

Article

User Experience and Adherence in Immersive Virtual Reality Rehabilitation for Fibromyalgia: A Post Hoc Exploratory Analysis

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Abstract

Fibromyalgia is a chronic pain condition associated with reduced quality of life, psychological symptoms, cognitive impairment, and low adherence to exercise-based interventions. Immersive virtual reality (IVR) has gained attention as a rehabilitation approach; however, the relationship between user experience, adherence, and clinical outcomes remains unclear. This post hoc exploratory secondary analysis was derived from a randomized controlled clinical trial (NCT07605143) and included 16 women with fibromyalgia who completed a six-week IVR-based rehabilitation program. Associations between user experience, adherence, and clinical outcomes were explored among participants exposed to IVR. Quality of life was assessed using the Fibromyalgia Impact Questionnaire-Revised (FIQ-R), psychological symptoms using the Depression Anxiety Stress Scales (DASS-21), and user experience using the Player Experience of Need Satisfaction (PENS) questionnaire. Within-group changes were observed in FIQ-R scores ($p = 0.001$; $d = 1.08$) and DASS-21 stress levels ($p = 0.025$). Participants demonstrated favorable adherence and positive user experience. A significant correlation was identified between intuitive control and changes in depression scores ($\rho = 0.63$, $p = 0.008$). This exploratory analysis identified favorable user experience and adherence among women participating in an IVR-based rehabilitation program. However, due to the absence of a concurrent control group, no conclusions regarding treatment efficacy can be drawn. These findings should be considered hypothesis-generating.

Keywords: fibromyalgia; adherence; immersive virtual reality; therapeutic exercise



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1. Introduction

Fibromyalgia is a chronic pain condition characterized by widespread musculoskeletal pain, fatigue, sleep disturbances, and cognitive impairment, affecting approximately 2–4% of the population, predominantly women [1]. Its pathophysiology involves mechanisms of

central sensitization, altered nociceptive processing, and dysfunction in descending pain inhibitory pathways, along with alterations in brain networks associated with emotional and cognitive regulation [2,3]. In addition to physical symptoms, fibromyalgia is strongly associated with psychological disturbances such as anxiety, depression, and stress, which contribute to symptom amplification and reduced quality of life [4,5].

Exercise-based interventions are widely recommended as first-line non-pharmacological treatments, demonstrating beneficial effects on pain, function, and psychological outcomes [6–8]. However, their effectiveness in real-world settings is often limited by poor adherence [9], which remains one of the main barriers to long-term therapeutic success. In chronic pain populations, adherence is influenced not only by symptom burden but also by motivational and experiential factors, including perceived enjoyment, engagement, and self-efficacy [10–12]. Therefore, interventions that enhance the patient's experience may play a critical role in improving adherence and clinical outcomes.

Immersive virtual reality (IVR) has emerged as a promising tool in rehabilitation, providing interactive environments that integrate multisensory stimulation, real-time feedback, and task-oriented activities [13–15]. Previous studies have demonstrated that this approach can improve clinical and psychological outcomes in patients with fibromyalgia, supporting its feasibility and therapeutic potential [16–18]. In particular, previous work conducted by our research group demonstrated improvements in quality of life and psychological symptoms following IVR-based exercise interventions in women with fibromyalgia [19,20]. However, despite these promising findings, the behavioral mechanisms underlying these effects remain insufficiently understood.

Beyond its direct physiological and neurocognitive effects, IVR may exert its influence through behavioral pathways. Specifically, the immersive and interactive nature of virtual environments may enhance user experience, which in turn could promote adherence to treatment [21,22]. From the perspective of Self-Determination Theory, motivation is sustained when psychological needs such as competence, autonomy, and enjoyment are satisfied [23,24]. These constructs can be assessed using tools such as the Player Experience of Need Satisfaction (PENS), which captures key dimensions of user interaction within virtual environments [25,26]. In this context, user experience may function as a critical mediator linking the intervention to behavioral engagement [27–29].

Adherence can therefore be conceptualized as a behavioral bridge between the experience of the intervention and its clinical outcomes [30]. Interventions that enhance immersion and enjoyment may increase participation, which in turn may lead to greater improvements in clinical variables such as quality of life and psychological symptoms [31]. Despite this theoretical framework, few studies have empirically examined the relationship between user experience, adherence, and clinical outcomes in fibromyalgia, particularly within immersive virtual reality interventions.

