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ARTICLE

Effects of Virtual Reality-Based Digital Therapy on Negative Emotion, Pain Level and Quality of Life in Patients With Postherpetic Neuralgia

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Abstract

Aims/Background Patients with postherpetic neuralgia (PHN) often experience impairments of emotion, sleep and quality of life. This study aims to explore the usage of digital therapy enhanced with virtual reality technology in the improvement of mood, pain level, and quality of life in patients experiencing moderate to severe pain.

Methods In this prospective, single-centre clinical study, 100 herpes zoster patients experiencing moderate to severe neuropathic pain from November 2024 to January 2025 were enrolled. In addition to the application of 5% lidocaine topical patch combined with Pre-Bahrain system medication, the patients received a 14-day virtual reality (VR) treatment, encompassing evaluations at several time points: the first day (T0), the third day (T1), the seventh day (T2), and the 14th day (T3).

Results The results of emotion and pain in all PHN patients evaluated at four time points showed that the self-reported scores of generalised anxiety disorder 7 (GAD-7), numerical rating scale (NRS), and visual analogue scale (VAS) were improved during the 14-day treatment period ($p < 0.05$). Outcomes in sleep, stress and mood disturbance scale, based on the Patient-Reported Outcomes Measurement Information System (PROMIS-A) and PROMIS-B, showed that the patients' sleep status, stress levels and emotional problems achieved improvements. The PROMIS-A and PROMIS-B of VR treatment at T1, T2 and T3 were significantly higher compared with that at T0 ($p < 0.05$). PHN patients achieved significantly higher levels of self-efficacy at T1, T2 and T3 during VR treatment compared with results recorded at T0 ($p < 0.05$). Meanwhile, the Patient Health Questionnaire-9 (PHQ-9) results showed that the quality of life and health of PHN patients were significantly improved following the 14-day treatment ($p < 0.05$). Over time, PHN patients have grown satisfied with VR therapy.

Conclusion Digital therapy based on virtual reality technology has a profoundly beneficial impact on the management of pain, the alleviation of psychiatric symptoms, and the improvement of the quality of life of PHN patients.

Clinical Trial Registration Chinese Clinical Trial Registry (ChiCTR2400092850).

Key words: virtual reality; postherpetic neuralgia; emotions; sleep; quality of life

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Introduction

Herpes zoster is a disease caused by varicella-zoster virus, often marked by a band-like rash on the chest, back, neck, head, face, waist, lower limbs, etc. (Le

and Rothberg, 2019; Patil et al, 2022). The incidence of herpes zoster is particularly high among middle-aged and elderly people, people with weak constitutions, young people under chronic stress, and those who stay up late at night (Koshy et al, 2018). Postherpetic neuralgia (PHN) is defined as pain that lasts 1 month or more following recovery from herpes zoster and is the most common complication of shingles (Gruver and Guthmiller, 2023; Lv et al, 2024). PHN can last for months or even years, with about 30% to 50% of patients with PHN suffering for more than 1 year and some even up to 10 years (Blumstein et al, 2023; Gross et al, 2020).

The origin of PHN lies in immune deficiency, which leads to inflammation and necrosis of ganglia, resulting in neuropathic pain (JÁNOS et al, 2013). The nature of the pain can be diverse, manifesting as burning, electric shock-like, knife cutting-like, or tearing sensations, and people affected by PHN can fall victim to either one type of pain or a combination of multiple types (Qiu et al, 2021). PHN patients often experience impairments of emotions, sleep, and quality of life. Studies have reported that 45% of patients suffer from moderate to severe emotional disturbances, which present as anxiety, depression, inattention, and other symptoms (Fujiwara et al, 2023; Sharma et al, 2024). The severity of pain in patients correlates with the extent to which their vitality, sleep, and overall quality of life are affected. Early and effective pain control, along with alleviation of accompanying sleep and emotional disorders, can improve patients' quality of life. In clinical practice, pharmacological therapy is most commonly used due to its rapid onset of action; however, it carries risks of side effects such as nausea, drowsiness, and drug dependence (Niemeyer et al, 2024). Long-term use may also induce drug resistance, resulting in decreased efficacy. Interventional treatments involve the precise injection of a small amount of medication around the painful nerve, achieving anti-inflammatory, analgesic, and neuroregenerative effects (Lin et al, 2019). Neuroblockade demonstrates significant efficacy in controlling breakthrough pain in PHN, particularly suitable for early treatment. Nevertheless, the effects of neuroblockade are not permanent and require regular treatments to maintain efficacy.

