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Effectiveness of a Combined Virtual Reality–Based and Mindfulness Intervention on Pain Acceptance in Individuals with Spinal Cord Injury

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ABSTRACT

The present study aimed to examine the effectiveness of a combined virtual reality–based and mindfulness intervention on pain acceptance in individuals with spinal cord injury. This was a quasi-experimental study with a pretest–posttest control group design and a two-month follow-up. The statistical population included all individuals with spinal cord injury (quadriplegia) who referred to the welfare centers of Fars Province and the Raad Institute in Shiraz in 2024. The sample consisted of 30 individuals with spinal cord injury selected through purposive sampling and randomly assigned to an experimental group (n = 15) and a control group (n = 15). The experimental group received the combined virtual reality and mindfulness intervention in 8 sessions. Both groups completed the Chronic Pain Acceptance Questionnaire (CPAQ) at three time points: pretest, posttest, and two-month follow-up. Data were analyzed using SPSS version 23 with mixed analysis of variance, as well as independent-samples and paired-samples t tests. The findings indicated that the mean pain acceptance scores in the combined intervention group improved more from pretest to posttest and follow-up compared with the control group, supporting the effectiveness of the combined virtual reality–based and mindfulness intervention on pain acceptance in individuals with spinal cord injury. Given the demonstrated effectiveness of the combined virtual reality–based and mindfulness intervention on pain acceptance in individuals with spinal cord injury, clinicians may use this integrated virtual reality and mindfulness package in the treatment of patients with spinal cord injury.

Keywords: virtual reality; mindfulness; pain acceptance; spinal cord injury.

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Introduction

Spinal cord injury (SCI) is widely recognized as one of the most severe and life-altering neurological conditions, characterized by partial or complete disruption of motor, sensory, and autonomic functions below the level of injury (1). The etiology of SCI encompasses both traumatic causes, such as motor vehicle accidents, falls, and sports-related injuries, and non-traumatic causes, including tumors, infections, and degenerative spinal disorders (1). Beyond its immediate physiological consequences, SCI represents a complex biopsychosocial phenomenon that profoundly alters individuals' physical capabilities, social roles, occupational engagement, and psychological well-being. Global epidemiological evidence highlights the substantial burden of SCI, not only in terms of disability-adjusted life years but also in the long-term

economic and social costs associated with rehabilitation, assistive technologies, and lifelong care (2). Consequently, SCI is increasingly conceptualized as a chronic condition requiring multidisciplinary management approaches that extend beyond biomedical treatment.

Among the most debilitating and persistent complications following SCI is chronic pain, which affects a substantial proportion of individuals and significantly undermines quality of life (3). Pain in SCI is multifaceted, commonly categorized into neuropathic pain—arising from damage to the nervous system—and nociceptive or musculoskeletal pain resulting from biomechanical strain, overuse, or secondary complications (4). Epidemiological studies and meta-analyses indicate that chronic pain prevalence among individuals with SCI is remarkably high, often exceeding that observed in other chronic conditions, and is frequently described as severe, persistent, and resistant to conventional pharmacological treatments (3). Furthermore, standardized data sets developed for SCI pain assessment emphasize that pain is not merely a sensory experience but also a multidimensional construct involving emotional, cognitive, and functional domains (5, 6). Pain interferes with sleep, reduces participation in rehabilitation programs, exacerbates psychological distress, and contributes to social isolation, thereby reinforcing a cycle of disability and diminished well-being.

Traditional biomedical approaches to pain management in SCI, including pharmacotherapy and surgical interventions, often yield limited effectiveness, particularly in neuropathic pain conditions (4). This limitation has led to increased recognition of the importance of psychological and behavioral factors in the maintenance and modulation of chronic pain. Contemporary theoretical frameworks, particularly the biopsychosocial model, posit that pain perception is shaped not only by physiological processes but also by cognitive appraisals, emotional regulation, attention, and coping strategies (7). In individuals with SCI, these factors are often compounded by additional stressors such as functional dependence, uncertainty about the future, and changes in identity and self-concept. Consequently, interventions targeting psychological processes have gained prominence as essential components of comprehensive pain management.

