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Mind-Body Interventions for Treatment of Phantom Limb Pain in Persons with Amputation

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Abstract

Phantom limb pain (PLP) is a significant source of chronic pain in most persons with amputation at some time in their clinical course. Pharmacologic therapies for this condition are often only moderately effective and may produce unwanted adverse effects. There is growing empirical evidence of the therapeutic effectiveness of mind-body therapies for the relief of chronic pain; therefore, an exploration of their role in relieving amputation-related chronic pain is warranted. We undertook a focused literature review on mind-body interventions for patients with amputation who experience PLP. Because of study heterogeneity, only descriptive presentations of the studies are presented. Only studies of hypnosis, imagery, and biofeedback, including visual mirror feedback, were found; studies on meditation, yoga, and tai chi/qigong were missing from the literature. Few studies of specific mind-body therapies were dedicated to management of PLP, with the exception of mirror visual therapy. Overall, studies were largely exploratory and reflect considerable variability in the application of mind-body techniques, making definitive conclusions inadvisable. Nevertheless, the weight of existing findings indicates that a mind-body approach to PLP pain management is promising and that specific methods may offer either temporary or long-term relief, either alone or in combination with conventional therapies. The authors discuss the potential for usefulness of specific mind-body therapies and the relevance of their mechanisms of action to those of PLP, including targeting cortical reorganization, autonomic nervous system deregulation, stress management, coping ability, and quality-of-life. The authors recommend more and better quality research exploring the efficacy and mechanisms of action.

Keywords

Amputation; Phantom Limb Pain; Visual Mirror Feedback; Mind-Body Medicine

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Currently, 1.6 million people in the United States live with a limb loss; by 2050, this number will likely double.[1] Most persons undergo amputation for peripheral vascular insufficiency, trauma, or malignancy, with greater numbers of lower than upper limb loss (5:1 ratio).[1,2] Individuals with limb amputation face physical and psychosocial challenges during their

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adjustment process, including (1) impairment in physical functioning, (2) pain, (3) prosthesis use, (4) change in employment status, (5) alteration in body image and self-concept, and (6) poor psychosocial adjustment.[3] Individuals with amputation must often cope with chronic pain, including residual (stump) and phantom limb pain (PLP).

Current literature is divided on the impact of PLP. PLP appears to be constant in only 18%–25% of persons with amputation. In reported studies, the prevalence of PLP depends on how it is denned: “any” PLP ranges from 51% to 80%, whereas pain experienced at least a few times per week is reported in 28%–37% (Table 1) [4,6,8–11,13–15] The incidence and natural history of PLP is even more uncertain; only small, relatively brief longitudinal studies have so far been reported.[5,7,12,15] Longitudinal studies suggest that PLP decreases in time,[5,7,12,15] making high prevalence estimates in populations several years post amputation even more notable and making the interpretation of therapy efficacy very difficult. Pain in other body locations as a result of prosthesis use is found in up to 45% of the population.[16,17] PLP, a challenging source of chronic pain in this population, is the focus of this report.

Efficacious therapies to reduce the suffering of persons with amputation are still elusive. The literature describes a variety of pharmaceutical, surgical, and other conventional therapeutic approaches to pain management in persons with amputation, including more than 30 types of therapy for PLP.[18–20] These procedures include the following modalities: (1) sympathectomy,[21] (2) stump manipulation,[21] (3) stump ultrasound,[22] (4) injection with local anesthetics and analgesics,[21] (5) transcutaneous nerve stimulation with discrimination training,[23] (6) nerve blocks,[24] (7) cordotomy,[25] (8) pharmacologic therapies,[20,26,27] and (9) myoelectric prosthesis.[28] The overall findings of this literature conclude that these various therapies range from ineffective to slightly effective. With conventional treatments for PLP having had mixed and often limited success,[22,29] providers and the public have begun to examine and use nonconventional approaches. However, clinical studies of nonconventional approaches reporting some success in treating PLP are few in number, and generally describe small numbers of subjects. Published studies on nonconventional or complementary and alternative medicine approaches to treatment of PLP have included acupuncture, energy healing, and mind-body therapies (e.g., hypnosis, biofeedback [including visual mirror feedback], eye movement desensitization and reprocessing, guided imagery, and relaxation techniques).[30–33]

Mind-body therapy approaches to pain management are a small but growing area of investigation and use. The National Institutes of Health states that mind-body therapies focus on the interactions among the brain, mind, body, and behavior, with the intent to use the mind to affect physical functioning and promote health.[34]

Mind-body therapies use and enhance the mind’s ability to be aware of and self-regulate symptoms. Techniques include biofeedback, hypnosis, yoga, tai chi, qi gong, meditation, guided imagery, progressive relaxation, and deep breathing exercises. According to the 2007 National Health Interview Survey, 19.2% of adults reported using mind-body therapies in the past 12 mos.[2,3]