Therefore, the aim of this exploratory secondary analysis was to examine the relationship between immersive experience, treatment adherence, and clinical improvement in women with fibromyalgia participating in an immersive virtual reality-based rehabilitation program.

2. Materials and Methods

2.1. Design and Subjects

The present study corresponds to a post hoc exploratory secondary analysis derived from a randomized controlled clinical trial registered at ClinicalTrials.gov (NCT07605143). The original trial was designed to investigate the effects of an immersive virtual reality (IVR)-based rehabilitation program in individuals with fibromyalgia. The study was conducted at the Kinesiology Center of Universidad San Sebastián, Concepción, Chile, within

the framework of a community engagement initiative (Project ID 4404). Ethical approval was granted by the Scientific Ethics Committee of Universidad San Sebastián (Approval No. 171-25), and all procedures were performed in accordance with the principles of the Declaration of Helsinki [32]. Written informed consent was obtained from all participants prior to enrollment and data collection.

In the original randomized controlled trial, participants were allocated to either an immersive virtual reality exercise group or a conventional exercise control group. The purpose of the present secondary analysis was not to compare treatment groups, but rather to explore potential associations between user experience, adherence, and changes in clinical outcomes among participants exposed to IVR. To address this objective, only participants allocated to the IVR group were included in the present analyses.

User experience was assessed using the Player Experience of Need Satisfaction (PENS) questionnaire, which was specifically designed to evaluate motivational and experiential aspects associated with interaction in virtual environments. Because the instrument was administered exclusively to participants receiving IVR, equivalent user-experience data were not available for the control group. Consequently, the control group was not included in the present analyses. Given the exploratory nature of this post hoc investigation and the absence of a concurrent comparison group, the findings should be interpreted as hypothesis-generating and should not be considered evidence of treatment efficacy. The sample size for the present study was determined by the number of participants allocated to the IVR arm of the original clinical trial.

Eligible participants were adults aged 18 years or older with a medical diagnosis of fibromyalgia established according to the American College of Rheumatology criteria [33]. Recruitment was conducted through patient associations, social media announcements, and referrals from healthcare professionals. Individuals were screened for eligibility prior to enrollment.

Inclusion criteria were (i) age ≥ 18 years; (ii) confirmed diagnosis of fibromyalgia; and (iii) ability to understand and comply with study procedures. Exclusion criteria included (i) pregnancy or breastfeeding; (ii) oncological pain conditions; (iii) uncontrolled metabolic disorders; and (iv) vestibular dysfunctions or other conditions that could potentially be aggravated by exposure to immersive virtual reality environments.

The present investigation builds upon a broader research program conducted by our group examining the role of immersive virtual reality in fibromyalgia rehabilitation. Previous studies from the same research line include a quasi-experimental investigation reporting improvements in clinical and psychological outcomes [19], as well as a pilot study supporting the feasibility and applicability of IVR-based exercise interventions in this population [20].

2.2. Intervention

The intervention consisted of a supervised physiotherapy-based exercise program delivered over six consecutive weeks, with two sessions per week, resulting in a total of 12 treatment sessions. Each session lasted approximately 30 min and combined conventional aerobic exercise with immersive virtual reality (IVR)-based activities. The IVR component was delivered using an Oculus Quest 2™ head-mounted display (Meta Platforms Inc., Menlo Park, CA, USA) and the FitXR platform (FITAR LIMITED, London, UK).

Each treatment session began with a 10 min warm-up performed on a TFB cycle ergometer (BH Fitness, Vitoria-Gasteiz, Spain). The purpose of this phase was to prepare participants for the subsequent virtual reality activities through gradual cardiovascular activation and increased body temperature. Exercise intensity during the warm-up was monitored using the modified Borg Rating of Perceived Exertion scale, and participants were

encouraged to maintain a moderate intensity corresponding to approximately 3–5 points on the scale.

Participants were familiarized with the virtual reality equipment before the first intervention session, including headset placement, controller handling, and navigation within the virtual environment. This familiarization process was intended to improve comfort, facilitate interaction with the virtual environment, and minimize potential difficulties during subsequent sessions.

