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SYSTEMATIC REVIEW

Effect of immersive virtual reality as a therapeutic strategy in university students with neck pain

Efecto de la realidad virtual inmersiva como estrategia terapéutica en estudiantes universitarios con dolor cervical

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ABSTRACT

Introduction: imersive virtual reality as been shown to have analgesic effects by facilitating attentional distraction and altering pain perception. Its implementation in therapeutic settings could result in significant functional improvements, particularly for college students suffering from neck pain.
Objective: the purpose of this study is to evaluate the impact of immersive virtual reality as a therapeutic strategy for pain management and cervical range of motion among university students through a systematic review with meta-analysis.
Method: a systematic review was conducted following the PRISMA guidelines, exploring the PubMed and ScienceDirect. Research published in the last five years that applied interventions using virtual reality in young adults with neck pain was included. Methodological quality was assessed using the PEDro scale. In addition, a meta-analysis was performed on three selected studies that reported information related to cervical range of motion, using standardized effect size and a random effects model.
Results: the meta-analysis revealed a significant improvement in cervical ROM after virtual reality-based interventions, especially during rotational movements. The combined effect size was moderate to large (SMD: 0,70-2,47), showing statistically significant results in all studies analyzed. Overall, the methodological quality was considered good (PEDro ≥6).
Conclusions: Immersive virtual reality appears to be an effective tool for improving cervical range of motion among students with clinically relevant neck pain; therefore, its integration into university rehabilitation programs is suggested, as well as further clinical research using larger samples.

Keywords: Immersive Virtual Reality; Virtual Reality; Neck Pain; Pain; Range of Motion.

RESUMEN

Introducción: la realidad virtual inmersiva ha demostrado tener efectos analgésicos al facilitar la distracción atencional y alterar la percepción del dolor. Su implementación en entornos terapéuticos podría resultar en mejoras funcionales significativas, particularmente para estudiantes universitarios que sufren de dolor cervical.

Objetivo: estudio tiene como propósito evaluar el impacto de la realidad virtual inmersiva como una estrategia terapéutica para el manejo del dolor y el rango de movimiento cervical entre estudiantes universitarios, a través de una revisión sistemática con metaanálisis.

Método: se llevó a cabo una revisión sistemática siguiendo las directrices PRISMA, explorando las bases de datos PubMed y ScienceDirect. Se incluyeron investigaciones publicadas en los últimos cinco años que aplicaron intervenciones utilizando realidad virtual en adultos jóvenes con dolor cervical. La calidad metodológica se evaluó mediante la escala PEDro. Además, se realizó un metaanálisis sobre tres estudios seleccionados que reportaron información relativa al rango de movimiento cervical (ROM), empleando tamaño del efecto estandarizado y un modelo de efectos aleatorios.

Resultados: el metaanálisis reveló una mejora significativa en el ROM cervical tras realizarse intervenciones basadas en realidad virtual, especialmente durante movimientos rotacionales. El tamaño combinado del efecto fue moderado a grande (SMD: 0,70–2,47), mostrando resultados estadísticamente significativos en todos los estudios analizados. En términos generales, la calidad metodológica fue considerada buena (PEDro ≥6).

Conclusiones: La realidad virtual inmersiva se presenta como una herramienta efectiva para mejorar el rango de movimiento cervical entre estudiantes con dolores necks importantes clínicamente relevantes; por lo tanto, se sugiere su integración dentro de programas rehabilitadores universitarios, así como fomentar más investigaciones clínicas utilizando muestras más amplias.

Palabras clave: Realidad Virtual Inmersiva; RV; Dolor de Cuello; Dolor; Rangos de Movimiento.

INTRODUCTION

Neck pain is one of the most common reasons for seeking physical therapy and rehabilitation; and it is a public health problem due to its high prevalence, persistence, and functional impact. It is estimated that up to 70 % of people will experience neck pain at least once in their lifetime, with a recurrence rate within the first year after the acute episode.[1] In the case of university students, neck pain has become an increasingly reported phenomenon, associated with prolonged use of technological devices, poor posture, physical inactivity, and psycho-emotional factors derived from academic workload.[2,3]

According to the International Association for the Study of Pain (IASP), pain is defined as "an unpleasant sensory and emotional experience associated with, or similar to that associated with, actual or potential tissue damage".[2,4] In the case of neck pain, the dysfunction is not limited to the physical sphere, but can compromise the student's quality of life, academic performance, emotional regulation, and social participation. Recent studies have shown that 39 % and 42 % of university students have alterations in cervical mobility, with a predominance in women and health science students.