Research in mind-body medicine reveals that these therapies can enhance the ability to ameliorate symptoms such as pain, stress, anxiety, depression, and fatigue, often found in patients with chronic conditions, as well as improve coping ability and quality-of-life. For example, mindfulness meditation has been shown to improve stress and mood[35]; yoga with controlled breathing and visualization has been shown to decrease sleep disturbance,[18] and hypnosis has been found to reduce postsurgical pain and distress.[19,20]

The prevalence of PLP among persons with amputation and its impact in terms of suffering and reduced quality-of-life, combined with the limitations of efficacy in conventional approaches, justifies a continued search for alternative treatments. In particular, because mind-body therapies have shown promise for self-regulation and amelioration of various chronic painful conditions, an exploration of research on their application to PLP—a condition that exemplifies the complex interaction of body and mind—seems especially warranted. The purpose of this focused literature review was to evaluate existing intervention studies of mind-body techniques for reducing PLP in persons with amputation.

METHODS

Data Sources

Systematic searches were conducted on PubMed (MEDLINE), Institute of Scientific Information Web of Knowledge, EMBASE, Cumulative Index to Nursing and Allied Health, Cochrane libraries, and Alternative Medicine Database electronic databases from the period of 1994 to 2010. Search terms included the following: *amputee*, *amputation*, *psychological distress*, *phantom pain*, *depression*, *anxiety*, *stress management*, *mind-body medicine*, *meditation*, *guided imagery*, *imagery*, *hypnosis*, *biofeedback*, *autogenic training*, *progressive muscle relaxation*, *yoga*, *breathing exercise*, *tai chi*, and *chi(qi) gong*. A manual search of references from retrieved articles was also conducted. Because of the paucity of intervention trials using mind-body techniques for amputation-related pain, both randomized-controlled clinical trials (RCTs) and studies of lesser methodologic rigor were included, that is, simple clinical trials, case reports, and case series. Studies were excluded if they (1) lacked an intervention, (2) were not published in English, and (3) did not address PLP as the primary outcome among persons with limb amputation. Other than one dissertation, studies outside peer-reviewed journals were not reviewed. Where overlapping reports were found, only the most complete article was chosen.

Study Selection

Of 670 articles retrieved through search strategies, 19 independent reports met the criteria and were reviewed by two independent researchers. Of the 19 articles selected, 2 (including the dissertation) were randomized controlled clinical trials, 8 were simple clinical trials, and 10 were case reports or series. All studies addressed PLP. The studies available for review reported results of interventions in hypnosis, imagery, and biofeedback. No articles that met the review criteria were found for meditation, yoga, tai chi, or qigong as adjuvant therapies for pain and/or psychologic distress in amputees.

Data Extraction and Quality Assessment

Information extracted from the studies included descriptions of the following elements: (1) intervention technique, (2) sample size and composition, (3) intervention duration, (4) follow-up period, and (5) detailed outcome assessments with statistical analyses. The completeness of the descriptions of the above elements was used to judge the quality of case reports and simple trials. RCTs were assessed with the quality criteria explicated by Balk et al.[36]

Non-RCTs and case studies are considered of lower methodologic quality because they do not adequately control for bias.[37] Of the two RCTs reviewed, neither met criteria for a high-quality clinical trial. Rickard's[38] study came closest to meeting criteria for a high-quality trial, but concealment of random allocation was unclear, and data regarding the comparability of the groups at baseline was missing.[38] In addition to these flaws, in the second RCT conducted by Chan et al.,[19] the randomization method was inadequate, and it was unclear whether the assessments and analyses were blinded.[19] The authors of this study also failed to report control of other potentially confounding factors such as medication usage and other treatments being used by the patients. Sample sizes of these studies were small (18–20 subjects), and the studies were heterogeneous in terms of both mind-body techniques and outcomes. A third RCT was excluded because its primary outcome was phantom limb sensation and awareness rather than PLP.[39]

Data Synthesis

Because of the small number of studies and the heterogeneity of the mind-body techniques used in the reports meeting our selection criteria, no quantitative synthesis of the findings was attempted. The following represents a summary of available studies examining mind-body techniques. To assist the reader, the mind-body techniques are described briefly before the study reports. Tables 2–5 also present study elements for ease of comparison across studies.

RESULTS

Hypnosis

The American Society of Clinical Hypnosis defines hypnosis as "a state of inner absorption, concentration and focused attention."[52] Hypnosis is a form of information processing in which peripheral awareness and critical analytic cognition are suspended, readily leading to apparently involuntary changes in perception, memory, and mood that have profound behavioral and biologic consequences.[53] Hypnosis has been used for more than a century as a therapeutic approach for a variety of physical and mental health conditions and is frequently cited in the literature as an effective mind-body intervention for pain.[54] Numerous studies suggest that hypnosis is effective as a primary or adjunctive treatment of acute pain related to medical and surgical procedures such as bone marrow aspiration, burn wound dressing changes, labor pain, and for chronic pain under conditions such as fibromyalgia and headache.[55] A review of controlled trials of hypnotic analgesia indicates that hypnosis reduces pain better than no treatment at all for conditions such as headache, cancer-related pain, fibromyalgia, osteoarthritis, low back pain, and disability-related pain.[56] In 1996, the