Virtual reality (VR) is a high-tech simulation system generated by computer simulation with immersion, interactivity, conception, and multi-perception as the basic characteristics (Izard et al, 2018). Digital therapeutics is a software program-based therapy that provides patients with evidence-based therapeutic interventions to prevent, manage, or treat disease (Koebe and Bohnet-Joschko, 2023). Compared with traditional services, digital therapeutics have the advantages of reproducibility, lower cost and easier access. Currently, VR-based digital therapeutics are widely used in the field of psychiatry, aiding in the improvement of cognitive and routine functions by creating virtual environments to stimulate the patient's brain and provide short-term feedback based on individual performance (Carl et al, 2019). In the absence of long-term intervention, patients will fall victim to anxiety disorders, depression, bipolar disorder and other mental disorders due to different personalities, intensity and frequency of stimulation. Thus, it is critical to find a solution that improves patient experience and outcomes, physician productivity, and hospital revenue. Taking into account the background information, we conducted a preliminary study evaluation and analysis of the application of VR-based digital

therapy in herpes zoster patients experiencing moderate to severe neuropathic pain, with the aim of evaluating the efficacy and safety of the approach in relieving pain among patients.

Methods

Study Subjects

In this prospective, single-arm, open-label, single-centre clinical study, patients received VR-based treatment in addition to the standard clinical treatments and other treatment regimens prescribed by the physicians without interference from the investigators. Herpes zoster patients experiencing moderate to severe neuropathic pain were enrolled from November 2024 to January 2025 using the stratified randomisation method. The sample size was determined using the formula in the following:

$$n = (Z\alpha/2 + Z\beta)^2 \times 2 \times \sigma^2/d^2$$

where $\alpha = 0.05$, $\beta = 0.10$, $d = 2.2$, and $\sigma = 4.58$. A sample size of 91 was calculated (Cameron and Esserman, 2018; Zhang et al, 2024). Considering a 9–10% loss rate, this study planned to recruit 99–101 patients. A total of 100 patients with moderate to severe pain and postherpetic neuralgia were finally recruited to this study. All data from this clinical study were obtained from Wannan Rehabilitation Hospital (the Wuhu Fifth People's Hospital). The study was approved by the Ethics Committee of Wannan Rehabilitation Hospital (the Wuhu Fifth People's Hospital) (No.WWWY-IRB-2024 (KY)-001-01) and conducted in accordance with the Declaration of Helsinki. All procedures, which had been reviewed by the Chinese Clinical Trial Registry (ChiCTR2400092850, https://www.chictr.org.cn/showproj.html?proj=241891), were performed in accordance with institutional guidelines. Informed consent of patients was obtained on the day of enrollment.

Inclusion criteria of this study are as follows: (1) age $\geq$18 years; (2) fulfilling PHN diagnostic criteria (i.e., a history of herpes zoster, and appearance of neuralgia symptoms after recovery from herpes zoster rash); (3) chronic pain lasting more than 12 months; (4) clinical diagnosis of chronic moderate to severe pain due to PHN, with an average pain intensity over the past month $\geq$7 points, evaluated using visual analogue scale (VAS); (5) normal cognitive function; and (6) voluntary compliance with the test procedures and regulations.

Patients fulfilling the following criteria were excluded: (1) trigeminal neuralgia, herpes zoster in the eyes, ears, head and face, neck, or hands; (2) severe vision loss and hearing impairment; (3) diseases or medical conditions that are prone to nausea or dizziness, such as cerebral insufficiency, vestibular dysfunction, cholecystitis, etc.; (4) epilepsy, dementia, migraine, or other neurological disorders that may prevent the use of VR for convenience; and (5) a history of mental illness, including depression, generalised anxiety disorder, and schizophrenia.