Following the warm-up, participants completed approximately 20 min of immersive virtual reality exercise using the FitXR platform. Prior to each session, participants selected their preferred virtual environment and difficulty level (beginner, intermediate, or advanced). Difficulty levels differed according to movement complexity, exercise intensity, execution speed, and coordination demands. Selection was individualized according to participant preferences and perceived tolerance to exercise, allowing participants to choose the level that they considered most appropriate for each session.

The immersive exercise program was organized into three sequential phases. The first phase consisted of approximately five minutes of mobility and activation exercises involving the upper limbs, lower limbs, and trunk. These activities were guided by virtual avatars and accompanied by real-time visual and auditory feedback designed to facilitate movement execution and participant engagement.

The second phase comprised approximately ten minutes of interactive motor tasks and coordination exercises performed within gamified virtual environments. Activities included boxing-style movements, target-directed reaching tasks, multidirectional upper-limb actions, and eye–hand coordination exercises synchronized with visual stimuli presented within the virtual environment. These exercises were intended to promote active participation, motor engagement, and sustained interaction with the virtual platform.

The final phase lasted approximately five minutes and focused on recovery and relaxation. Participants performed low-intensity movements, stretching exercises, and guided breathing activities designed to facilitate a gradual reduction in physical effort and promote post-exercise recovery.

All intervention sessions were conducted under the supervision of a physiotherapist, who was responsible for ensuring participant safety, assisting with equipment setup, monitoring exercise performance, and providing support whenever necessary. Participants assigned to the control group completed the same physiotherapy program and exercise dosage under therapist supervision but without exposure to immersive virtual reality, thereby maintaining equivalence in treatment duration, exercise volume, and therapist supervision between groups.

2.3. Assessment of Outcomes

Adherence to the intervention was defined as the percentage of completed sessions relative to the total number of scheduled sessions during the six-week intervention period. Adherence was selected as a behavioral indicator of engagement with the rehabilitation program, reflecting the extent to which participants completed the prescribed intervention dose. Attendance was recorded individually for each participant at every treatment session by the supervising physiotherapist. In addition to overall adherence, participant retention was calculated as the proportion of individuals who completed the intervention relative to those initially allocated to the IVR group.

User experience was assessed using the complete Player Experience of Need Satisfaction (PENS) questionnaire. The instrument comprises 20 items distributed across five dimensions: competence, autonomy, enjoyment/intrinsic motivation, intuitive control, and immersion/presence. Responses are rated on a 7-point Likert scale ranging from

1 (“strongly disagree”) to 7 (“strongly agree”). Scores for each dimension were calculated as the mean of the corresponding items, with higher values indicating a more favorable user experience. The questionnaire was administered after completion of the intervention to capture participants’ perceptions of their interaction with the immersive virtual environment. PENS has been widely used in virtual reality and exergaming research to assess motivational, experiential, and engagement-related aspects associated with technology use and user interaction [25,34]. Because the instrument specifically evaluates experiences occurring within virtual environments, it was administered exclusively to participants allocated to the IVR group.

The Fibromyalgia Impact Questionnaire-Revised (FIQ-R) is one of the most widely used disease-specific outcome measures in fibromyalgia research and provides a comprehensive assessment of physical functioning, overall disease impact, and symptom severity associated with the condition [35,36]. The FIQ-R is one of the most frequently used outcome measures in fibromyalgia research and provides a comprehensive assessment of the perceived burden associated with the condition [37]. Higher scores indicate greater disease impact and poorer health-related quality of life.

Psychological symptoms were evaluated using the Depression Anxiety Stress Scales (DASS-21), a validated self-report questionnaire designed to assess emotional distress across three domains: depression, anxiety, and stress [38]. Each subscale provides an independent measure of symptom severity, with higher scores indicating greater psychological distress. The DASS-21 has been extensively used in clinical and chronic pain populations due to its adequate psychometric properties and sensitivity to changes in emotional symptoms. Given the high prevalence of psychological symptoms in fibromyalgia, assessment of depression, anxiety, and stress was considered relevant for exploring potential associations between user experience and emotional outcomes.