National Institutes of Health assembled a Technology Assessment Panel on the integration of behavioral and relaxation approaches into the treatment of chronic pain and insomnia, which reported that relaxation and hypnosis are effective in reducing chronic pain.[57]

We identified a case report and review of case reports, one RCT, and one non-RCT in the use of hypnosis as an adjuvant therapy for PLP. Reports of cases indicate substantial improvement in PLP with hypnosis training Table 2).[30,38,40] In the small clinical trial, patients 6 mos postamputation with PLP were randomized to either three individual sessions of hypnosis for PLP or the waitlisted control group. Repeated-measures analysis of variance showed statistically significant time-by-group effects ($P < 0.001$) in the McGill Pain Questionnaire Pain Intensity Rating and the Daily Pain Rating Scale. In addition, in the treatment group, prehypnotic pain decreased during the course of the three hypnosis sessions.

In the only uncontrolled trial, a multifaceted intervention was used, including hypnotic analgesia, visualization and movement of an imaginary limb, psychologic hypnosis, and self-hypnosis.[40] In addition to improvements in immediate presession to postsession pain via Visual Analogue Scale, median pain scores by nonparametric paired-sample testing fell significantly. In his review of case reports, Oakley et al.[30] proposed two types of hypnotic approach to PLP using imagery—ipsative/imagery and movement/imagery. The first one uses images to modify a patient’s representation of and to improve their pain; the second one uses suggestions to make the patient move the phantom limb and to be able to control the pain. In general, the studies reduced pain frequency or intensity. Oakley et al.[30] found no evidence that either form of hypnosis was superior to the other. As a whole, these case reports and studies are suggestive of support for the use of hypnosis as an effective intervention for PLP (and residual stump pain) in the short term. Additional well-controlled randomized studies are needed before conclusions can be made. It is particularly unclear whether the positive effects of hypnosis on pain control are persistent.

Guided Imagery

Imagery is described as a thought process that invokes and uses the senses: vision, audition, smell and taste, senses of movement, position, and touch. It is considered a communication mechanism between perception, emotion, and bodily change and is defined as using one’s imagination to create mental images that involve all senses to assist the body in healing, maintaining health, or reducing stress and promoting relaxation.[58–60] A recent national survey found that guided imagery was the ninth most commonly used complementary and alternative medicine therapy (2.2%) by adults 18 yrs or older in the United States in 2007.[61] Interactive Guided Imagery is a unique form of guided imagery created in a therapeutic setting as a result of (1) patient/therapist interaction, (2) interaction between the patient and his or her images, and (3) interaction among the patient’s images.[62] During an Interactive Guided Imagery session, initially, the patient was guided to a state of relaxation and encouraged to describe the spontaneous imagery that happens at that particular moment. The therapist elicits the patient’s imagery and responds in an appropriate way. The Interactive Guided Imagery session continues in an interactive and personalized manner. It mobilizes the latent, innate healing abilities of the patient to promote pain control and accelerate rehabilitation, recovery, and health enrichment.[62] The Interactive Guided Imagery approach is eclectic, holistic, humanistic, and nondogmatic, incorporating skills from many related disciplines including hypnosis, Jungian psychology, psychosynthesis, self-actualization, and ego-state psychology.[62]

Imagery is thought to be helpful in a number of conditions, including chronic pain, psychologic distress, sleep disturbance, cancer, and cardiovascular disease.[31,63,64] Our review identified four studies on imagery for persons with amputation experiencing PLP: one case series and three uncontrolled trials (Table 3).[33,65–67] These studies used a variety of models of mental imagery in the treatment of PLP in persons with amputation. Zuckweiler[64] and Zuckweiler and Kaas[67] used a novel imaging technique to increase the experience of movement of the phantom limb. All patients in the case series were free of pain at 6 mos after the conclusion of treatment. In the uncontrolled trial, PLP frequency diminished after treatment and at 6 mos. In a second trial focused on central nervous system mechanisms, MacIver et al.[33] used sensation and movement imagery in combination with psychotherapy and relaxation techniques. In addition to demonstrating improvements in pain intensity, the investigators reported reductions in cortical reorganization, a central nervous system mechanism thought to cause PLP.[33,68–70] Instead of cortical reorganization, Beaumont et al.[66] measured psychologic variables in investigating mechanisms of reduction in PLP. The locus of control, social support, and general psychologic distress werenegatively correlated with reductions in pain.[66] Finally, in a study of visual mirror feedback, the investigators used mental imagery as a control condition.[19] In the mental imagery condition, participants in the study were instructed to imagine moving their phantom rather than viewing the unaffected limb in a mirror. Visual stimulation with the mirror was superior in reducing PLP.[19]