Treatment Options

Combination Therapy

For patients receiving combination therapy, lidocaine (H20180007, Beijing Tide Pharmaceutical Co., Ltd., Beijing, China) combined with Bahrain (H20203040, Chongqing Saiwei Pharmaceutical Co., Ltd., Chongqing, China) was used (Fornasari et al, 2022; Mercan et al, 2021). For every patient, up to three 5% lidocaine topical patch was applied to PHN-free skin, covering the most painful areas, for no longer than 12 hours. Pre-Bahrain was given at a dose of 75 or 150 mg twice a day, depending on the severity of the patient's pain; alternatively, a dose of 50 mg or 100 mg was given three times a day.

Virtual Reality Treatment

On the basis of combination therapy, the subjects received four sessions of VR treatments (VR analgesic digital therapy-multicentre immersive cognitive behavioural therapy), each with a duration of 30 minutes. The treatment efficacy was evaluated on the first day (T0), third day (T1), seventh day (T2), and 14th day (T3) following the VR treatment.

The VR treatment venue was furbished according to the following requirements: (1) The VR treatment room has an area of $\geq$50 m^2, with the walls painted in dark grey, dark brown and colours of dark tones. The room is illuminated with soft and comfortable light, with the dimmed light preferably set at 500–1000 lux. (2) Projection equipment used includes a digital light processing (DLP) 2.0 projector (E500JD, BenQ, Taipei, China), two to four HoloLens (Microsoft HoloLens 2, Microsoft, Seattle, WA, USA), and four sets of VR equipment (HTC Vive, HTC Corporation, Hsinchu, China). (3) Electroencephalography (EEG) system encompasses server-side personal computer (PC) multi-core processor (Intel i7, Microsoft, Seattle, WA, USA), tablet computer (Huawei Matebook D16, Huawei Technologies Co., Ltd., Shenzhen, China), audio (JBL Studio 5, JBL Company, Woodbury, NY, USA). (4) A motion capture system, including a whole-body motion capture kit with sensors, was utilised.

The VR treatment consists of two modules—namely, the pain and psychological assessment module, and the personalised training module, which lasts for a total of 30 minutes. (1) In the pain and psychological assessment module, an assessment system based on digital scales was used to assess the pain, depression and anxiety of patients for 10 minutes. (2) The personalised training module, lasting 20 minutes, encompasses a series of training programs tailored according to the patient's age, pain level, occupations, and hobbies, including breathing training using yoga and breathing ball (2 courses); meditation (2 courses); body scanning and self-perception; concentration training involving opposing formations, apple picking, and colouring (3 courses); relaxation training in water and different seasons (10 courses); and cognitive training by means of Schulte cubes and graph computing (3 courses). The training programs lie heavily in utilising immersive healing space and focusing on the real somatosensory interactive training, and during the monitoring process, multiple rounds of health data are collected. According to the

evaluation feedback results, personalised matching is carried out according to the characteristics of the equipment and environment.

Treatment Contraindications

When applying the 5% lidocaine topical patch, it is necessary to pay attention to the physical condition of the elderly patients and the skin condition of the application site, and it is recommended to reduce the area of use for weak patients or patients with liver and kidney insufficiency. Patients who follow the physician's instructions to take Pre-Bahrain may be susceptible to peripheral edema, whereas congestive heart failure patients with cardiac function grade III or IV should use the patch with caution. At least one attending physician should be present to manage adverse events during the VR treatment. Adverse events occurring throughout the trial should be recorded, typically by a research assistant, who will also remind patients of possible discomfort due to the virtual environment and the utilisation of VR headsets and glasses, including headache, dizziness, or nausea. In most cases, the above symptoms are temporary and will disappear upon the VR headset removal.

Data Collection

Prior to VR treatment administration, baseline data, medical history and other information of the patients were collected. After the completion of the first VR treatment, results from the first day of VR treatment were taken as the standard, and the evaluation of the treatment was performed at T0, T1, T2 and T3. Strict training should be given to the participants to ensure that they understand and master the evaluation criteria and measurement methods, so as to improve the accuracy of the evaluation methods and ensure the consistency of the evaluation results from different sessions.