Within this paradigm, pain acceptance has emerged as a central construct in understanding adaptation to chronic pain. Rooted in acceptance-based models such as Acceptance and Commitment Therapy (ACT), pain acceptance involves a willingness to experience pain without excessive attempts to control or avoid it, coupled with continued engagement in meaningful life activities (8). Rather than focusing on eliminating pain, acceptance-based approaches emphasize altering the individual's relationship with pain, reducing experiential avoidance, and fostering psychological flexibility. Empirical research has consistently demonstrated that higher levels of pain acceptance are associated with improved physical functioning, reduced emotional distress, and enhanced quality of life across chronic pain populations, including those with SCI (9). Importantly, pain acceptance is not a static trait but a dynamic process that can fluctuate over time and be influenced through targeted interventions.

One of the most effective strategies for enhancing pain acceptance is mindfulness-based intervention. Mindfulness refers to the intentional, nonjudgmental awareness of present-moment experiences, including bodily sensations, thoughts, and emotions. In the context of chronic pain, mindfulness facilitates disengagement from maladaptive cognitive patterns such as catastrophizing and rumination, while promoting a more adaptive and accepting stance toward pain experiences. Evidence from clinical and observational studies suggests that mindfulness-based interventions can reduce psychological distress,

improve emotional regulation, and enhance well-being in individuals with SCI (10, 11). Moreover, mindfulness has been shown to mediate the relationship between pain and quality of life, highlighting its role as a key mechanism of change in psychological interventions for chronic pain (10).

Despite its demonstrated benefits, the implementation of mindfulness interventions in individuals with SCI is not without challenges. Traditional mindfulness programs often require sustained attention, regular practice, and physical comfort, which may be difficult to achieve in populations experiencing severe pain, fatigue, or mobility limitations. These barriers can reduce adherence and limit the effectiveness of interventions. As a result, there is a growing interest in innovative delivery methods that can enhance engagement, accessibility, and adherence to mindfulness practices.

Virtual reality (VR) has emerged as a promising technological tool in this context. VR is defined as a computer-generated simulation that enables users to interact with immersive, three-dimensional environments through multisensory experiences. One of the key features of VR is its ability to create a strong sense of presence, allowing individuals to feel as though they are physically located within the virtual environment. This immersive quality has significant implications for pain management, as attention plays a crucial role in modulating pain perception. By capturing and directing attentional resources, VR can reduce the salience of pain signals and decrease perceived pain intensity (12). Clinical studies have demonstrated that VR interventions can produce short-term reductions in neuropathic pain in individuals with SCI, supporting their feasibility and therapeutic potential (12).

Beyond its role as a distraction tool, VR also offers unique opportunities for therapeutic skill development. VR environments can be designed to simulate calming natural settings, guide breathing exercises, and facilitate body awareness practices, thereby providing an ideal platform for delivering mindfulness interventions. Research integrating VR with mindfulness training has shown promising results, indicating that VR can enhance the acquisition and practice of mindfulness skills by providing structured, engaging, and immersive experiences (13-15). These studies suggest that VR may help overcome some of the limitations of traditional mindfulness programs, particularly in populations with physical or cognitive constraints.

Recent advancements in the field have further explored the combined use of VR and mind–body therapies. Scoping reviews indicate that integrating VR with interventions such as mindfulness, meditation, and relaxation is not only feasible but also potentially effective in reducing pain and improving psychological outcomes across various clinical populations (16). Additionally, randomized controlled trials have demonstrated that VR-based programs incorporating psychological skills training can produce sustained improvements in pain-related outcomes, including pain interference and emotional distress (17). In the context of chronic pain, VR-guided mindfulness and exercise programs have shown encouraging results in terms of both effectiveness and participant engagement (18).

Specifically in SCI populations, emerging evidence highlights the potential of VR interventions to address neuropathic pain and improve functional outcomes. Comprehensive reviews have documented the multidimensional benefits of VR, including reductions in pain intensity, improvements in mood, and enhanced engagement in rehabilitation activities (19). However, the literature also emphasizes the need for more rigorous and standardized studies, particularly those examining long-term outcomes and the integration of VR with established psychological interventions.