Biofeedback

Biofeedback is a self-regulatory technique that has been used for decades to help individuals learn control of autonomic physiologic processes, such as heart rate, muscle tension, blood pressure, and vasoconstriction.[71] The hypothesis is that the pain experience is maintained or exacerbated by autonomic nervous system deregulation.[71] Biofeedback signals, which can be visual or auditory analogs of the physiologic changes, focus self-regulatory efforts. Biofeedback methods used to treat phantom pain are many and include (1) electromyography, (2) muscle tension biofeedback, (3) thermal (peripheral skin temperature) biofeedback, (4) visual mirror feedback, and (5) auditory biofeedback.[71]

Studies have shown that people experiencing PLP, especially those complaining of burning pain, present lower skin temperature at the stump distal end than at a corresponding point on the intact limb.[72–74] Thermal biofeedback therapy, as promulgated by Sherman et al.,[74] teaches PLP patients to increase skin temperature at the stump distal end.[74] In addition, patients with PLP presenting with spontaneous muscular hyperactivity in the stump, including involuntary spontaneous jerking, seem to benefit from electromyography biofeedback.[75,76] Physiologically, when one autonomic nervous system function is regulated, such as skin temperature, it positively impacts other functions. For example, cold limbs indicate arteriolar vasoconstriction caused by increased sympathetic activation; in contrast, warm limbs are a sign of arteriolar vasodilation as a result of decreased sympathetic drive and increased parasympathetic activation. Sympathetic activation, a common feature of anxiety and hyper-vigilance, is seen in a variety of chronic health conditions, including chronic pain.[71] Thermal biofeedback, combined with simple relaxation techniques, trains PLP patients to both increase the temperature of the stump and to relax.[71] In time, repeated use of thermal biofeedback provides patients with an increased ability to deal with stress and reduce pain.[71]

Two studies on traditional biofeedback treatment of PLP, a case report and an uncontrolled clinical trial, met our selection criteria (including publications after 1994) (Table 4).[77,78] In the case report, pain was completely resolved through a combination of electromyography and thermal biofeedback.[77] Despite earlier reports on the effectiveness of thermal biofeedback in some forms of PLP, the uncontrolled trial did not show significant reductions in the primary outcome variable (McGill Pain Questionnaire Pain Intensity), but McGill Pain Questionnaire sensory pain was significantly reduced.[78]

Visual Mirror Feedback and Associated Techniques

In the last 15 yrs, a novel approach to the treatment of PLP—visual mirror feedback (VMF) — has gained the attention of researchers in the field of rehabilitation medicine, with a proliferation of clinical trials to study its effect on PLP in persons with amputation as well as its mechanism of action. Studies involving VMF are not limited to PLP; they also include complex regional pain syndrome therapy and stroke rehabilitation.[63,79,80] In addition, new refined devices that use the same principles of the original cardboard visual mirror feedback box (virtual reality technology and left/right reversing prisms) have been developed.[45,46,49,51]

VMF is a technique introduced by Ramachandran and Altschuler[81] in 1992 to treat pain of central origin such as PLP. The VMF procedure requires the use of a rectangular box made of wood or cardboard. A mirror is placed vertically in the middle of the box, dividing it into two compartments, with the top and front of the box removed. A patient places his/her affected limb in one side of the box and the intact limb in the other side. By looking at the intact limb and its reflection on the mirror, patients observe that the intact limb visually takes the place of the phantom limb, creating an illusion that the phantom has been revived.[41]

In 1993, during his first experiment with VMF, Ramachandran and Altschuler[81] observed that while facing a mirror box with open eyes and following the commanded movement of the intact limb, his patient was able to see and feel the phantom limb moving. During the course of the intervention, his patient also had a marked reduction in pain intensity. The results of this experiment marked the beginning of a series of studies that contributed to advances in neurosciences' "new view of brain functions" and its "strong inter-sensory interaction as well as plasticity of the brain modules" (p. 1693). Seven articles on VMF as an intervention for phantom pain met ourselection criteria, along with three articles using virtual reality technology (Table 5).[19,42–51] The first set of investigations was carried out by Ramachandran and Rogers-Ramachandran[42] in 1996 and reported again in 2009.[81] Ramachandran described a goal: to "resurrect the phantom visually and study the inter-sensory effects of visual input on phantom sensations" (p. 377).[42] Ten patients with upper limb amputation, phantom limb sensation, and pain were treated with VMF following an individualized protocol. The length of treatment varied from six single sessions of 5 mins to 15 mins a day for a few weeks. During and after the intervention, participants reported a reduction in pain, ability to move the frozen limb in the cases that this sensation was present, disappearance of the phantom arm in one of the patients, relief from spasm in the phantom arm, and touch perception in the phantom limb when the intact limb was touched. These experiments “suggest that there is an amount of latent plasticity even in adult human brain,” whereby “precisely organized new pathways, bridging the two hemispheres, can emerge in less than three weeks.”(p. 386).[42] As a result of his experiments, Ramachandran recommended imaging studies such as functional magnetic resonance imaging and positron emission tomography scan to elucidate new pathways of sensory interactions.