Sentiment Evaluation

Sentiment was evaluated using generalised anxiety disorder 7 (GAD-7) (Hughes et al, 2021). Using this method, the patients are required to recall the situation of the past two weeks and fill out the questionnaire accordingly. The GAD-7 form has a total of 7 items, with each scoring 0–3 points. A higher total score indicates a higher level of anxiety faced by the patient.

Pain Assessment

Pain level was assessed using a numerical rating scale (NRS) (Wikström et al, 2019). The NRS is a single-dimensional numerical analog scoring method, with a total score of 101 points ranging from 0 to 100, where 0 denotes a painless feeling while 100 represents the highest level of pain. The scale is suitable for use in highly educated patients.

Visual analogue scale (VAS) is widely used in clinical pain assessment owing to the ease of deployment and clear usage guidelines (He et al, 2022). It can sensitively reflect the changing course of a patient's pain and is becoming a recognised scale for the subjective evaluation of pain levels. The lowest score is 0, which indicates no pain, whereas the highest score is 10, which indicates severe pain. Patients can

note the level of pain they are experiencing on a line marked with 0 to 10 points. A higher score indicates more severe pain.

Sleep, Stress and Mood Disturbance Assessment

Patient-Reported Outcomes Measurement Information System (PROMIS-A) (Reeve et al, 2007) has a total of 8 items and uses a 5-level scoring scale, ranging from 0 to 4 points for each item. A higher score suggests a higher severity of the patient's condition. In this method, patients are required to self-report their sleep quality from the preceding 24 hours to assess and monitor their physical, psychological, and social health status. PROMIS-B (Reeve et al, 2007) has a total of 6 items and uses a 5-level scoring scale, ranging from 1 to 5 points. A lower score from PROMIS-B indicates a higher severity of the patient's condition. The physiological function and self-care ability of the patients were evaluated.

Evaluation of Self-Efficacy

Self-efficacy was evaluated using the pain self-efficacy questionnaire (PSEQ) (Nicholas, 2007). This method is used to rate how confident the patients feel in doing certain common daily chores despite the pain. The questionnaire has a total of 10 items, with each scoring from 1 to 6 points, where 1 point indicates 'not confident at all' whereas 6 points denotes 'fully confident'. A higher score indicates a better patient's condition.

Patient Health Questionnaire-9 (PHQ-9) was also employed to evaluate self-efficacy of the patients (Costantini et al, 2021) by querying the frequency of symptoms in the past two weeks leading up to the survey. The questionnaire has a total of 9 items, with each scoring 0 to 3 points, where 0 denotes none and 3 indicates almost every day. The severity of the patient's condition increases with the score.

Evaluation of Treatment Satisfaction

After the end of treatment, the patients subjectively evaluated the VR treatment in four dimensions, namely usability of the equipment, satisfaction from using the equipment, degree of pain relief, and worthiness of recommending the treatment to others, with each item scoring from 0 to 10, where 0 indicates the lowest while 10 the highest.

Statistical Methods

The data were analysed using Statistical Package for the Social Sciences (SPSS) statistical software version 25.0 (IBM Corp., Armonk, NY, USA). The D'agostino-Pearson normality test was used to determine whether the data were normally distributed. Categorical data are expressed as counts and percentages. Such data were analysed using the Chi-square test. Normally distributed data are denoted by mean $\pm$ standard deviation (SD). The Bartlett test is used for homogeneity of variance, with test level set at $\alpha = 0.05$. If the $p > \alpha$, the rank-sum test would be used, but if the $p < \alpha$, the t-test would be utilised instead. The comparison of any two groups of data was carried out using the Student-Newman-Keuls q (SNK-q) method. Repeated measures analysis of variance (ANOVA) was used for the same set of data

Table 1. Baseline data of the patients with PHN.

