Vangronsveld K, Peters ML et al (2008) Reduction of pain-related fear and disability in post-traumatic neck pain: A replicated single-case experimental study of exposure in vivo. *The Journal of Pain* 9: 1123-1134.

De Jong JR, Vlaeyen JWS, de Gelder JM, Patijn J (2011) Pain-related fear, perceived harmfulness of activities, and functional limitations in complex regional pain syndrome type I. *Journal of Pain* 12: 1209-1218.

De Jong JR, Vlaeyen JWS, Onghena P et al (2005) Reduction of pain-related fear in complex regional pain syndrome type 1: The application of graded exposure in vivo. *Pain* 116: 264-275.

De Mos M, de Bruijn AGJ, Huygen FJPM et al (2007) The incidence of complex regional pain syndrome: a population-based study. *Pain* 129: 12-20.

Ek JW, van Gijn JC, Samwel H et al (2009) Pain exposure physical therapy may be a safe and effective treatment for longstanding complex regional pain syndrome type 1: a case series. *Clinical Rehabilitation* 23: 1059-1066.

Flor H (2003) Cortical reorganisation and chronic pain: Implications for rehabilitation. *Journal of Rehabilitative Medicine* 41: 66-72.

Flor H, Denke C, Schaefer M, Grüsser S (2001) Effect of sensory discrimination training on cortical reorganisation and phantom limb pain. *Lancet* 375: 1763-1764.

Flor H and Diers M (2009) Sensiorimotor training and cortical reorganization. *NeuroRehabilitation* 25: 19-27.

Förderreuther S, Sailer U and Straube A (2004) Impaired self-perception of the hand in complex regional pain syndrome (CRPS). *Pain* 110: 756-761.

Fujiwara T, Mizuno K, Hase K, Takebayashi T, Liu M and Tsuji T (2011) Prism adaptation therapy enhances rehabilitation of stroke patients with unilateral spatial neglect: a randomised controlled trial. *Neurorehabilitation and Neural Repair* 25: 711-720.

Galer BS, Butler S, Jensen MP (1995) Case reports and hypothesis: A neglect-like syndrome may be responsible for the motor disturbance in reflex sympathetic dystrophy (complex regional pain syndrome-1). *Journal of Pain and Symptom Management* 10: 385-391.

Galer BS and Jensen M (1999) Neglect-like symptoms in complex regional pain syndrome: results of a self-administered survey. *Journal of Pain Symptom Management* 18: 213–217.

Galer BS, Schwatz L and Allen G (2001) Complex Regional Pain Syndromes-Type I: Reflex Sympathetic Dystrophy, and Type II: Causalgia. In Loeser JD, Butler SH, Chapman MD, Richard C, Dennis C and Turk DC (Eds) Bonica's Management of Pain (3rd edn). Philadelphia: Lippincott Williams and Wilkins, pp 388-411.

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

Giorgi RG, Woods RL and Peli E (2009) Clinical and laboratory evaluation of peripheral prism glasses for hemianopia. *Optometry and Vision Science* 86: 492.

Gold JI, Reger R, Rizzo A, Buckwalter G, Kim S and Joseph M (2005) Virtual reality in out-patient phlebotomy: evaluating paediatric pain distraction during blood draw. *Journal of Pain* 6: S57.

Guo TZ, Offley SC, Boyd EA, Jacobs CR and Kingery WS (2004) Substance P signalling contributes to the vascular and nociceptive abnormalities observed in a tibial fracture rat model of complex regional pain syndrome type I. *Pain* 108: 95-107.

Harden RN and Bruehl S (2006) Diagnosis of Complex Regional Pain Syndrome: Signs, symptoms and new epirically derived diagnostic criteria. *Clinical Journal of Pain* 22(5): 415-419.

Harden RN, Bruehl S, Perez RSGM et al. (2010) Validation of proposed diagnostic criteria (the "Budapest Criteria") for Complex Regional Pain Syndrome. *Pain* 150: 268-274.

Harley CW (2004) Norepinephrine and dopamine as learning signals. *Neural Plasticity* 11: 191-204.

Hoffman HG, Patterson DR and Carrougher CJ (2000). Use of virtual reality for adjunctive treatment of adult burn pain during physical therapy. *Clinical Journal of Pain* 17: 229-235.

Hoffman HG, Richards TL, Coda B et al (2004) Modulation of thermal pain-related brain activity with virtual reality: evidence from fMRI. *Neuroreport* 15: 1245-1248.

