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A Review on the Impact of Virtual Reality and Visual Illusions in Managing Neuropathic Pain in Spinal Cord Injury

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Abstract: *Background: The worldwide association for the study of pain defines neuropathic pain as "pain caused by a lesion or disease of the somatosensory nervous system." Spinal cord injury patients may have 40-60% neuropathic pain, which is difficult to cure. First-line therapy is usually pharmacologic, however only 30-50% of patients benefit. There is little research on nonpharmacologic therapy. VR and VI training may help treat neuropathic pain.*
Methods: In April 2017, PubMed, CINHAL, Scopus, and Embase databases generated 38 publications using similar search keywords. Six articles remained after duplication, title, abstract, and inclusion/exclusion screens. This systematic evaluation examined the efficacy of VR and VI training in treating neuropathic pain in spinal cord injury patients. Results: Six papers were reviewed after the electronic search and screening. Five of six papers showed that VR and VI improved neuropathic pain intensity and quality. Conclusion: VR and VI in spinal cord injury therapy may significantly reduce neuropathic pain. Compared to pharmaceutical therapies, VI or VR was a suitable choice for neuropathic pain management.

Keywords: spinal cord injury, virtual reality, visual illusion.

I. INTRODUCTION

The International Association for the Study of Pain defines neuropathic pain as "pain caused by a lesion or disease of the somatosensory nervous system" at either peripheral or central nervous system level. The diagnosis of neuropathic pain is difficult because it may occur without a stimulation or with a typically harmless stimulus. Neuropathic pain may be characterised by lesion or disease process localisation, aetiology (peripheral or central), or anatomical structure. Diabetes, peripheral nerve damage, brachial plexus avulsion, and compressive neuropathies cause peripheral neuropathic pain [2]. Multiple sclerosis, stroke, spinal cord damage, syringomyelia, and Parkinson's Disease may cause central neuropathic pain. Despite expectations, some individuals with central nervous system damage may experience pain and other pleasant effects. These positive symptoms are either unpleasant, called dysesthesias, or not unpleasant, called paresthesias. These pleasant symptoms may cause stimulus-evoked or stimulus-independent pain. Exaggerated reaction to a painful stimuli is called hyperalgesia, whereas non-painful stimulation causes allodynia.[2] "Spontaneous pain" happens without a distinct cause. Paresthesias—tingling or itching—and dysesthesias—throbbing, shooting, stabbing, or burning—are stimulus-independent pain symptoms. Approximately 3.75 million instances of persistent neuropathic pain are estimated in the US [2].[2] Neuropathic pain affects 40-60% of incomplete spinal cord injury patients and is difficult to detect and treat due to its complexity.[3,4] Physical examination and history are used to diagnose nervous system lesions based on pain distribution and clinical features. Diagnostic tests and imaging may help diagnose neuropathic pain.[1,5] In a patient with suspected central neuropathic pain, a brain MRI may show the lesion, or a nerve conduction examination can show a sensory lesion in peripheral neuropathy. No gold standard test for neuropathic pain exists. Pharmacologic care is often the initial step in treating neuropathic pain, although effective drugs only produce 30-50% relief in a small minority of patients [5].Patients sometimes describe ongoing or worsened pain despite medication. Several FDA-approved neuropathic pain treatments include anti-epileptics and antidepressants.

No opioids are authorised for neuropathic pain.[2] Massage, ultrasound, neurostimulation, cognitive-behavioral therapy, and therapeutic exercise are untested for treating neuropathic pain. VR training integrates several sensory systems to deliver interactive biofeedback. Strength, flexibility, range of motion, core or balance training, yoga, Tai Chi, and pilates are typical physical therapy treatments for chronic pain.The evidence that exercise helps chronic pain is weak.[6] Some trials show reduced pain intensity and better physical function, however there are substantial discrepancies. R training on Wii Fit™ and Kinect for Xbox® has been examined in physical therapy to improve balance and gait in stroke, ankle sprain, and senior community residents [6].Studies have shown that VR training combined with conventional balance training improves balance in chronic stroke patients. VR training improved postural balance and lower limb strength in community-dwelling older persons. De Rooij et al.'s comprehensive review and meta-analysis of VR training's impact on stroke patients' balance and gait[10] found that VR training is more successful than conventional balance or gait training. The research analysed studies with wide inclusion criteria, variety, and different end measures, making it difficult to assess VR training's efficacy.