	Male (n = 47)	Female (n = 53)	χ^2/t	p
Age (years)	59.24 ± 3.22	59.45 ± 3.13	0.334	0.741
BMI (kg/m^2)	20.60 ± 1.59	20.28 ± 1.60	1.001	0.320
Educational attainment			0.577	0.749
Elementary school	17 (36.17)	20 (37.73)		
Secondary school	20 (42.55)	19 (35.85)		
University and above	10 (21.28)	14 (26.42)		
Pain cycles			0.078	0.961
1–5 days	14 (29.79)	17 (32.08)		
6–10 days	27 (57.45)	29 (54.72)		
11–15 days	6 (12.76)	7 (13.20)		
History of surgery			0.062	0.803
Yes	21 (44.68)	25 (47.17)		
No	26 (55.32)	28 (52.83)		
Pain level			0.133	0.714
Moderate	24 (51.06)	29 (54.72)		
Severe	23 (48.94)	24 (45.28)		

Abbreviations: BMI, Body mass index; PHN, postherpetic neuralgia.

at time points T0, T1, T2 and T3. The $p < 0.05$ was considered statistically significant.

Results

Baseline Data

In order to rule out the influence of gender factors on the treatment effect, the baseline data of PHN patients enrolled in this study were compared separately according to their gender before enrollment. There was no statistical significance ($p > 0.05$), as presented in Table 1.

Evaluation of Emotion and Pain in Patients With PHN

PHN patients enrolled in this study were evaluated on the first day after completing the first VR treatment, and were evaluated at time points T0, T1, T2 and T3. The results of mood and pain evaluation showed that the GAD-7, NRS, and VAS scores were improved during the 14-day treatment period. Compared with the first day of receiving VR treatment (T0), the intra-group comparison and repeated measures ANOVA (main effect: time) revealed statistically significant differences at time points T1, T2 and T3 ($p < 0.05$), as presented in Table 2.

Evaluation of Sleep, Stress and Mood Disturbance in PHN Patients

Table 3 shows the results of PROMIS-A and PROMIS-B, which indicate that sleep, stress and mood disturbance were improved during the 14-day treatment period. Compared with the first day of receiving VR treatment (T0), the intra-group comparison and repeated measures ANOVA (main effect: time) revealed statisti-

Table 2. Comparison of emotion and pain evaluation in PHN patients at different treatment time points.

Evaluation scale	Treatment time point	VR treatment (n = 100)	SNK-q	p	Time effect	
					F	p
GAD-7	T0	20.17 ± 2.79	3.046[a]	0.002	255.430	<0.001
	T1	19.00 ± 2.64	15.480[b]	<0.001		
	T2	15.02 ± 1.81	11.392[c]	<0.001		
	T3	12.12 ± 1.79	24.284[d]	<0.001		
NRS	T0	72.40 ± 7.74	3.904[a]	<0.001	180.448	<0.001
	T1	68.40 ± 6.71	8.371[b]	<0.001		
	T2	63.77 ± 6.81	14.739[c]	<0.001		
	T3	51.23 ± 5.10	22.839[d]	<0.001		
VAS	T0	8.60 ± 0.49	9.304[a]	<0.001	779.515	<0.001
	T1	7.85 ± 0.64	17.526[b]	<0.001		
	T2	6.85 ± 0.87	23.070[c]	<0.001		
	T3	4.20 ± 0.75	49.113[d]	<0.001		

Notes: [a] Comparison of T0 with T1; [b] Comparison of T1 with T2; [c] Comparison of T2 with T3; [d] Comparison of T0 with T3.
Abbreviations: GAD-7, generalised anxiety disorder 7; PHN, postherpetic neuralgia; NRS, numerical rating scale; VAS, visual analogue scale; SNK-q, Student-Newman-Keuls q.

cally significant differences at time points T1, T2 and T3 ($p < 0.05$), as presented in Table 3.

Evaluation of Self-Efficacy in PHN Patients

Table 4 presents the self-reported PSEQ results of patients regarding pain tolerance, which showed that the self-efficacy of the patients at time points T1, T2 and T3 was significantly enhanced compared with T0 ($p < 0.05$). Meanwhile, the PHQ-9 results regarding the 14-day treatment showed significant improvements in the quality of life and health status of PHN patients ($p < 0.05$). Compared with the first day of receiving VR treatment (T0), the intra-group comparison and repeated measures ANOVA results (main effect: time) presented statistically significant differences at time points T1, T2 and T3 ($p < 0.05$).