Johnson S, Hall J, Barnett S et al (2012) Using graded motor imagery for complex regional pain syndrome in clinical practice: Failure to improve pain. *European Journal of Pain* 16: 550-561.

Juottonen K, Gockel M, Silén T, Hurri H, Hari R and Forss N (2002) Clinical report: Altered central sensorimotor processing in patients with complex regional pain syndrome. *Pain* 98: 315-323.

Keane S, Turner C, Sherrington C and Beard JR (2006) Use of Fresnel prism glasses to treat stroke patients with hemispatial neglect. *Archives of Physical Medicine and Rehabilitation* 87: 1668-1672.

Lagueux E, Charest J, Lefrançois-Caron E et al (2012) Modified graded motor imagery for complex regional pain syndrome type 1 of the upper extremity in the acute phase: a patient series. *International Journal of Rehabilitation Research* 35: 138-145.

Lewis JS, Kersten P, McCabe CS, McPherson KM, and Blake DR (2007) Body perception disturbance: A contribution to pain in complex regional pain syndrome. *Pain* 133: 111-119.

Lewis JS, Kersten P, McPherson KM, Taylor GJ, Harris N, McCabe CS and Blake DR (2010) Wherever is my arm? Impaired upper limb position accuracy in Complex Regional Pain Syndrome. *Pain* 149: 463-469.

Lewis JS and McCabe CS (2010) Body perception disturbance (BPD) in CRPS. *Practical Pain Management* 10: 60-66.

Lotze M, Montoya P, Erb M et al (1999) Activation of cortical and cerebellar motor areas during executed and imagined hand movements: an fMRI study. *Journal of Cognitive Neuroscience* 11: 491-501.

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

Maihofner C, Baron R, DeCol R et al (2007) The motor system shows adaptive changes in complex regional pain syndrome. *Brain* 130: 2671-2687.

Maihofner C, Handwerker HO, Neundorfer B, and Birklein F (2003) Patterns of cortical reorganization in complex regional pain syndrome. *Neurology* 61*:* 1707-1715.

Matthys K, Smits M, Van der Geest JN et al (2009) Mirror-induced visual illusion of hand movements: A functional magnetic resonance imaging study. *Archives of Physical Medicine and Rehabilitation* 90: 675–681.

McCabe C (2011) Mirror visual feedback therapy. A practical approach. *Journal of Hand Therapy* 24: 170–179.

McCabe C, Cohen H and Blake DR (2007) Somaesthetic disturbances in fibromyalgia are exaggerated by sensory-motor conflict: Implications for chronicity of the disease? *Rheumatology* 46: 1587-1592.

McCabe CS, Haigh RC, Halligan PW and Blake DR (2005) Simulating sensory-motor incongruence in healthy volunteers: Implications for a cortical model of pain. *Rheumatology* 44: 509–516.

McCabe CS, Haigh RC, Ring EFJ, Halligan PW, Wall PD and Blake DR (2003). A controlled pilot study of the utility of mirror visual feedback in the treatment of complex regional pain syndrome (type 1). *Rheumatology* 42: 97-101.

Merskey H and Bogduk N (1994) Classification of chronic pain: Descriptions of chronic pain syndromes and definitions of pain terms. 2nd Ed. Seattle, WA: IASP Press.

Moseley GL (2004). Graded motor imagery is effective for long standing complex regional pain syndrome: A randomised controlled trial. *Pain* 108: 192-198.

Moseley GL (2005a) Is successful rehabilitation of complex regional pain syndrome due to sustained attention to the affected limb? A randomised clinical trial. *Pain* 114: 54-61.

Moseley GL (2005b) Distorted body image in complex regional pain syndrome. *Neurology* 65: 773.

Moseley GL (2006) Graded motor imagery for pathologic pain: A randomised controlled trial. *Neurology* 67: 2129-2134.

Moseley GL (2010) Rehabilitation of people with chronic complex regional pain syndrome. In Mogil JS (Ed) Pain - An updated review: Refresher Syllabus. Seattle: IASP Press pp. 125-133.

Moseley GL, Gallace A and Spence C (2009) Spaced based, but not arm-based shift in tactile processing in complex regional pain syndrome and its relationship to cooling of the affected limb. *Brain* 132: 3142-3151.

Moseley GL, Parsons TJ and Spence C (2008c) Visual distortion of a limb modulates the pain and swelling evoked by movement. *Current Biology* 18: R1047-R1048.

Moseley GL, Zalucki NM, Birklein F et al (2008b) Thinking about movement hurts: The effect of motor imagery on pain and swelling in people with chronic arm pain. *Arthritis and Rheumatism* 59: 623-631.