Three additional case reports were consistent with Ramachandran’s initial findings. The results of the uncontrolled clinical trial of VMF were less impressive, demonstrating a 36% reduction in PLP. In the one small randomized trial, those who were assigned to VMF achieved complete PLP resolution as compared with 17% in the sham-mirror therapy and 33% in the “mental visualization” group. The virtual reality studies used an avatar created by sensors either on the intact limb or the residual limb. Improvements in pain control were similar to those reported using VMF therapy, although improvement tended to decrease with time since treatment.[45,49,51]

DISCUSSION

Although more research is needed on specific mind-body therapies to supply definitive evidence of their usefulness for PLP, the weight of existing findings indicates that a mind-body approach to PLP pain management is promising and that specific methods may offer either temporary or long-term relief, alone or in combination with conventional therapies. In particular, because conventional treatments are not always successful[22,29,78] and may produce unwanted adverse effects, it is important to consider how mind-body therapies may enhance care of PLP patients.

Relevance of Mind-Body Therapies to Mechanisms of Action of PLP

To better understand the possible roles that mind-body therapies may play in PLP management, it may be helpful to review the mechanisms of PLP. Although answers regarding the causes of PLP have remained elusive, much progress has been made recently. It is now understood that multiple factors involving both the central and peripheral nervous system contribute to PLP.[82] Central factors involve both the spinal cord and the brain. They include central sensitization in the spinal cord, characterized by increased excitability, and expansion of receptive fields into adjacent sensory areas.[83] In addition, changes in input into the neural matrix-a network of neurons in several brain regions including the thalamus, somatosensory cortex, reticular formation, and limbic system together form an anatomical representation of self.[84] Perhaps most significantly, changes in the functional structural architecture of the primary somatosensory cortex result in phantom sensations arising from adjacent areas.[81] For example, pursing of the lips resulted in activation of primary motor and sensory cortices corresponding to the phantom by functional magnetic resonance imaging,[33] and greater cortical reorganization was associated with increased PLP.[82]

Peripheral nervous system changes include nociceptive input from the residual limb, as when a neuroma forms in the stump and peripheral neuropathy may contribute to worsening of pain.[85] Paradoxically, stimulation of the stump through discrimination training or myoelectric prosthesis tends to reduce PLP.[28] In addition, emotional factors, including anger and stress, are known to exacerbate pain sensations in PLP, with both central (e.g., increased sympathetic nervous system activity) and peripheral (e.g., muscle tensing and regional sympathetic stimulation) factors being involved.[78,86] Cognitive factors such as coping ability are also associated with pain modification in PLP.[83] It has also been hypothesized that pain memories and proprioceptive memory may play a role in the character and degree of PLP.[33,87,88]

In her first review, Flor[83] stated that "so far, few mechanism-based treatments for PLP have been proposed" (p. 182). However, recent research indicates the potential for usefulness of several specific mind-body therapies based on the relevance of their mechanisms of action to those of PLP. For example, one of the most successful and well-studied therapies, Mirror Visual Feedback, appears to target cortical reorganization,[81] including changes in the somatosensory cortex and the neural matrix. Other therapies that use guided mental imagery, including therapeutic uses of hypnosis, may also target reduction of cortical reorganization. For example, MacIver et al.[33] found that motor imagery stimulated the contralateral cortex and reduced cortical reorganization. Anderson et al.[89] found that motor imagery was associated with activation of the thalamic sensory nuclei. Biofeedback mechanisms use the mind-body's ability to self-regulate and restore autonomic nervous system deregulation,[71] as in the use of electromyography and thermal biofeedback to decrease muscle tension and increase temperature of the stump, resulting in pain modification.[77,78,90]

Need for High-Quality Studies of Mind-Body Therapies

A surprising finding in this literature review was the paucity of research studies available in the English language on mind-body therapies for phantom pain in persons with amputation. Only studies of hypnosis, imagery, and biofeedback, including visual mirror feedback, were found. Although the available findings are promising for the role of mind-body therapies, the articles reviewed here have shortcomings that limit our ability to generalize the findings, including small numbers of participants, uncontrolled experimental designs, and lack of study replication. There is a need for RCTs with well-defined and clearly reported treatment protocols to evaluate the efficacy of the various approaches that have been suggested, whether those approaches be hypnosis, imagery, or biofeedback. Moreover, in this review, not all therapies were used in a consistent and standard manner, which also affected the generalizability across studies of the mind-body therapies. There is also a need for standardized measures of the PLP to be taken preintervention and postintervention, along with other measures of psychologic and social adjustment. With these caveats in mind, there is an overall need for replication and validation of promising findings in hypnosis, guided imagery, and biofeedback. In addition, extended follow-up to measure changes in quality and intensity of pain over time, as well as in-depth interviews of study participants for qualitative analysis of their experience, are advisable.