Treatment Satisfaction of PHN Patients

Fig. 1 shows that during the course of VR treatment, the PHN patients have grown more satisfied with four aspects of the treatment, namely usability of the equipment, satisfaction from using the equipment, degree of pain relief, and worthiness of recommending the treatment to others.

Discussion

Treating PHN poses a multifaceted challenge as drugs, interventions, and psychotherapy are needed (Tang et al, 2023). PHN patients experience an extreme level

Table 3. Comparison of sleep, stress and mood disturbance in PHN patients at different treatment time points.

Evaluation scale	Duration of treatment	VR treatment (n = 100)	SNK-q	p	Time effect	
					F	p
PROMIS-A	T0	30.17 ± 5.12	2.848[a]	0.004	81.322	<0.001
	T1	28.00 ± 5.64	7.174[b]	<0.001		
	T2	25.13 ± 4.81	8.132[c]	<0.001		
	T3	20.15 ± 3.79	15.729[d]	<0.001		
PROMIS-B	T0	6.40 ± 1.74	8.221[a]	<0.001	868.965	<0.001
	T1	8.40 ± 1.70	21.338[b]	<0.001		
	T2	11.77 ± 1.81	25.778[c]	<0.001		
	T3	17.23 ± 1.10	52.610[d]	<0.001		

Notes: [a] Comparison of T0 with T1; [b] Comparison of T1 with T2; [c] Comparison of T2 with T3; [d] Comparison of T0 with T3.
Abbreviations: PHN, postherpetic neuralgia; PROMIS, Patient-Reported Outcomes Measurement Information System.

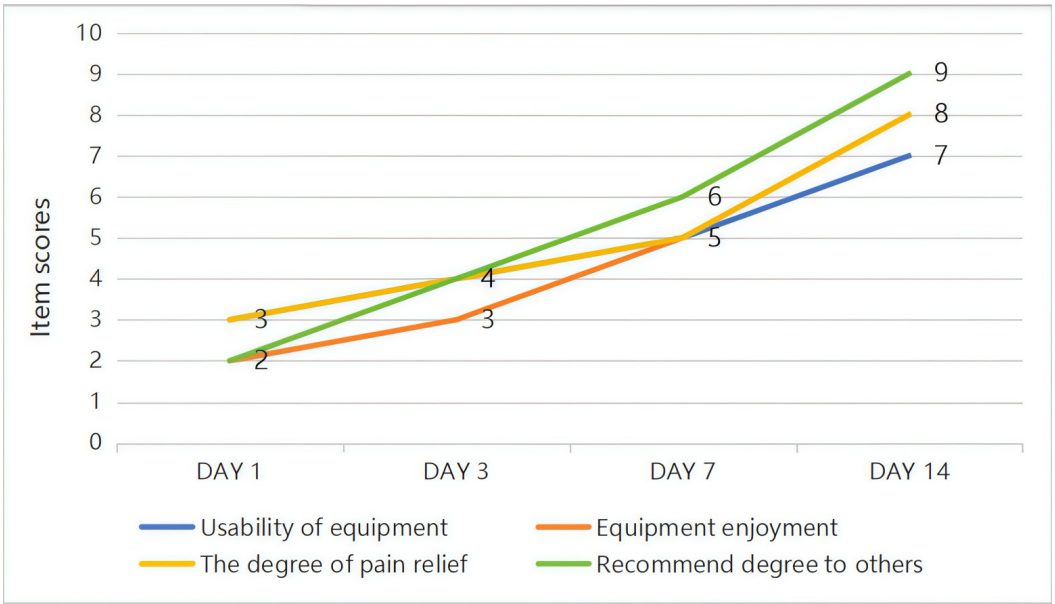

Fig. 1. Treatment satisfaction of PHN patients.

of pain, manifested as burning, electric shock, knife cutting, pinprick or tearing, which unfortunately is often accompanied by emotional, sleep and quality of life impairments. Herpes zoster virus is often latent in the ganglia and develops when the immune resistance is weakened; however, many methods and medications can effectively relieve or even treat severe pain in patients with PHN (Kennedy and Gershon, 2018).