The theoretical rationale for combining VR and mindfulness is grounded in their complementary mechanisms of action. While mindfulness promotes acceptance, cognitive flexibility, and emotional regulation, VR enhances attentional engagement and experiential learning. Together, these approaches may create a synergistic effect, facilitating deeper and more sustained changes in the individual's relationship with pain. VR can provide a supportive and controlled environment in which individuals can practice mindfulness skills, gradually increasing their tolerance for discomfort and reducing avoidance behaviors. At the same time, the novelty and immersive nature of VR may enhance motivation and adherence, addressing one of the key challenges in psychological interventions for chronic pain.

Despite these promising developments, several gaps remain in the current literature. First, there is a limited number of studies specifically examining the impact of combined VR and mindfulness interventions on pain acceptance in individuals with SCI. Second, most existing research has focused on pain intensity as the primary outcome, with less attention given to psychological constructs such as acceptance, which are critical for long-term adaptation. Third, the heterogeneity of VR interventions and the lack of standardized protocols make it difficult to draw definitive conclusions לגבי their effectiveness. Finally, there is a need for studies that evaluate the feasibility and acceptability of these interventions in real-world clinical settings.

The present study addresses these gaps by investigating the effectiveness of a combined virtual reality–based and mindfulness intervention on pain acceptance in individuals with spinal cord injury. By focusing on pain acceptance as a primary outcome, this study aligns with contemporary approaches that prioritize functional improvement and psychological adaptation over mere symptom reduction. Furthermore, by integrating technological innovation with evidence-based psychological practices, the study contributes to the development of accessible, noninvasive, and patient-centered interventions for chronic pain management in SCI. The methodological framework and preliminary findings of this research are detailed in the study document , which provides empirical grounding for the current investigation.

Accordingly, the aim of the present study is to examine the effectiveness of a combined virtual reality–based and mindfulness intervention on pain acceptance in individuals with spinal cord injury.

Methods and Materials

Study Design and Participants

This study employed a quasi-experimental method with a pretest–posttest design, including a control group and a two-month follow-up. The statistical population consisted of all individuals with spinal cord injury who attended Fars Welfare Centers and the Fars Province Disabled Association in Shiraz in 2024. The sample consisted of 30 individuals with spinal cord injury who were selected through purposive sampling and then randomly assigned to either the combined virtual reality– and mindfulness-based treatment group or the control group.

The inclusion criteria were as follows: minimum age of 16 years and maximum age of 45 years; diagnosis of quadriplegic spinal cord injury confirmed by a specialist physician; a history of spinal cord injury of at least 2 years; no dependence on psychotropic or opioid substances according to the patient's medical history and records; and no acute psychiatric disorders as diagnosed by a psychiatrist. The exclusion criteria included unwillingness to continue participation, absence from more than two sessions, and a history of epilepsy or migraine.

The research procedure was conducted as follows. In the first stage, to develop the combined virtual reality– and mindfulness-based intervention, a 360-degree virtual reality video entitled Floating on the River, produced by Lin Han (2015), which depicts a boat floating on a river, and another 360-degree video entitled Pebble in the Lake were prepared. Using the InShot software, these videos were dubbed respectively with the mindfulness audio meditations Images and Sounds and Wise Mind. The number and duration of treatment sessions were determined after combining the materials and establishing their content validity. It should be noted that the 360-degree virtual reality videos and mindfulness meditations had previously been used in the studies by Amaya Chandrasiri et al. (2020) and Navarro et al. (2016).

To determine content validity, after obtaining expert opinions, the inter-rater agreement coefficient (kappa coefficient) was calculated and found to be 99%, indicating confirmation of the content validity of the treatment package.

In the next stage, in order to evaluate the effectiveness of the combined virtual reality– and mindfulness-based treatment, 30 individuals with spinal cord injury were selected purposively and randomly assigned to the experimental and control groups (15 participants in each group). Assessment was conducted using the questionnaire developed by McCracken et al. (2004).