Conventional treatments include therapeutic exercises, manual therapy, neurodynamic techniques, electrical stimulation, or ultrasound, among others. However, many young patients abandon therapy due to low motivation, limited time, monotonous routines, or lack of feedback.[6,7] This raises the need to incorporate innovative strategies that promote therapeutic adherence and optimize functional outcomes.

In this scenario, immersive virtual reality (IVR) has emerged as a disruptive technological tool capable of transforming the patient's experience during rehabilitation. IVR allows the user to immerse themselves in three-dimensional environments designed to promote therapeutic movement in a playful, motivating, and sensorially stimulating way.[8] By stimulating visual, proprioceptive, and vestibular systems, this technology does more than distract attention from pain (analgesic effect); it facilitates functional neuroplasticity and motor relearning.[9]

In addition, IVR can be customized to address specific tasks in the cervical range of motion, making it a particularly useful strategy for improving neck rotation, flexion-extension, and lateral tilt, which are essential variables in cervical vertebrae functionality. Despite [10,11] growing interest in this technology, scientific evidence on its specific efficacy in young university populations with cervical pain is still scarce, scattered, or methodologically heterogeneous.

The purpose of this study is to conduct a systematic review of the literature, accompanied by an exploratory meta-analysis, in order to analyze the impact of immersive virtual reality on cervical range of motion among university students experiencing cervical pain. This work seeks to bring together existing scientific evidence and suggest new directions for its clinical application in the fields of physical therapy and rehabilitation in university settings.

METHOD

Study design

A systematic review with an exploratory meta-analysis was conducted, following the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) guidelines. The purpose was to compile existing evidence on the impact of immersive virtual reality on cervical range of motion among university students with cervical pain.(12)

Inclusion and exclusion criteria

The PICOS criteria were used to establish which studies were eligible:

P (Population): University students (aged ≥18 years) clinically diagnosed with acute or chronic neck pain. I (Intervention): Implementation of immersive virtual reality, either as the primary treatment or as an adjunct to conventional therapies. C (Comparator): Control groups that received conventional therapy, placebo, or no treatment.(13) O (Outcomes): Changes in cervical range of motion (rotation, flexion-extension, and lateral tilt), pain intensity, kinesiophobia, and functionality. S (Design): Randomized clinical trials, quasi-experimental studies, or pilot studies with pre-post evaluation.(14,15)

Articles without full text access, duplicates, narrative reviews, editorials, and those related to instrumental validations that did not involve immersive virtual reality were excluded.

Sources of information and search strategy

A systematic search was conducted in the PubMed and ScienceDirect databases, covering publications in English and Spanish from 2019 to 2024. The following MeSH terms were used together with Boolean operators in PubMed: "Immersive Virtual Reality"[All Fields] OR "Virtual Reality"[MeSH Terms] OR "Virtual Reality"[All Fields]) and ScienceDirect ("Immersive Virtual Reality" OR "Virtual Reality") AND ("Neck Pain") AND ("Range of Motion").

In addition, this search was supplemented by a manual reference analysis based on the selected studies. Bibliographic management and final selection were carried out using the Rayyan QCRI platform.

Selection process

Two reviewers conducted independent evaluations of titles, abstracts, and full texts; any discrepancies were resolved by consensus. The PRISMA diagram illustrates the flow during document selection. Finally, seven studies were included for qualitative review and three more for meta-analysis.

Methodological evaluation

The relevant methodological quality was analyzed using the PEDro scale; research with a score of six or higher was considered adequate. This scale examines aspects such as randomization, blinding, comparability between groups, adequate follow-up, and intention-to-treat analysis.

Data extraction

The following relevant data were recorded from each selected study: author, year, country, research design, demographic characteristics, specific method used, intervention duration, type of cervical movements studied, quantitative results (median, standard deviation), and statistics.

Statistical analysis

An exploratory meta-analysis was performed considering only those three studies whose results allowed comparisons regarding the range of motion, especially cervical rotation and flexion-extension. An exploratory meta-analysis was performed considering only those three studies whose results allowed quantitative comparisons of the range of cervical motion, specifically in rotation and flexion-extension movements. To estimate the effect of treatment, the standardized effect size (SMD) was calculated using Cohen's d formula, applied in contexts of comparison between independent groups (inter-groups). Studies with intra-subject (crossover) designs were not included.