Drug therapy forms the foundation of pain relief. The combination of VR-based digital therapy and drugs for the treatment of PHN can effectively relieve pain, reduce the dosage of analgesics, minimize adverse reactions, and improve

Table 4. Comparison of self-efficacy in PHN patients at different treatment time points.

Evaluation scales	Duration of treatment	VR treatment (n = 100)	SNK-q	p	Time effect	
					F	p
PSEQ	T0	20.23 ± 2.18	12.586[a]	<0.001	1245.283	<0.001
	T1	25.00 ± 3.10	14.388[b]	<0.001		
	T2	31.02 ± 2.81	28.483[c]	<0.001		
	T3	42.12 ± 2.70	63.079[d]	<0.001		
PHQ-9	T0	25.40 ± 1.59	4.282[a]	<0.001	1376.072	<0.001
	T1	24.40 ± 1.71	22.682[b]	<0.001		
	T2	20.77 ± 1.28	38.750[c]	<0.001		
	T3	14.23 ± 1.10	57.773[d]	<0.001		

Notes: [a] Comparison of T0 with T1; [b] Comparison of T1 with T2; [c] Comparison of T2 with T3; [d] Comparison of T0 with T3.
Abbreviations: PHQ-9, Patient Health Questionnaire-9; PHN, postherpetic neuralgia; PSEQ, pain self-efficacy questionnaire.

the quality of life of patients. Pain not only affects the physical and mental health of individuals, but also imposes a huge burden on society. There are numerous types of traditional pain treatment approaches, but each has its own set of limitations (Warner et al, 2025). At present, the field of digital therapeutics sees a steady growth in terms of acceptance and application, and the usage of VR technology has broadened into the domain of pain treatment. Virtual reality technology uses assistive tools such as headsets to build a three-dimensional virtual world with multi-sensory participation, such as sight, hearing, and smell, so that users can have an immersive feeling. The potential mechanisms underlying VR-assisted pain relief involve multiple aspects, including distraction, psychological correction, and neuroplasticity (Karaman et al, 2019). In terms of distraction, VR technology provides highly realistic virtual environments, keeping patients immersed in interactive scenarios that effectively divert their attention from pain. Through psychological correction, VR technology also offers a positive and supportive psychological environment for patients. In the virtual setting, patients can learn strategies to cope with and regulate emotions by simulating various scenarios and situations, thereby improving their mental state and reducing negative emotions and anxiety associated with pain. Through repeated VR training, neural connections can be strengthened, enhancing the brain's efficiency in processing information, thus improving cognitive function and potentially affecting the perception and processing of pain in an indirect manner. Studies have shown that VR technology, as an emerging auxiliary or alternative method for pain relief, has broad applicability, not only for managing PHN but also for various types of acute and chronic pain (Knobel et al, 2024; Vincent et al, 2021).

In this study, PHN patients were evaluated on day 1 after completing the first VR treatment, and were evaluated on the first, third, seventh, and 14th days. The emotion and pain evaluation showed that the GAD-7, NRS, and VAS scores of the

patients improved during the 14-day treatment period. Compared with the first day of VR treatment, the third, seventh and 14th days of VR treatment achieved significantly more benefits ($p < 0.05$). VR therapy may interfere with key parts of the body's built-in pain relief system, including the brain, brainstem, and spinal cord, aiding in curtailing the extent of pain perception. Hoffman et al (2020) reported that VR technology can help reduce patients' sensitivity to pain by putting them in a virtual world, which is built and enabled through a combination of devices, including head-mounted displays, headsets, or joysticks, all of which can track head movements through detection of multimodal stimuli (sight, sound, touch, and smell).

The PROMIS-A and PROMIS-B results for the sleep, stress and mood disturbance evaluation showed that during the 14-day treatment, the patients exhibited improvements in sleep, stress and emotional problems, and the third, seventh and 14th days of VR treatment were statistically significant. Relaxation, hypnotic suggestion, and cognitive therapy, which are commonly used to treat insomnia, can be built into methods that can be implemented in a virtual situation using VR technology. In the virtual scene, the autonomic nervous system can be adjusted through audio-visual stimulation to induce positive emotions and relaxation experiences, reduce the level of somatic and cognitive arousal that interferes with sleep, and generate subtle hints through the guidance of relaxation and hypnosis, so as to change the negative cognition and emotions that affect sleep, and finally achieve the effect of treating insomnia (Carr et al, 2020).