The experimental group received the combined virtual reality– and mindfulness-based treatment. After completion of the intervention, and again two months later at follow-up, both groups completed the research questionnaire once more. A pretest was administered to all participants in both groups, including one treatment group and one control group. The experimental group received the combined virtual reality– and mindfulness-based intervention in eight 14-minute sessions delivered by the researcher. During these sessions, while immersed in a virtual environment, participants viewed the 360-degree virtual reality videos Floating on the River and Pebble in the Lake, which had been dubbed respectively with the mindfulness audio meditations Images and Sounds and Wise Mind, using a VR Box headset.

Data Collection

Chronic Pain Acceptance Questionnaire (CPAQ): The Chronic Pain Acceptance Questionnaire, developed by McCracken et al. (2004), has been widely used in research related to chronic pain. This questionnaire contains 20 items. The activity engagement items are items 4, 7, 11, 13, 14, 15, 16, 17, 18, and 20, and the pain willingness/acceptance items are items 1, 2, 3, 5, 6, 8, 9, 10, 12, and 19. Each item is scored on a 7-point Likert scale ranging from 0 (never) to 6 (always). The questionnaire includes two subscales: (a) activity engagement (i.e., pursuing daily activities despite pain), and (b) pain acceptance (i.e., the relative absence of efforts to avoid or control pain). The total pain acceptance score is calculated as follows: first, the activity engagement items are scored directly on the 7-point scale from 0 (never) to 6 (always), whereas the pain acceptance items are reverse-scored, from 6 (never) to 0 (always). Then, the scores of the two subscales are summed. In this scale, the minimum possible score is 0 and the maximum is 120, with higher scores indicating greater pain acceptance. Johnson et al. (2009) reported Cronbach's alpha coefficients of 0.79 and 0.75 for activity engagement and pain acceptance, respectively. In addition, Mesgarian et al. (2012) reported a Cronbach's alpha of 0.74 for this questionnaire. In the present study, Cronbach's alpha for the questionnaire was 0.88.

VR Box Virtual Reality Headset: The headset used in this study was the VR Box 2 virtual reality headset, measuring 197 × 135 × 95 mm and weighing 250 g, and equipped with a Bluetooth remote control. This headset was designed and manufactured in 2019 by the VR Box Company in China. VR Box is the second generation of virtual reality headsets from the well-known VR Box brand. Unlike the previous generation, which had very limited capabilities, the new generation includes improvements that make it a considerably better option for purchasing a virtual reality headset, and it is suitable for mobile phones ranging from 5.3 to 6 inches. The remote control is compatible with Android, iOS, and PC operating systems. The headset features adjustable lenses and focal distance for creating a clearer image, wide adjustable straps for secure placement on the face, and soft foam pads both where the phone is inserted and where the headset contacts the face. It also includes side slots for passing charging and earphone cables, as well as air ventilation for viewing 360-degree videos. To watch both 3D and standard movies with this headset, it is not necessary for the mobile phone to have a gyroscope sensor; thus, it supports all smartphones. The headset displays high-quality images via a mobile phone and allows participants to become immersed in scenarios through visual and auditory stimuli. Using the Bluetooth remote control, the phone can be controlled while it is placed inside the headset on the participant's eyes.

Intervention

The combined virtual reality– and mindfulness-based intervention consisted of the 360-degree virtual reality video Floating on the River, produced by Lin Han (2015), which displays a boat floating on a river and was dubbed with the mindfulness audio meditation Images and Sounds.

This video was shown through a mobile phone inserted into the headset and placed over the participant's eyes. The duration of this video was 7 minutes. Then, another 360-degree video titled Pebble in the Lake, which had been dubbed using the InShot software with the mindfulness meditation Wise Mind, was presented to the participant; its duration was also 7 minutes. These mindfulness meditations were later used by other researchers as well (13, 14).

This treatment was delivered over the course of 8 sessions. In the first session, the researcher explained all conditions and procedures of the combined virtual reality and mindfulness treatment process to the participant.

During the first session, the participant provided a full personal and clinical history, and any questions or ambiguities were addressed. Participants were informed that the combined virtual reality and mindfulness treatment would be conducted using goggles placed over their eyes.