One exception, in terms of volume of studies, is those on VMF. The growing exploration and promising findings for VMF lend support for its use in rehabilitation centers, either alone or in combination with other mind-body therapies. Moreover, the value of VMF cannot be separated from the context in which it was developed and has contributed to the expansion of the new understanding of brain functions and advances in neuroscience. Because early experiments in the late 1970s on the effects of amputation on somatosensory maps in adult mammals, the resurgence of interest in the clinical phenomena of phantom limbs and the development of the VMF device and therapy in the early 1990s, many advances have been made in neuroscience with evident benefit for many people with chronic neurologic disorders including PLP in persons with amputation.

Additional research investigating the usefulness of other mind-body therapies for PLP should also be explored. Specifically, mindfulness meditation, a cognitive and behavioral technique involving the intentional self-regulation of attention to present-moment experience[91] has already shown to significantly lower stress—well known to exacerbate pain phenomena—as well as ameliorate depression and anxiety, also associated with increased pain.[92] Moreover, mindfulness has been shown to reduce pain in specific conditions and to enhance coping ability.[92–94] To our knowledge, there are no studies of mindfulness for persons with amputation, including those experiencing PLP. Additional research using existing therapies not found in this review include possible sympathetic blocks using hypnotic analgesia. Hypnotic analgesia may operate at the spinal cord level and may be compared with regional anesthesia.[95]

Overall, one major advantage of mind-body therapies as part of a comprehensive pain management program is the ability to enhance capacity for self-regulation and self-efficacy, which can increase quality-of-life. Offering techniques known to expand these capabilities for those with disabilities is critically important to the well-being of this population and their reintegration into society.

The understanding of the phenomena of phantom pain and sensations is now being articulated in the science of rehabilitation, and the important role played by mind-body therapies in the treatment of this condition is only now beginning to be appreciated. More and better research on mind-body therapies for PLP, including studies of mechanisms of action, will extend the frontiers of research in the neurosciences on interactions of brain, body, and behavior and enhance health care and quality-of-life for this deserving population.

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TABLE 1

Prevalence of phantom limb pain across studies

First Author (Year)	Sherman (1984)[4]	Jensen (1985)[5]	Katz (1990)[6]	Nikolasjen (1997)[7]	Kooijman (2000)[8]	Ehde (2000)[9]	Borsje (2004)[10]	Ephraim (2005)[11]	Hunter (2008)[12]	Hanley (2009)[13]	Desmond (2010)[14]	Bosnians (2010)[15]
Country	United States	Denmark	Canada	Denmark	Netherlands	United States	Netherlands	United States	Canada	United States	Ireland	Netherlands
Study type	Cross-sectional	Cohort[a]	Cross-sectional	Randomized controlled trial[a,b]	Cross-sectional	Cross-sectional	Cross-sectional	Cross-sectional	Cohort[a]	Cross-sectional	Cross-sectional	Cohort[a]
Method	Survey	Interview	Interview	Interview	Survey	Survey	Survey	Interview	Interview	Survey	Survey	Survey
Response/retention rate[c]	55%	59%	91%	84%	80%	56%	30%	71%	78%	47%	49%	57%
N	2694	34	61	36	72	255	468	914	11	104	141	62
Upper/lower	Both	Both	Both	Lower	Upper	Lower	Both	Both	Upper	Upper	Upper	Both
Years since amputation	mean, 26–30	2	mean, 5 (0.1–46)	0.5	median, 19	median, 7	mean, 15–18	median, 4 (<1–66)	2	median, 7 (0.2–60)	mean, 50 (5–63)	1.50
Population	Military	General	General	Nontraumatic	General	General	General	General	Traumatic	General	Trauma[d]	General
Frequency												
Any *vs.* none	78%	59%	72%	75%	51%	72%	72%	80%	63%	79%	64%	
At least few per month	64%				44%		53%	59%[e]		68%	43%	
At least few per week	37%				33%	36%	32%				28%	
At least a few per day		21%			25%		20%	21%		26%	18%	35%

[a] Percentages reflect incidence.

[b] Deaths excluded from retention rate totals reflect item response rate.

[c] Epidural *vs.* epidural plus general anesthesia.

[d] 98% as a result of trauma.

[e] "Sometimes."