Adverse events were monitored throughout the intervention period. Participants were instructed to report any discomfort, dizziness, cybersickness symptoms, visual disturbances, or other events potentially associated with virtual reality exposure [39]. All reported events were documented and managed according to established safety procedures. The occurrence, severity, and potential relationship to the intervention were reviewed throughout the study to ensure participant safety and intervention tolerability.

2.4. Statistical Analysis

Statistical analyses were performed using JASP software (version 0.18.3; JASP Team, Amsterdam, The Netherlands). Descriptive statistics were calculated for all study variables and are presented as mean $\pm$ standard deviation for continuous variables and frequencies with percentages for categorical variables, as appropriate.

Data distribution was evaluated using the Shapiro–Wilk test. Within-group changes in clinical outcomes between baseline and post-intervention assessments were analyzed using paired-samples *t*-tests when normality assumptions were met or Wilcoxon signed-rank tests when data were not normally distributed. Effect sizes were calculated to facilitate interpretation of the magnitude of observed changes and were reported as Cohen’s *d* for parametric analyses and rank-biserial correlation (*rrb*) for non-parametric analyses.

Associations between adherence, user experience (PENS dimensions), and changes in clinical outcomes were explored using correlation analyses. Pearson’s correlation coefficient was used for normally distributed variables, whereas Spearman’s rank correlation coefficient was used when normality assumptions were not satisfied. Correlation analyses focused on relationships between adherence, PENS dimensions, and changes in FIQ-R and DASS-21 scores within participants exposed to immersive virtual reality.

Given the exploratory nature of the study, no correction for multiple comparisons was applied. Therefore, correlation findings should be interpreted cautiously and considered hypothesis-generating. Statistical significance was established at $p < 0.05$. Where appropriate, 95% confidence intervals were calculated to provide additional information regarding the precision of the observed effects.

3. Results

3.1. Participant Characteristics

The study included 16 women with fibromyalgia allocated to the immersive virtual reality (IVR) group. Participants presented a clinically representative profile characterized by middle age, high prevalence of overweight/obesity, low levels of physical activity, and frequent use of pharmacological treatment. Additionally, most participants reported comorbid conditions commonly associated with fibromyalgia, supporting the clinical complexity of the sample. The baseline sociodemographic and clinical characteristics of the participants are summarized in Table 1.

Table 1. Baseline sociodemographic and clinical characteristics of participants.

Variable	Experimental Group ($n = 16$)
Female, n (%)	16 (100)
Age (years), mean $\pm$ SD	48.3 $\pm$ 12.9
Height (cm), mean $\pm$ SD	156.6 $\pm$ 6.9
Weight (kg), mean $\pm$ SD	72.1 $\pm$ 12.9
BMI (kg/m^2), mean $\pm$ SD	29.4 $\pm$ 4.7
Overweight/Obesity, n (%)	14 (87.5)
Physically inactive ¹ , n (%)	12 (75.0)
Use of pharmacological treatment, n (%)	13 (81.3)
Presence of comorbidities, n (%)	10 (62.5)

¹ Physical inactivity was defined according to self-reported low levels of physical activity. Data are presented as mean $\pm$ standard deviation (SD) or frequency and percentage (%), as appropriate. BMI: Body Mass Index; SD: Standard Deviation.

Figure 1 presents the participant flow throughout the study. A total of 42 individuals were assessed for eligibility, of whom 36 were randomized into either the IVR group or the control group. Six participants discontinued the intervention during follow-up, resulting in a final analytical sample of 16 participants in the IVR group and 12 in the control group.

Adverse events were mild and transient, consisting primarily of dizziness and cyber-sickness symptoms reported during IVR exposure. No serious adverse events or intervention discontinuations related to safety concerns were observed.

3.2. Clinical Outcomes Following IVR Intervention

Participants in the IVR group demonstrated significant improvements in quality of life following the intervention, evidenced by a reduction in FIQ-R scores with a large effect size. Regarding psychological symptoms, significant reductions were observed in stress levels, whereas depression and anxiety scores did not show statistically significant changes. Depression outcomes demonstrated greater interindividual variability compared with the remaining psychological domains. Changes in clinical outcomes following the IVR intervention are presented in Table 2.