Disorganisation in the primary somatosensory brain underlies visual illusory (VI) training, which uses biofeedback and interactive training like VR.[11] Visual feedback in task-specific training and visual illusions from mirror therapy or guided imagery can reorganise the primary somatosensory cortex and activate movement-related cortical mechanisms without pain. VI training is commonly utilised with VR to increase brain plasticity. Cacchio et al.'s 2009 RCT[12] employed mirror treatment and visual feedback to reduce neuropathic pain in CRPS type 1 and stroke patients. The experimental group receiving active mirror treatment reported decreased pain and increased function after 4 weeks of training. Villiger et al.[4] and Moseley[13] used VI training with motor imagery and VR to lessen spinal cord injury pain.

Researchers and doctors seek new therapies for neuropathic pain, which is common in neurologic illnesses and difficult to control with drugs. VR and VI training may help treat neuropathic pain.[3] Correcting the uneven transmission between sensory feedback and motor output reduces pain by managing somatosensory system disturbances.[3,14] This systematic evaluation examined the efficacy of VR and VI training in treating neuropathic pain in spinal cord injury patients.

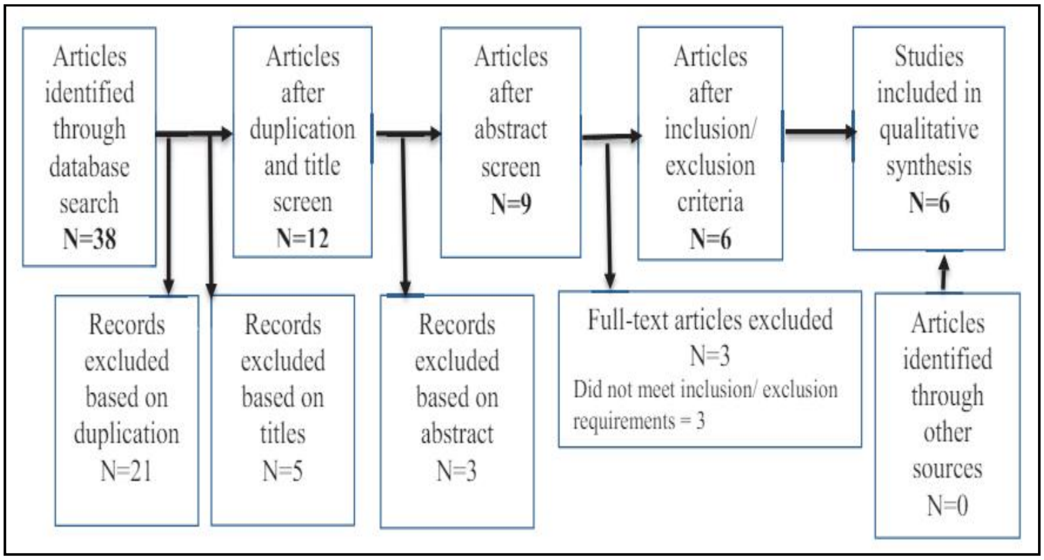
METHODS

We searched PubMed, CINAHL, Scopus, and Embase in November 2016 using the same search terms: “spinal cord injury” OR “sci” OR “paraplegia”, “virtual reality” OR “visual illusion” AND “neuropathic pain.” The search focused on English-language articles over the last decade. A recent April 2017 search using the same criteria revealed no results. Screening was performed on 38 items found in the search. A duplication screen deleted 21 articles, a title screen eliminated five, and an abstract screen eliminated three. Nine papers were screened for spinal cord damage, neuropathic pain, and virtual reality. After this last screening, six papers were left for the systematic review. Table 1 Search findings and Figure 1 PRISMA Flow Diagram summarise the search and screening findings.