TABLE 2

Hypnosis for phantom limb pain among persons with amputation

Case	Condition	Treatment	Results	*P*
Oakley et al. (2002)[30] case review	PLP for 4 yrs (AKA); 76-yr-old woman	Eight weekly 25-min sessions of hypnosis.	100% pain relief and continued phantom sensations	n/a
	Review of 11 cases of PLP (duration, 0.5–25 yrs) (arm, AKA, BKA)	Hypnosis sessions (3–64) of varying length. Cases include five ipsative-imagery– and six movement-imagery–based therapies. Five included relaxation training; one, cognitive therapy; and one, mirror therapy.	Reduction in pain frequency or intensity; improvement in physical or psychologic function	n/a
Bamford (2006)[40]; uncontrolled trial (n = 25)	PLP (mean duration, 7 yrs) (arm, leg); 10 women and 15 men aged 27–78 yrs	Six weekly sessions + home practice three times daily using hypnotic analgesia, visualization and movement of imaginary limb, psychologic hypnosis, and self-hypnosis	Significant reduction in median pain after intervention, maintained 6 mos later (NRS, 8 of 10 to 3 of 10); results not sensitive to side (right *vs.* left) or cause of amputation (trauma *vs.* other) (Wilcoxon)	<0.001
Rickard (2004)[38] RCT $n = 20$	PLP with/without stump pain (arm, AKA, BKA; 0.5–63 yrs ago); men and women aged 31–70 yrs	Three individual hypnosis sessions *vs.* waitlisted control	Reduction in pain before to after intervention. By MPQ-SP: intervention group, mean (SD) from 58.8 (26.02) to 10.1 (6.28); control, from 49.5 (25.27) to 46.4 (14.67) (ANOVA)	<0.001

AKA, above-the knee (transfemoral) amputation; ANOVA, analysis of variance; BKA, below-the-knee (transtibial) amputation; MPQ-SP, McGill Pain Questionnaire Pain Intensity Scale; NRS, numeric rating scale; PLP, phantom limb pain; n/a, not applicable; RCT, randomized controlled trial.

TABLE 3

Mental imagery training for phantom limb pain among persons with amputation

Case	Condition	Treatment	Results	*P*
McAvinue and Robertson (2011)[65] case series (*n* = 4)	PLP (AKA, BKA 1.7 to 19 yrs previously) on 40-yr-old man, 45-yr-old man, 66-yr-old man, and 25-yr-old woman	Four weekly sessions of movement imagery training followed by 6 wks training on increasing the awareness of the phantom and in movement of the stump and imagined movement of the phantom; daily practice and pain diaries	All participants improved in imagery after training, although two more than the others. Through interrupted time series analysis, one of the four participants noted an improvement in PLP.	n/a
Zuckweiler (2005)[64] uncontrolled trial (*n* = 14)	PLP (leg, hand, finger 1–21 yrs previously); 71% male, aged 30–80 yrs	5 to 15 imagery sessions using ZIPS over 4–20 wks; ZIPS encourages precise body image and improved mind-body sensory messaging.	Significant reduction in PLP frequency at end of intervention and at 6 mos (7-point scale, χ^2)	<0.001
Maclver et al. (2008)[33] uncontrolled trial (*n* = 13)	PLP for 3–51 yrs (arm); 11 men, 3 women	Six training sessions: guided body scan for relaxation followed by sensory and motor imagery training; participants were encouraged to practice daily with a 40-min CD and do a 10-min exercise to use without a CD.	Significant decrease in pain intensity (NRS, 7.5 of 10 to 4.0 of 10) and exacerbations (6.0 to 3.0); training resulted in reduced motor and sensory cortical reorganization (inappropriate activation of contralateral hand/arm cortical area) by fMRI	<0.001
Beaumont et al. (2011)[66] uncontrolled trial (*n* = 6)	PLP for 0.6–28 yrs (arm, AKA, BKA); all men, aged 32–65 yrs	Participants chose 10 of 48 movements from a video to practice with the phantom. Training (30 mins, twice weekly) over 4 wks added two movements per week to the initial 4. At home, participants practiced 30 mins with a video for an additional 4 wks.	Imagery ability improved in all but one. Four participants noted at least 30% reduction in pain after the intervention, but only one noted persistence of the improvement at 6 mos (without practice). Psychologic health appeared to be a factor in degree of improvement.	n/a

AKA, above-the knee (transfemoral) amputation; BKA, below-the-knee (transtibial) amputation; fMRI, functional magnetic resonance imaging; NRS, numeric rating scale; PLP, phantom limb pain; n/a, not applicable; ZIPS, Zuckweiler's Image Imprinting.

TABLE 4

Biofeedback for phantom limb pain amonq persons with amputation

Case	Condition	Treatment	Results	*P*
Belleggia and Birbaumer (2001)[77] case report (*n* = 1)	PLP (arm 3 yrs previously); 69-yr-old man	Six weekly EMG and thermal biofeedback/relaxation sessions (1 hr), then six weekly thermal biofeedback sessions	Elimination of pain (VAS) at end of treatment, maintained at 3- and 12-mo follow-ups, with decreased differences in EMG and temperature between the stump and the contralateral arm	n/a
Harden et al. (2005)[78] uncontrolled trial (*n* = 9)	PLP (arm, leg); five men, four women with mean age of 57.6 yrs	Six weeks of thermal autogenic biofeedback sessions; follow-up at 12 mos	Only sensory MPQ-SP significantly different before and after treatment; daily pain intensity (VAS) reduced by mean of 39%	0.05

EMG, electromyography; MPQ-SP, McGill Pain Questionnaire Pain Intensity Scale; PLP, phantom limb pain; n/a, not applicable; VAS, Visual Analogue Scale.