They were also reminded that these goggles were safe and would not cause any harm, pain, or pressure. Afterwards, feedback was obtained from the participants regarding how they felt after watching the videos.

This same process continued throughout all 8 sessions; after each session, participants were asked to provide feedback following the videos. At the end of the 8 sessions, the effects of this treatment package were evaluated.

Data Analysis

Data analysis was conducted at both descriptive and inferential levels. At the descriptive level, indices of central tendency and dispersion (mean, standard deviation, and standard error) were used. At the inferential

level, after examining the assumptions of normal distribution of variables, homogeneity of variances, and variance–covariance matrices, mixed analysis of variance, paired comparison tests, and dependent-samples t tests were used. Analyses were performed using SPSS version 23.

Findings and Results

The results of the chi-square test examining differences in the frequency distribution of demographic variables between the two groups indicated that these demographic characteristics did not differ significantly between groups ($p > .05$).

Table 1: Descriptive Statistics of Pain Acceptance by Group Across Research Phases

Variable	Group	Pretest Mean	Pretest SD	Posttest Mean	Posttest SD	Follow-up Mean	Follow-up SD
Pain Acceptance	Combined virtual reality– and mindfulness-based treatment	74.73	18.29	84.26	15.18	84.33	15.26
Pain Acceptance	Control	71.93	10.498	72.26	10.329	71.26	17.407

As shown in Table 1, the mean scores for pain acceptance in the intervention group (combined virtual reality– and mindfulness-based treatment) increased more than those in the control group at the posttest and follow-up stages compared with the pretest. The use of parametric repeated-measures tests requires several preliminary assumptions, including normality of score distributions, homogeneity of variances, and equality of covariance matrices. The results of the Shapiro–Wilk test for normality, Levene's test for homogeneity of variances, and Mauchly's test for sphericity are presented in Tables 2, 3, and 4.

Table 2. Shapiro–Wilk Test for the Assumption of Normality of Pain Acceptance Scores in the Two Groups Across the Three Study Phases

Variable	Group	Pretest Statistic	Sig.	Posttest Statistic	Sig.	Follow-up Statistic	Sig.
Pain Acceptance	Combined virtual reality– and mindfulness-based treatment	0.928	0.255	0.935	0.327	0.949	0.506
	Control	0.943	0.419	0.942	0.404	0.946	0.468

Table 3. Test of Homogeneity of Variances for Pain Acceptance Scores in the Two Groups Across the Three Study Phases

Variable	Pretest F	Sig.	Posttest F	Sig.	Follow-up F	Sig.
Pain Acceptance	1.94	0.133	1.53	0.216	2.33	0.083

Table 4. Mauchly's Test of Sphericity for the Covariance Matrix of Scores in the Two Groups

Variable	Statistic	Chi-square	df	Sig.
Pain Acceptance	0.45	43.86	2	0.001

The purpose of examining the assumption of normality is to determine whether the distribution of sample scores is consistent with a normal distribution in the population. This assumption implies that the observed difference between the sample score distribution and the normal population distribution is equal to zero. For this purpose, the Shapiro–Wilk test was used. The results presented in Table 3 indicate that the null hypothesis of normality was retained for the study variable at all three stages—pretest, posttest, and follow-up—in both groups, as all significance levels were greater than 5%.

In addition, Levene's test confirmed the assumption of equality of variances across groups for the study variable at all three stages, since all significance levels were above 5%. However, the assumption of sphericity, examined using Mauchly's test, was rejected for the research variable ($p < .05$). Therefore, in testing the study hypotheses, corrected multivariate procedures such as the Greenhouse–Geisser and Huynh–Feldt corrections were used.