Moseley GL, Zalucki NM and Weich K (2008a) Tactile discrimination, but not tactile stimulation alone, reduces chronic limb pain. *Pain* 137: 600-608.

Parsons LM and Fox PT (1998) The neural basis of implicit movements used in recognising hand shape. *Cognitive Neuropsychology* 15: 583-615.

Philips HC (1987) Avoidance behaviour and its role in sustaining chronic pain. *Behaviour Research and Therapy* 25: 273-279.

Pleger B, Janssen F, Schwenkreis P, Volker B, Maier C and Tegenthoff M (2004) Repetitive transcranial magnetic stimulation of the motor cortex attenuates pain perception in complex regional pain syndrome type I. *Neuroscience Letters* 356: 87-90.

Pleger B, Ragert P, Schwenkreis P, Förster AF, Wilimzig C, Dinse H, Nicholas V, Maier C and Tegenthoff M (2006) Patterns of cortical reorganization parallel impaired tactile discrimination and pain intensity in complex regional pain syndrome. *Neuroimage* 32: 503-510.

Pleger B, Tegenthoff M, Ragert P et al (2005) Sensorimotor retuning in complex regional pain syndrome parallels pain reduction. *Annals of Neurology* 57: 425-429.

Raja SN, Meyer RA, Ringkamp M and Campbell JN (2010) Peripheral neural mechanisms of nociception. In Wall PD and Melzack R (Eds) Textbook of Pain (4th edn). London: Churchill Livingstone, pp. 11-57.

Ramachandran VS and Altschuler EL (2009) The use of visual feedback, in particular mirror visual feedback, in restoring brain function. *Brain* 132: 1693-1710.

Ramachandran VS, Rogers-Ramachandran D and Cobb S (1995) Touching the Phantom limb. *Nature* 377: 489-490.

Rock I and Victor J (1964) Vision and touch: An experimentally created conflict between the two senses. *Science* 143: 594-596.

Rothgangel AS, Braun SM, Beurskens AJ, Seitz RJ and Wade DT (2011) The clinical aspects of mirror therapy in rehabilitation: A systematic review of the literature. *International Journal of Rehabilitation Research* 34: 1-13.

Sander WS, Eshelman D, Steele J and Guzette CE (2002) Effects of distraction using virtual reality glasses during lumbar punctures in adolescents with cancer. *Oncology Nursing Forum* 29: E8-E15.

Sato K, Fukumori S, Matsusaki T et al (2010) Non-immersive virtual reality mirror visual feedback therapy and its application for the treatment of complex regional pain syndrome: An open-label pilot study. *Pain Medicine* 11: 622-629.

Schneider SM and Workman ML (2000) Virtual reality as a distraction intervention for older children receiving chemotherapy. *Paediatric Nursing* 26: 593-597.

Schwoebel J, Friedman R, Duda N and Coslett HB (2001) Pain and the body schema: evidence for peripheral effects on mental representations of movement. *Brain* 124: 2098 – 2104.

Sumitani M, Shibata M, Iwakura T et al (2007a). Pathologic pain distorts visuospatial perception. *Neurology* 68: 152-154.

Sumitani M, Rossetti Y, Shibata M et al (2007b). Prism adaptation to optical deviation alleviates pathologic pain. *Neurology* 96: 128-133.

Tichelaar YIGV, Geertzen JHB, Keizer D and van Wilgen PC (2007) Mirror box therapy added to cognitive behavioural therapy in three chronic complex regional pain syndrome type I patients: A pilot study. *International Journal of Rehabilitation Research* 30: 181-188.

Van de Meent H, Oerlemans M, Bruggeman A et al (2011) Safety of "pain exposure" physical therapy in patients with complex regional pain syndrome type 1. *Pain* 152: 1431-1438.

Veldman PHJM, Reynen HM Arntz IE and Gorris RJA (1993) Signs and symptoms of reflex sympathetic dystrophy: Prospective study of 829 patients. *Lancet* 342: 1012-1016.

Vlaeyen JWS and Linton SJ (2000) Fear avoidance and its consequence in chronic musculoskeletal pain: a state of the art. *Pain* 85: 317-332.

Wicksell RK, Ahlqvist J, Bring A, Melin L and Olsson GL (2008) Can exposure and acceptance strategies improve functioning and life satisfaction in people with chronic pain and whiplash-associated disorders (WAD)? A randomized controlled trial. *Cognitive Behaviour Therapy* 37: 169-182.

Wise RA (2004) Dopamine, learning and motivation. *Neuroscience* 5: 483-494.