In cases where means and standard deviations (SD) were not directly reported, these values were estimated from t-statistics or p-values, according to the methods proposed in the Cochrane Handbook for Systematic Reviews of Interventions (Higgins et al., 2022). No conversion from standard error (SE) to SD was required, as all calculations were standardized in actual or estimated SDs. Correlation between paired measures was not necessary, as the included studies did not use repeated measures designs. A random effects model was appropriate given the small total number of trials and the expected heterogeneity of VR devices and protocols. The analysis was performed using Python 3.11, making use of scientific libraries to calculate

SMD and graph the forest plot. We also compiled a table compatible with RevMan 5.4 to ensure subsequent replicability.

The meta-analysis included three studies that reported comparable quantitative data on cervical range of motion, specifically in rotation and flexion-extension. Standardized effect sizes (Cohen's SMD) and their respective 95 % confidence intervals were calculated using a random-effects statistical model[16] due to methodological and clinical heterogeneity among the studies. The calculations were performed with Python 3.11 statistical tools,[17] using scientific libraries for manual analysis. Additionally, an input table compatible with RevMan 5.4 software was prepared to ensure the replicability of the analysis and the generation of the forest plot graph.[18]

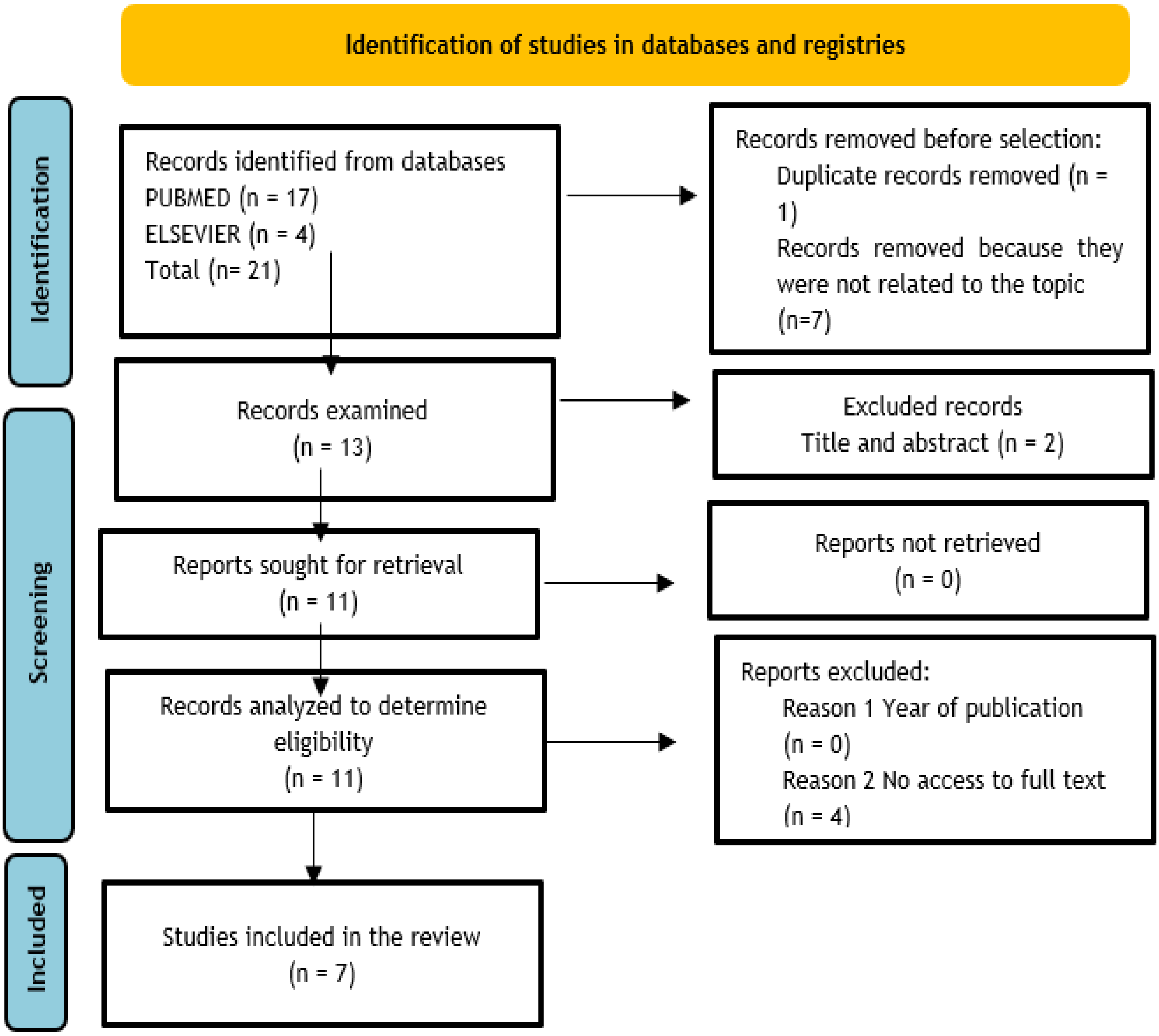

Figure 1. PRISMA 2020 flow diagram for the selection of research in new systematic reviews