Table 5. Results of Within-Subjects Effects in Repeated-Measures Analysis of Variance for Pain Acceptance

Variable	Source	Test	Sum of Squares	df	Mean Square	F	Sig.	Effect Size
Pain Acceptance	Time Effect	Sphericity Assumed	1027.378	2.000	513.689	31.377	0.001	0.359
		Greenhouse–Geisser	1027.378	1.291	795.972	31.377	0.001	0.359
		Huynh–Feldt	1027.378	1.379	745.025	31.377	0.001	0.359
		Lower-bound	1027.378	1.000	1027.378	31.377	0.001	0.359
	Time × Group Effect	Sphericity Assumed	719.022	6.000	119.837	7.320	0.001	0.282
		Greenhouse–Geisser	719.022	3.872	185.690	7.320	0.001	0.282
		Huynh–Feldt	719.022	4.137	173.805	7.320	0.001	0.282
		Lower-bound	719.022	3.000	239.674	7.320	0.001	0.282

The results presented in Table 6 indicate that there was a statistically significant overall difference in the mean pain acceptance scores across the study phases ($p = .001$). Furthermore, the interaction effect of time and group membership was also significant for this variable ($p = .001$). In other words, the differences in pain acceptance scores across the three stages—pretest, posttest, and follow-up—were significant in the total sample, with an effect size of 35.9%.

In addition, the difference in pain acceptance scores across the three measurement points between the groups was statistically significant, indicating that the pattern of change in scores across pretest, posttest, and follow-up differed significantly between the groups. The magnitude of the group difference across the study phases for pain acceptance was 28.2%. The results of the between-subjects comparison, that is, the comparison of the two groups in pain acceptance, are presented in Table 6.

Table 6. Results of Between-Subjects Effects Analysis for Pain Acceptance

Variable	Source	Sum of Squares	df	Mean Square	F	Sig.	Effect Size	Statistical Power
Pain Acceptance	Group	147.62	3	49.207	6.75	0.001	0.266	0.967
	Error	408.00	56	7.28				

Based on the findings presented in Table 7, the mean pain acceptance scores differed significantly between the experimental and control groups ($p = .001$). The results showed that 26.6% of the individual differences in pain acceptance were attributable to differences between the two groups. At the posttest and follow-up stages, there was a statistically significant difference between the mean pain acceptance scores of the control group and those of the combined virtual reality– and mindfulness-based treatment group. This finding indicates that the effect of the combined intervention was 35.9% at posttest and 32.7% at follow-up. The comparison of mean pain acceptance scores across the study phases within the intervention group, using the Bonferroni post hoc test, is presented in Table 7.

Table 7. Results of the Bonferroni Post Hoc Test Comparing Mean Pain Acceptance Scores Across Study Phases in the Intervention Group

Variable	Group	Comparison of Phases	Mean Difference	Sig.
Pain Acceptance	Combined virtual reality– and mindfulness-based treatment	Pretest vs. Posttest	11.53	0.001
		Pretest vs. Follow-up	11.60	0.003
		Posttest vs. Follow-up	0.067	0.998

The results of the Bonferroni post hoc test shown in Table 8 indicate that the mean difference in pain acceptance scores between pretest and posttest, as well as between pretest and follow-up, was statistically significant in the combined virtual reality– and mindfulness-based treatment group ($p < .05$). However, the mean difference between posttest and follow-up in the intervention group was not statistically significant ($p > .05$). Accordingly, it can be concluded that, at the within-group level, the combined virtual reality– and mindfulness-based treatment led to improvement in pain acceptance at both posttest and follow-up relative to pretest. However, the scores remained stable from posttest to follow-up, indicating maintenance of treatment effects over time.

Discussion and Conclusion

The findings of the present study demonstrated that the combined virtual reality–based and mindfulness intervention significantly increased pain acceptance in individuals with spinal cord injury compared with the control group, and that these improvements were maintained at follow-up. The repeated-measures analysis indicated a significant main effect of time as well as a significant interaction effect between time and group, suggesting that the trajectory of change in pain acceptance differed meaningfully between the intervention and control conditions. Specifically, participants in the intervention group showed a marked increase in pain acceptance from pretest to posttest, which remained stable at the follow-up stage, whereas the control group exhibited minimal fluctuations across measurement points. These results underscore the efficacy of integrating immersive virtual environments with mindfulness-based strategies in enhancing adaptive psychological responses to chronic pain in spinal cord injury.