TABLE 5

Visual mirror feedback and associated techniques for phantom limb pain for persons with amputation

Case	Condition	Treatment	Results	*P*
Ramachandran (1993)[41] and Ramachandran and Rogers-Ramachandran (1996)[42] case series (*n* = 10)	PLP (arm and hand amputations 19 days to 9 yrs previously); men and women aged 23–73 yrs	Individualized exploratory protocol of VMF for 5 to 15 mins daily for a few weeks; exploration included both motor and sensory stimulation	Self-reported reduction in or complete resolution of pain and ability to move the phantom limb	n/a
Darnall (2009)[43] case report (*n* = 1)	PLP (BKA 3 yrs previously); 35-yr-old man	Home-based mirror therapy, relaxation, and psychotherapy	After 3 mos, the man was completely free of pain.	n/a
MacLachlan et al. (2004)[44] case report (*n* = 1)	PLP (AKA); 32-yr-old man	Two to three sessions per day for 3 wks	Reduction in phantom pain (100%) and stump pain (50%) (NRS) after treatment. After 3 mos, PLP control, 30%.	n/a
Murray et al. (2006)[45,46] case series (*n* = 5)	PLP (arm, AKA, BKA 1–40 yrs previously); three men aged 56–63 yrs and two women aged 61–65 yrs	Immersive virtual reality system was used to transpose the movement of the existing limb into the space of the missing limb. 30-min sessions: four movement tasks of the virtual limb; number of sessions not specified.	Transient improvement in PLP, decaying with time. Patient with recent (1 yr) amputation noted the most benefit. All had vivid sensations of moving phantom.	n/a
Hanling et al. (2010)[47] case series (*n* = 4)	PLP (BKA); three 22-yr-old men, one 27-yr-old man	Daily mirror therapy for 30 mins for 5–6 days before amputation	Moderate stump pain but only mild occasional PLP 1 mo after amputation.	n/a
Wilcheretal. (2011)[48] case report (*n* = 1)	PLP (arm and shoulder amputation <1 mo previously); 24-yr-old man	PLP, refractory to medical management, treated with twice-daily VMF accompanied by auditory stimuli (hand claps)	Reduction in PLP from average or 8/10 to max of 6/10 with withdrawal of most medications	n/a
Mercier and Sirigu (2009)[49] uncontrolled trial (*n* = 8)	PLP (arm amputation 1–16 yrs previously); all men aged 19–54 yrs	Virtual visual feedback therapy twice weekly for 8 wks. Intact limb filmed performing ten movements; images digitally inverted; participant followed image with phantom limbs	Mean decrease in pain by 38% (VAS). Five of eight reported 30% or more improvement. Pretreatment-posttreatment paired-sample *t* test significant at 1 and 4 wks.	0.02 (1 wk); 0.04 (4 wks)
Sumitani et al. (2008)[50] uncontrolled clinical trial (*n* = 22; 11 with amputation)	PLP and sensation (six arm and five lower-limb amputations 3–900 wks previously); nine men and two women aged 32–74 yrs	Mirror therapy: individual sessions of 10 mins once daily for weeks: mean (SD) of 20.4 (23.8); participants moved intact limb with observation in the mirror and imagined movement of the phantom.	All: decrease in pain (NRS)- mean pretreatment, 6.6 (1.7); posttreatment, 4.2 (2.8); participants with greater imagery showed more decrease than patients without: 51.4% (31.8%) *vs.* 12.5% (21.7%). Imagery correlated with deep pain descriptors.	<0.002
Cole et al. (2009)[51] uncontrolled clinical trial (*n* = 14)	PLP (half-arm, half-leg amputations 5 mos to 10 yrs previously); ten men and four women aged 27 to 83 yrs	Virtual reality imaging (avatar) with motor task activated by movement of the residual limb; sessions lasted 60–90 mins	Four of seven with arm and four of seven with leg amputations reported reductions in pain >30% (VAS). Pain relief tended to be transient.	
Chan et al. (2007)[19] randomized/sham-controlled trial of mirror therapy *vs.* imagery therapy (*n* = 22; 18 completers)	PLP (lower limb)	Four-week 15-min daily practice; used different visual mirror feedback techniques: (1) VMF, (2) viewed CM, or (3) trained in MV.	Pain intensity (VAS) postintervention decreased: VMF, 100%; CM, 17%; MV, 33%. >50% of CM and MV subjects reported increases in pain intensity. 89% of those who switched to VMF therapy reported decreased pain.	0.04 (VMF *vs.* CM); 0.002 (VMF *vs.* MV)

AKA, above-the knee (transfemoral) amputation; BKA, below-the-knee (transtibial) amputation; CM, covered mirror; n/a, not applicable; NRS, numeric rating scale; PLP, phantom limb pain; VAS, Visual Analogue Scale; VMF, visual mirror feedback; MV, mental visualization.