Table 1: Search Results

SEARCH STRATEGY	PubMed	CINAHL	Scopus	Embase	Total
(spinal cord injury OR sci) or paraplegia	1165898	20241	145916	1682763	3014818
(virtual reality OR visual illusion)	16699	3656	99499	6811	126665
((spinal cord injury) OR sci)) OR paraplegia)) AND ((virtual reality or visual illusion))	760	45	199	413	1417
((spinal cord injury) OR sci)) OR paraplegia)) AND ((virtual reality or visual illusion)) and neuropathic pain	8	8	12	12	40
Filters: published in the last 10 years; English	8	8	12	10	38

Figure 1: PRISMA Flow Diagram



The Physiotherapy Evidence Database (PEDro) and 2011 Oxford Centre for Evidence-Based Medicine evaluated the six publications. A PEDro score of 1 indicates the least internal validity of physical therapy interventional trials, while 10 indicates the most validity.[15] The evaluated papers averaged 4.67 PEDro points from 2-10. Evidence was assessed using the 2011 Oxford Centre for Evidence-Based Medicine (CEBM) scale. Based on design, the CEBM is a five-point scale that rates research quality. A lower score indicates a better study.[16] Level 1 investigations are systematic reviews. Level 2 randomised control trials are the highest level of research in this review. This review includes two level 2 studies, two level 3 studies, and two level 4 studies.

RESULTS

Five of six papers showed VR and VI improved neuropathic pain intensity and quality. In 39 spinal cord injury patients, Soler et al.[17] showed lower pain levels in the experimental group than the placebo group in the highest-level research. This study examined the effects of VI with and without TrDCS on neuropathic pain. For more than six months, individuals must have had neuropathic pain at least four out of ten on a Numeric Rating Scale (NRS). Participants were randomly assigned to four groups. Virtual walking was added to TrDCS in the experimental group, whereas a video with different people and scenes was used in the TrDCS group. The VI group got sham TrDCS and VI, while the placebo group received sham TrDCS with VI. The NRS ranged from 0 to 10, with 10 being the worst. Soler et al.[17] observed that the experimental group had significantly less pain than VI alone ($p = 0.008$) and the placebo group ($p = 0.004$). The experimental group had significantly less pain than TrDCS ($p = 0.05$), VI ($p = 0.008$), and placebo ($p = 0.009$) at day 24. At day 38, there was no difference between the groups, but at 12 weeks post-treatment, the experimental group had sustained higher pain reduction than TrDCS and VI (Mann-Whitney U: p = 0.052 and 0.053) at levels approaching significance. This research shows that VI and auxiliary therapies may control neuropathic pain long-term.

Ozkul et al.[14] performed a crossover research with all subjects receiving TENS and VI in the second highest study in our review. Twenty-four inpatients with traumatic SCI and DN4 and VAS scores of four or above were randomly allocated to two groups. VAS and NPS measured pain intensity and quality. Each group had 10 five-day-a-week sessions for two weeks. TENS was administered to the spine for 30 minutes each day with four electrodes. The TENS application parameters were 80 Hz pulse frequency, 180 duration, and 0-100 mA/s intensity range. The VI intervention included 15 minutes of virtual walking each day with the client's upper body reflected on a lower body walking video. One group started TENS, the other VI. The groups swapped interventions after the first. Both groups got the same treatment in reverse order. Clinical differences across groups were not significant, showing that intervention sequence did not affect clinical outcomes. However, the TENS intervention significantly reduced pain within the group (VAS, p

< 0.05). The NPS showed a substantial reduction in pain characteristics after VI ($p < 0.05$). Jordan and Richardson[3] analysed early findings from a bigger project on virtual walking and neuropathic pain in spinal cord injury patients. Thirty-five traumatic spinal cord damage patients got virtual walking or wheeling (control group). A 20-minute first-person film of an actor strolling down a route was shown to the experimental group. Participants imagined performing the actor's motions. The condition was hidden from the examiner until testing was complete. Virtual walking reduced pain more than virtual wheeling ($p = 0.03$).