The observed improvement in pain acceptance aligns with theoretical and empirical perspectives emphasizing the centrality of acceptance processes in chronic pain adaptation. Pain acceptance, conceptualized as the willingness to experience pain without excessive attempts at avoidance or control while maintaining engagement in valued activities, has been consistently associated with improved functioning and reduced disability (8). In individuals with spinal cord injury, daily fluctuations in pain acceptance have been shown to influence both physical and psychosocial functioning, highlighting its dynamic and clinically meaningful nature (9). The present findings extend this body of evidence by demonstrating that pain acceptance is not only associated with better outcomes but can also be actively enhanced through targeted intervention, particularly when combining mindfulness and virtual reality modalities.

The effectiveness of the mindfulness component of the intervention can be interpreted within the broader literature on mindfulness-based approaches in spinal cord injury and chronic pain populations. Mindfulness facilitates a shift in attentional processes, enabling individuals to observe pain-related sensations, thoughts, and emotions in a nonjudgmental and accepting manner. This shift reduces cognitive fusion with pain-related thoughts and decreases maladaptive coping strategies such as catastrophizing and avoidance. Empirical evidence indicates that mindfulness-based interventions can improve psychological well-being

and reduce the negative impact of pain in individuals with spinal cord injury (10, 11). Furthermore, mindfulness has been identified as a mediator between pain and quality of life, suggesting that enhancing mindfulness skills can indirectly improve overall functioning. The present study supports these findings by showing that mindfulness, when delivered in an innovative format, contributes to increased pain acceptance.

In addition to mindfulness, the virtual reality component of the intervention likely played a crucial role in enhancing treatment outcomes. Virtual reality provides an immersive, multisensory environment that captures attentional resources and reduces the salience of pain signals. Previous research has demonstrated that VR interventions can produce short-term reductions in neuropathic pain intensity in individuals with spinal cord injury, supporting their feasibility and therapeutic potential (12). Moreover, comprehensive reviews have highlighted the multidimensional benefits of VR, including improvements in mood, engagement, and functional outcomes (19). The present findings are consistent with this literature, suggesting that VR not only reduces pain perception but also facilitates psychological processes such as acceptance when integrated with appropriate therapeutic content.

A key contribution of the current study lies in the integration of VR and mindfulness into a single intervention protocol. While previous studies have examined these approaches separately, emerging evidence suggests that their combination may yield synergistic effects. VR can enhance mindfulness practice by providing structured, engaging, and immersive environments that support attentional focus and experiential learning. Studies have shown that VR-based mindfulness training is feasible and acceptable, and can enhance the acquisition of mindfulness skills (13-15). In this context, VR serves not merely as a distraction tool but as a platform for delivering therapeutic content in a more accessible and engaging manner. The present study builds on this evidence by demonstrating that such integration can lead to meaningful improvements in pain acceptance among individuals with spinal cord injury.

The sustained effects observed at follow-up further highlight the potential of the combined intervention for producing lasting changes in psychological functioning. The absence of significant differences between posttest and follow-up scores in the intervention group suggests that participants were able to maintain the gains achieved during the intervention period. This finding is consistent with studies reporting long-term benefits of VR-based interventions that incorporate psychological skills training (17). It also aligns with research indicating that mindfulness-based practices can lead to enduring changes in cognitive and emotional processes, particularly when individuals continue to apply learned skills in their daily lives. The stability of treatment effects is particularly important in chronic conditions such as spinal cord injury, where long-term management strategies are essential.

The findings of this study can also be interpreted within the broader context of the biopsychosocial model of pain. Chronic pain in spinal cord injury is influenced by a complex interplay of physiological, psychological, and social factors (7). By targeting both attentional and cognitive-emotional processes, the combined VR and mindfulness intervention addresses multiple components of this model. VR primarily influences attentional mechanisms by redirecting focus away from pain, while mindfulness targets cognitive and emotional processes by fostering acceptance and reducing reactivity. Together, these approaches may disrupt the vicious cycle of pain, distress, and avoidance that often characterizes chronic pain conditions.