Self-efficacy was assessed in patients with PHN. The PSEQ results showed that the self-efficacy of the patients on the third, seventh and 14th days of VR treatment was statistically enhanced compared with the first day of VR treatment. At the same time, the PHQ-9 results showed that the quality of life and health status of PHN patients were significantly improved following the 14-day treatment. Studies by psychologists in several countries have shown that VR technology alleviates psychological anxiety in patients through the voice information transmitted to them by VR equipment and the immersive environment created by the equipment (Failla et al, 2022; Maples-Keller et al, 2017); such treatment effect align well with our results in this study.

It is important to note that the patients who participated in this trial did not have a very high level of education, but after 14 days of VR treatment, it affected their emotional state, attention, cognition, and brain activity by stimulating the patient's desire and physiological response. This technology brings a high level of flexibility and convenience to treatment scenarios, and acceptance of VR therapy by patients has grown over time, so has their satisfaction towards the treatment.

The VR can simulate reality, which is not limited by space and time, and can aid in clinical testing and evaluation. This technology also allows real-time treatment, which is time-sensitive. Nevertheless, certain limitations of this study should be acknowledged. The VR treatment effect on the patients was monitored within a limited span of 14 days. While this timeframe can capture some immediate or short-term therapeutic responses, it is clearly insufficient for a comprehensive evaluation of the long-term effects of VR therapy. To gain a deeper understanding of the durability and potential impact of VR therapy, we strongly recommend that fu-

ture studies extend the observation period. By increasing the observation time, we can more accurately assess the sustained effects of VR therapy after treatment and whether patients can maintain the improvements gained over the long term. Furthermore, the lack of a control group may lead to a biased evaluation of the VR intervention's effectiveness, and excluding potential confounding factors (such as the participants' natural recovery process) from the analysis could influence the results, thus underestimating the true impact of the VR intervention. To overcome the limitations of single-arm studies and more accurately assess the efficacy and safety of VR intervention in PHN patients, we recommend adopting a randomised controlled trial design in future research.

Conclusion

Digital therapeutics based on VR technology offer an effective solution to manage pain, alleviate psychiatric symptoms, and improve the quality of life of PHN patients. However, to manage refractory PHN and severe pain, joint efforts of the patients, their families, and medical workers are necessary to achieve more optimal treatment.

Key Points

- Patients with postherpetic neuralgia (PHN) often suffer from impairments of emotion, sleep and quality of life, as well as anxiety disorder, depression, bipolar disorder and other mental disorders.
- Virtual reality (VR)-based digital therapy could relieve pain for PHN patients experiencing moderate and severe pain.
- PHN patients expressed high satisfaction towards the application of VR-based digital therapy.
- Digital therapeutics based on VR technology offer an effective solution to manage pain, alleviate psychiatric symptoms, and improve the quality of life of PHN patients.

Availability of Data and Materials

The datasets used and/or analysed during the current study are available from the corresponding author upon reasonable request.

Author Contributions

LZ, HW and BN designed the study. LZ, HW, BN, JH, MX, QC, YH, SX and ZD conducted the study. YH, SX and ZD collected and analysed the data. JH, MX and QC participated in drafting the manuscript. All authors contributed to the important editorial changes in the manuscript. All authors read and approved the final manuscript. All authors have participated sufficiently in the work and agreed to be accountable for all aspects of the work.

Ethics Approval and Consent to Participate

This study was approved by the Ethics Committee of Wannan Rehabilitation Hospital (the Wuhu Fifth People's Hospital) (No.WWWY-IRB-2024 (KY)-001-01) and was performed in accordance with the principles of the Declaration of Helsinki. Informed consent has been obtained from all participants involved in the study.

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Conflict of Interest

The authors declare no conflict of interest.

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