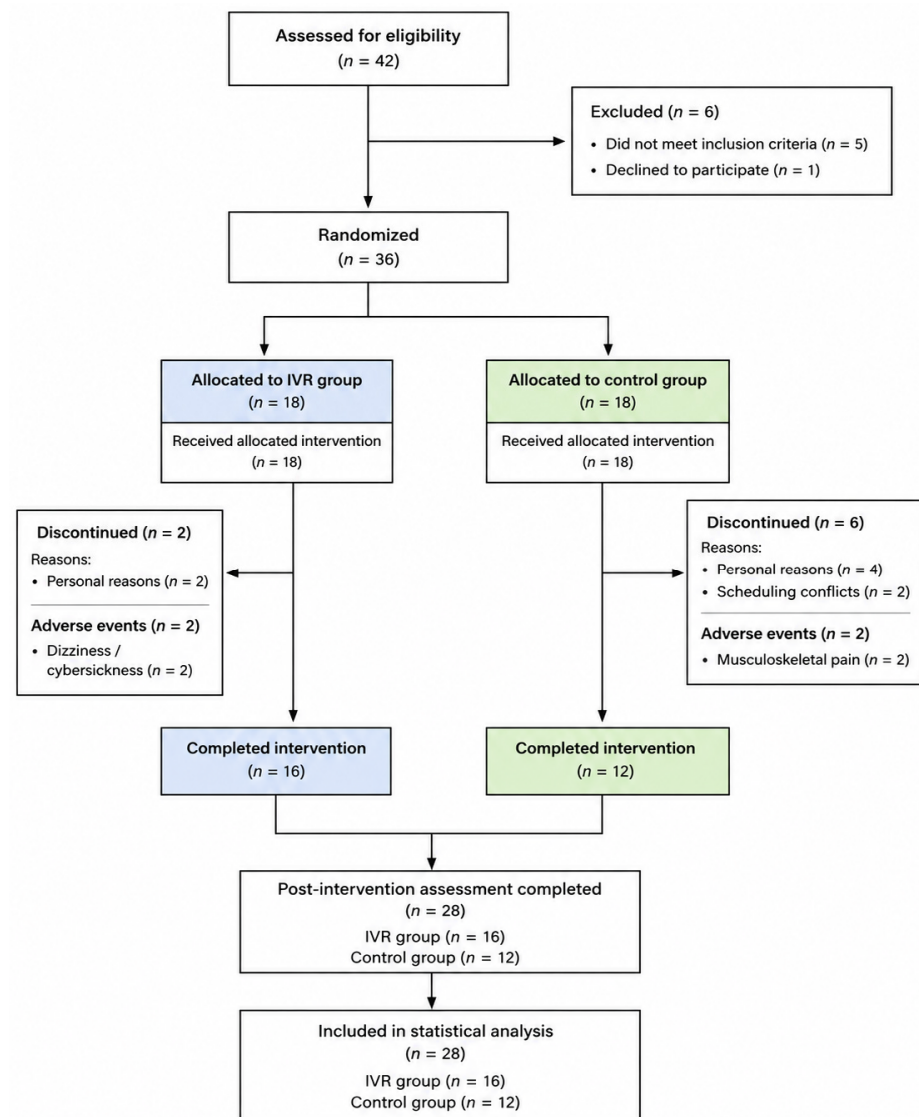


Figure 1. Flow diagram of participants throughout the study. Assessed for eligibility ($n = 42$); excluded ($n = 6$: did not meet inclusion criteria ($n = 5$), declined to participate ($n = 1$)); randomized ($n = 36$); allocated to immersive virtual reality (IVR) group ($n = 18$) or control group ($n = 18$); discontinued intervention (IVR group: $n = 2$; control group: $n = 6$); adverse events (IVR group: $n = 2$; control group: $n = 2$); completed intervention (IVR group: $n = 16$; control group: $n = 12$); included in statistical analysis (IVR group: $n = 16$; control group: $n = 12$). Arrows indicate participant flow between study stages.

Table 2. Exploratory clinical outcomes following the IVR intervention.