Furthermore, the present results are consistent with studies examining the integration of VR with mind–body therapies. Reviews have indicated that combining VR with interventions such as mindfulness,

relaxation, and hypnosis is feasible and potentially effective in reducing pain and improving psychological outcomes (16). Additionally, randomized trials have shown that VR-guided programs incorporating mindfulness and physical activity can enhance engagement and produce beneficial outcomes in chronic pain populations (18). The current study extends these findings to the specific context of spinal cord injury, providing evidence for the applicability of such interventions in this population.

Another important implication of the findings relates to the role of engagement and motivation in treatment adherence. One of the challenges of traditional mindfulness programs is the requirement for sustained attention and regular practice, which may be difficult for individuals experiencing chronic pain and fatigue. VR, with its immersive and interactive nature, may enhance motivation and reduce the perceived effort associated with mindfulness practice. This increased engagement may contribute to the effectiveness of the intervention, as participants are more likely to actively participate and persist in the training. The positive outcomes observed in the present study suggest that integrating technology into psychological interventions can enhance their accessibility and appeal, particularly for populations with physical limitations.

In addition, the findings highlight the importance of shifting the focus of pain management from symptom reduction to functional improvement and psychological adaptation. Traditional approaches often prioritize reducing pain intensity, which may not always be achievable in chronic conditions such as spinal cord injury. Acceptance-based approaches, in contrast, emphasize living a meaningful life despite the presence of pain. By increasing pain acceptance, the combined intervention may help individuals re-engage in valued activities, improve their quality of life, and reduce the impact of pain on daily functioning. This perspective is consistent with contemporary approaches to chronic pain management, which prioritize patient-centered outcomes and long-term well-being.

The results of this study should also be considered in light of the broader literature on spinal cord injury and chronic pain. Chronic pain remains one of the most challenging complications of SCI, with high prevalence rates and significant impact on quality of life (3). Standardized data sets emphasize the need for comprehensive assessment and management strategies that address multiple dimensions of pain (5, 6). The present study contributes to this literature by providing evidence for an innovative, nonpharmacological intervention that targets both psychological and attentional aspects of pain.

Despite the promising findings, several limitations should be acknowledged. The sample size was relatively small, which may limit the generalizability of the results. Additionally, the study employed a quasi-experimental design, and although random assignment was used, the lack of full experimental control may introduce potential confounding variables. The follow-up period was limited to two months, which restricts conclusions לגבי the long-term sustainability of the intervention effects. Furthermore, the study relied on self-report measures of pain acceptance, which may be subject to response biases. Finally, physiological indicators of pain and stress were not assessed, limiting the ability to examine underlying mechanisms of change.

Future research should address these limitations by employing larger and more diverse samples to enhance the generalizability of findings. Randomized controlled trials with longer follow-up periods are needed to evaluate the long-term effectiveness and durability of combined VR and mindfulness interventions. Additionally, future studies should incorporate objective physiological measures, such as

heart rate variability or neuroimaging data, to better understand the mechanisms underlying treatment effects. It would also be valuable to compare the combined intervention with other established treatments, such as cognitive-behavioral therapy or pharmacological approaches, to determine its relative effectiveness. Moreover, research should explore the optimization of VR environments and mindfulness protocols to maximize therapeutic outcomes.

From a practical perspective, the findings of this study suggest that combined virtual reality and mindfulness interventions can be incorporated into rehabilitation programs for individuals with spinal cord injury. Clinicians may consider using VR-based platforms to deliver mindfulness training in a more engaging and accessible manner, particularly for patients who face barriers to traditional interventions. The development of cost-effective and user-friendly VR systems could facilitate the widespread implementation of such interventions in clinical and community settings. Additionally, training healthcare providers in the use of VR technology and mindfulness-based approaches may enhance the quality of care and improve patient outcomes. Overall, the integration of technological innovation with evidence-based psychological interventions represents a promising direction for advancing the management of chronic pain in spinal cord injury.

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Authors' Contributions

All authors equally contributed to this study.

Declaration of Interest

The authors of this article declared no conflict of interest.

Ethical Considerations

The study protocol adhered to the principles outlined in the Helsinki Declaration, which provides guidelines for ethical research involving human participants.

Transparency of Data

In accordance with the principles of transparency and open research, we declare that all data and materials used in this study are available upon request.

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