Villiger et al.[4] studied 14 chronic spinal cord injury patients who received extensive VR augmented training to enhance lower limb function and reduce neuropathic pain. Participants operated a VR system with a first-person view of two lower limbs using sensors. The research tasks engaged four muscle groups (tibialis anterior, quadriceps, hip abductors, and hip adductors) and included participants via task completion feedback. Four to six weeks before the intervention, at the start, at the end, and 12-16 weeks after the intervention, the NPS evaluated pain. The four-week intervention plan included therapeutically appropriate activities devised with physical therapists. The participant used ankle dorsiflexion to juggle a ball between the left and right feet in foot bag juggling, "hamster splash" to move the animal on screen, "star kick" to kick the knee, and "planet drive" to avoid obstacles on the screen. Sixteen to twenty 45-minute sessions were held. After the intervention procedure, researchers observed a substantial reduction in pain intensity at study completion ($p < 0.004$) and at 12-16 week follow-up ($p < 0.031$). Results showed a substantial reduction in pain "unpleasantness" at trial end ($p < 0.004$) and at 12-16 week follow-up ($p < 0.016$). This research supports VR for neuropathic pain therapy in active lower extremity movement patients.

Moseley [13] studied five paraplegics in two parts. Moseley examined virtual walking, guided visualisation, and video viewing in the first section. In the first stage of the trial, virtual walking included sitting in front of a screen and mirror. Participants saw a clip of an actor jogging on a treadmill and lined up their upper half in the mirror to match the film. The customer moved their upper body and extremities to the film, making it seem like they were walking. In the second guided imagery condition, a psychologist showed the subject a pain-free, pleasurable scenario. An animated comedy video was watched in the third condition to control for visual input. All participants' mean (95% CI) pain reduction (100 mm VAS) after virtual walking, guided imagery, and the humour movie was 42 mm, 18 mm, and 4 mm, respectively. Virtual walking took 34.9 minutes, guided imagery 13.9 minutes, and video 16.3 minutes to return to pre-task pain. This research found virtual walking reduced pain and returned it to pre-task levels faster than guided imagery or viewing a film.

Moseley investigated the virtual walking condition further to discover its clinical use. Four individuals from the original trial did virtual walking for 10 minutes each day for 15 days in three weeks. Moseley measured pain VAS (100 mm) and pain relief in minutes. Pain VAS (100 mm) was assessed before and after the virtual walking intervention, then every minute for 30 minutes and every 10 minutes until pain returned to pre-task level or three hours, whichever happened first. Participants reported a mean (95% CI) pain reduction of 53 mm post-training and 43 mm after three months. Compared to baseline evaluations, clients enjoyed longer pain alleviation and less discomfort.[13] These findings show that virtual walking reduced pain in subjects. Five papers found that VR or VI training reduces neuropathic pain in spinal cord damage patients.

DISCUSSION

This systematic evaluation examined the efficacy of VR and VI training in treating neuropathic pain in spinal cord injury patients. Five of six reviewed publications showed that VR and VI improved neuropathic pain intensity and quality. We found little quality literature on managing and treating neuropathic pain in this cohort, perhaps due to its significant variability. More high-quality randomised control studies are required to discover the best VR or VI training length, frequency, kind, and patient group for pain management and therapy.

Virtual walking in a spinal cord injury rehabilitation regimen may significantly reduce neuropathic pain quality and severity. Some research suggests virtual lower extremity workouts may alleviate neuropathic pain. The efficacy of VR and VI training alongside other therapeutic therapies like electrical stimulation is unknown. Several studies used adjunct therapy to reduce VR or VI training's benefits.[14,17] Programmes that had participants move or contemplate moving reduced pain more.[3, 4,14,17,18] In the publications analysed, VI or VR were suitable neuropathic pain therapy options. A rehabilitation strategy should include VR or VI training for individuals who are not getting pain relief from other therapies as technology advances. Because technology is becoming cheaper and research is available, these therapies may be readily included into a physical therapy regimen to treat neuropathic pain in spinal cord injury patients.

II. CONCLUSION

VR and VI in SCI therapy may significantly reduce neuropathic pain. VI or VR was a feasible option to pharmaceutical therapies for neuropathic pain management.

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