Variable	Baseline	Post-Intervention	<i>p</i> -Value	Effect Size	95% CI
FIQ-R	66.6 ± 23.0	54.1 ± 19.6	0.001	d = 1.08	6.3 to 18.8
DASS-21 Depression	9.6 ± 6.3	9.2 ± 5.5	0.733	rrb = −0.14	−0.9 to 1.8
DASS-21 Stress	13.8 ± 5.0	11.7 ± 4.8	0.025	rrb = −0.68	−0.1 to 4.2
DASS-21 Anxiety	10.9 ± 5.2	10.8 ± 5.3	0.510	rrb = −0.24	−1.3 to 1.6

Data are presented as mean ± standard deviation. FIQ-R was analyzed using a paired samples *t*-test because change scores were normally distributed. DASS-21 subscales were analyzed using the Wilcoxon signed-rank test because change scores were not normally distributed. Confidence intervals (95% CI) represent the mean change between baseline and post-intervention assessments, calculated as baseline minus post-intervention values; therefore, positive values indicate clinical improvement. FIQ-R: Fibromyalgia Impact Questionnaire-Revised; DASS-21: Depression Anxiety Stress Scales-21; IVR: Immersive Virtual Reality; SD: Standard Deviation; CI: Confidence Interval; d: Cohen's *d*; rrb: rank-biserial correlation.

3.3. User Experience and Adherence

Retention in the IVR group was 88.9% (16/18 participants). Adherence metrics were calculated among participants who completed the intervention ($n = 16$), whereas retention was calculated for all participants originally allocated to the IVR group ($n = 18$). The two discontinuations were due to personal reasons unrelated to the intervention. Among completers, 75% of participants attended at least 75% of the scheduled sessions, indicating high engagement with the immersive rehabilitation program. No participant discontinued the intervention due to adverse events associated with immersive virtual reality exposure. User experience and adherence metrics are presented in Table 3.

Table 3. User experience and adherence metrics in the IVR group.

Variable	Mean $\pm$ SD
Completed sessions	9.5 $\pm$ 1.5
Adherence (%)	79.2 $\pm$ 12.5
Participants with $\geq 75\%$ adherence, n (%)	12 (75.0)
PENS Competence	6.3 $\pm$ 0.2
PENS Autonomy	6.5 $\pm$ 0.4
PENS Enjoyment/Pleasure	6.8 $\pm$ 0.3
PENS Intuitive Control	5.8 $\pm$ 0.7
PENS Presence/Immersion	6.2 $\pm$ 0.5

Data are presented as mean $\pm$ standard deviation (SD), frequency and percentage (%), or range, as appropriate. Adherence was calculated as the percentage of completed sessions relative to the total number of scheduled sessions during the intervention period. PENS: Player Experience of Need Satisfaction; IVR: Immersive Virtual Reality; SD: Standard Deviation.

3.4. Correlations Between User Experience, Adherence, and Clinical Outcomes

Correlation analyses revealed generally low-to-moderate associations between PENS dimensions, adherence, and clinical outcomes. The strongest association was observed between intuitive control and improvement in depression symptoms ($\rho = 0.63$, $p = 0.008$), indicating that participants who perceived greater ease and control during interaction with the virtual environment tended to demonstrate greater reductions in depressive symptoms. The distribution of individual responses and the observed association are illustrated in Supplementary Figure S1. However, given the exploratory nature of the analyses and the small sample size, these findings should be interpreted cautiously. Exact p -values and bootstrap-derived 95% confidence intervals for all correlations are presented in Supplementary Table S1. No significant correlations were observed between the remaining PENS dimensions and adherence or clinical outcomes. Correlations between PENS dimensions, adherence, and clinical outcomes are presented in Table 4.

Table 4. Correlations between PENS dimensions, adherence, and clinical outcomes in the IVR group.

Variable	Adherence (%)	Δ FIQ-R	Δ Stress	Δ Anxiety	Δ Depression
PENS Competence	−0.27	−0.23	−0.07	−0.31	0.27
PENS Autonomy	−0.11	−0.11	0.04	0.10	0.12
PENS Enjoyment/Pleasure	−0.07	0.22	−0.11	−0.23	−0.09
PENS Intuitive Control	0.41	0.21	−0.06	0.05	0.63 *
PENS Presence/Immersion	0.13	−0.29	−0.39	−0.13	−0.09

Values are presented as Spearman's correlation coefficients (ρ). Positive Δ values indicate greater clinical improvement following the intervention. Statistical significance was established at $p < 0.05$. * $p = 0.008$. Bold values indicate statistically significant correlations ($p < 0.05$). FIQ-R: Fibromyalgia Impact Questionnaire-Revised; PENS: Player Experience of Need Satisfaction; IVR: Immersive Virtual Reality. Exact p -values and 95% confidence intervals for all correlations are provided in Supplementary Table S1.

4. Discussion

The present exploratory secondary analysis examined the relationship between immersive experience, adherence, and clinical improvement in women with fibromyalgia participating in an immersive virtual reality (IVR)-based rehabilitation program. Importantly, because this post hoc analysis focused exclusively on participants exposed to IVR and did not include a concurrent control group, the observed clinical changes cannot be attributed to the intervention itself and should not be interpreted as evidence of treatment efficacy. The main findings were (i) changes in quality of life and stress levels observed among participants exposed to the intervention; (ii) moderate-to-high adherence and positive user experience across PENS domains; and (iii) an association between intuitive control and improvement in depressive symptoms. However, most dimensions of immersive experience were not significantly associated with adherence or clinical outcomes, suggesting that engagement in IVR-based rehabilitation may depend on multiple behavioral and contextual factors beyond immersion alone.

The reduction in FIQ-R scores observed among participants exposed to IVR is consistent with findings reported in previous studies evaluating IVR-based exercise interventions in fibromyalgia [40,41]. Importantly, the observed reduction in FIQ-R scores (12.5 points) falls within or exceeds commonly reported minimal clinically important difference thresholds for fibromyalgia, which have been estimated at approximately 8–14 points. This suggests that the observed improvement may be clinically meaningful despite the exploratory nature of the present analysis. Beyond conventional exercise effects, immersive environments may facilitate participation through attentional distraction, multisensory stimulation, and increased motivational engagement [42,43]. In chronic pain populations, these mechanisms may reduce the salience of nociceptive input and temporarily shift attention away from pain-related cognitions, potentially improving exercise tolerance and perceived functionality [44,45].

Stress levels also improved significantly following the intervention, whereas anxiety and depression did not demonstrate statistically significant changes [46,47]. This pattern is clinically plausible, as stress-related symptoms may respond more rapidly to short-term behavioral interventions than broader affective disturbances [48,49]. Immersive environments may transiently reduce hypervigilance and emotional overload through enjoyable and interactive experiences [50,51]. Nevertheless, the absence of significant changes in anxiety and depression suggests that longer interventions or psychologically targeted approaches may be necessary to modify more stable affective symptoms in fibromyalgia [52].

An exploratory association was observed between intuitive control and changes in depressive symptoms, although depression did not significantly improve at the group level. Therefore, this finding should be interpreted cautiously and considered hypothesis-generating. The individual variability underlying this association is illustrated in Supplementary Figure S1. Participants who perceived greater ease and control while interacting with the virtual environment demonstrated greater reductions in depression scores. This finding highlights the potential importance of usability-related dimensions in digital rehabilitation. While immersion is often considered the defining feature of virtual reality interventions, the present results suggest that the perceived ability to interact comfortably with the system may represent an important usability-related factor worthy of further investigation, particularly in populations characterized by cognitive fatigue and emotional distress [53–55]. From a behavioral perspective, intuitive interaction may reduce frustration and cognitive burden, thereby facilitating a more positive therapeutic experience.

Despite high levels of enjoyment, autonomy, and immersion, most PENS dimensions showed weak or non-significant associations with adherence and clinical outcomes. This finding contrasts with theoretical assumptions proposing that immersive experience di-

rectly drives engagement and therapeutic response [26,55]. Adherence in fibromyalgia rehabilitation is likely influenced by multiple factors, including fatigue severity, symptom fluctuations, transportation barriers, social support, and treatment expectations [56,57].

Nevertheless, adherence levels observed in the present study were clinically relevant, with most participants completing at least 75% of the prescribed sessions. These adherence levels are particularly relevant considering the persistent barriers to exercise participation commonly reported in fibromyalgia populations [56,58,59]. This finding supports previous reports suggesting that IVR may increase treatment acceptability and engagement in chronic pain populations [53,54]. The gamified and interactive nature of immersive environments may transform exercise into a more motivating and less aversive therapeutic experience, potentially reducing avoidance behaviors commonly observed in fibromyalgia [60–62]. Stress-related symptoms may be more sensitive to short-term changes in attentional engagement and emotional regulation than broader affective domains such as anxiety or depression [63].

Several methodological limitations should be considered when interpreting these exploratory findings. The small sample size may have limited statistical power, particularly for correlation analyses and psychological outcomes. In addition, this study represents a post hoc exploratory analysis derived from a randomized controlled trial. Although the original study included random allocation to experimental and control groups, the present analysis focused exclusively on participants exposed to IVR because user experience was assessed using the Player Experience of Need Satisfaction (PENS) questionnaire, which was only applicable to this intervention. Consequently, causal inferences regarding treatment efficacy cannot be made, and the findings should be interpreted as hypothesis-generating. The intervention duration was relatively short, and adherence was assessed primarily through session attendance, which may not fully capture behavioral engagement. User experience was assessed only in the IVR group and through self-reported measures, which may be influenced by social desirability, response bias, novelty effects, and placebo-related effects commonly observed in exercise and behavioral interventions. In addition, multiple correlation analyses were performed without correction for multiple comparisons, increasing the possibility of type I error. Furthermore, objective behavioral metrics derived directly from the virtual reality system and objective physical performance measures were not available. Future studies should incorporate objective indicators of engagement and functional performance, such as system-derived metrics and maximal or submaximal cardiorespiratory fitness assessments (e.g., VO_2max , six-minute walk test, or other physical performance tests). Finally, the absence of long-term follow-up prevents conclusions regarding the sustainability of the observed effects.

Despite these limitations, this study provides exploratory insights regarding the behavioral dimensions of immersive rehabilitation in fibromyalgia. The findings suggest that user engagement during IVR-based rehabilitation may not depend exclusively on immersion or enjoyment but also on how participants interact with and perceive control over the virtual environment. Future studies should incorporate larger randomized samples, longitudinal follow-up, and objective engagement metrics to better understand the mechanisms linking immersive experience, adherence, and clinical outcomes in chronic pain rehabilitation.

5. Conclusions

This post hoc exploratory analysis suggests that immersive virtual reality (IVR)-based rehabilitation may be associated with favorable user experience and adherence among women with fibromyalgia. The findings indicate that dimensions related to intuitive interaction and perceived control may play a role in behavioral engagement during rehabilitation. Changes in subjective clinical outcomes were observed among participants exposed to IVR;

however, due to the absence of a concurrent control group in the present analysis, the small sample size, and the reliance on self-reported measures, no conclusions regarding treatment efficacy can be drawn. These findings should be considered hypothesis-generating and warrant confirmation in adequately powered randomized controlled trials incorporating objective outcome measures and longitudinal follow-up.

Supplementary Materials: The following supporting information can be downloaded at: <https://www.mdpi.com/article/10.3390/sci8070143/s1>, Table S1: Spearman correlations between PENS dimensions, adherence, and clinical outcomes in the IVR group, including exact *p*-values and bootstrap-derived 95% confidence intervals; Figure S1: Scatterplot illustrating the association between PENS intuitive control and changes in depressive symptoms.

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Institutional Review Board Statement: The study was conducted in accordance with the Declaration of Helsinki and approved by the Scientific Ethics Committee of Universidad San Sebastián (Approval No. 171-25, 12 December 2025). The original randomized controlled trial from which this exploratory analysis was derived was registered at ClinicalTrials.gov (NCT07605143).

Informed Consent Statement: Informed consent was obtained from all subjects involved in the study.

Data Availability Statement: The data presented in this study are available on request from the corresponding author. The data are not publicly available due to privacy and ethical restrictions related to participant confidentiality.

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Conflicts of Interest: The authors declare no conflicts of interest.

Abbreviations

The following abbreviations are used in this manuscript:

IVR	Immersive Virtual Reality
FIQ-R	Fibromyalgia Impact Questionnaire-Revised
DASS-21	Depression Anxiety Stress Scales-21
PENS	Player Experience of Need Satisfaction
BMI	Body Mass Index

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