Based on the PRISMA diagram, a total of 21 potentially eligible articles were collected, of which 1 duplicate study and 7 studies unrelated to the topic were excluded, leaving 13 manuscripts. After reviewing the title and abstract, 11 potentially significant reports were selected. Based on this exclusion record, the research was reclassified according to the year of publication, as updated evidence published within the last five years was required, and studies to which full access was not obtained for further analysis. After these selection processes, the included texts were analyzed in full, resulting in a total of seven articles that met the previously established inclusion criteria and provided essential information for the research.

EVALUATION OF METHODOLOGICAL QUALITY

The methodological quality of the clinical trials was evaluated using the guidelines established in the PEDRo (Physiotherapy Evidence Database) Scale, which assesses the methodological reliability of the studies considered through 11 items. The first item is not included in the score as it evaluates the external quality of the studies.[15] After analyzing the seven articles, an average score of 6,4 was obtained, broken down as follows: one article was assigned a score of 9 (excellent), one study with a score of 8 (good), two with a total of 7 points (good), one article with a score of 6 (good), another article with a total of 5 (fair), and one article with a score of 3 points (poor).

Table 1. PEDRo scale Methodological quality assessment

Author	1	2	3	4	5	6	7	8	9	10	11	TOTAL
Cetin et al.[19]	1	1	1	1	0	0	1	1	0	1	1	7
Kragting et al.[20]	1	1	1	1	0	0	1	1	0	1	1	7
Gavish et al.[21]	1	0	0	0	0	0	0	1	0	1	1	3
Santos et al.[22]	1	0	1	0	0	1	1	1	0	0	1	5
Tejera et al.[23]	1	1	1	1	0	0	1	1	1	1	1	8
Emedoli et al.[24]	1	1	1	1	1	0	1	1	1	1	1	9
Nusser et al.[25]	1	1	0	1	0	0	1	1	0	1	1	6

RESULTS

Thus, the studies analyzed show the impact of implementing VR as a method of pain reduction, for example in research by Nussser et al.[25] and Emedoli et al.[24] report significant reductions in pain intensity ($p< 0,001$), while Morales shows a reduction in these symptoms up to 1 and 3 months after VR application ($p<0,01$). In contrast, Cetin et al.[19] only report small and moderate effects in terms of pain reduction ($d=0,44$) between the RV and cervical mobilization groups.

Similarly, the studies analyzed present results regarding CROM, specifically Kragting et al.[20] and Emedoli et al.[24] with a large effect on the maximum range of rotation ($p<0,001$, $d= 1,24$); ($p=0,040$), Nusser et al. particularly in rotation and flexion-extension, as well as Kragting et al· demonstrates a mild-moderate effect on the maximum range of flexion-extension ($p=0,018$), as does Cetin et al.[25] with the same impact on left and right lateral flexion between RV and CM ($d=0,54$ and $0,53$) and did not show a significant difference in ROM between the intervention groups ($p>0,005$). Authors such as Santos et al.[22], Tejera et al.[23], and Emedoli et al.[24] obtained an improvement in CROM in all directions with normalcy in all movements ($p>0,05$) when applying the VR strategy. In addition, Gavish et al.[21], using VRPhysio software and certified examiners, guarantee the application of VR therapy + cervical movements as suitable for rehabilitation.

In relation to cervical range of motion (ROM), studies have mainly reported advances in cervical rotation and flexion-extension, which were evaluated using inclinometers, motion sensors, or specialized applications. Three studies with comparable data were selected for the meta-analysis: Kragting et al., Emedoli et al., and Nusser et al. Standardized effect sizes (Cohen's SMD) were calculated using a random effects model due to the clinical heterogeneity observed in both the types of movements measured and the protocols used for the interventions.

The results of the meta-analysis indicate a consistent positive effect associated with the use of immersive virtual reality on cervical range of motion. The study by Kragting et al. showed a very large effect size for cervical rotation (SMD = 2,47; 95 % CI: 1,76–3,18), while Emedoli et al. found a moderate effect related to craniocervical rotation (SMD = 0,68; 95 % CI: 0,04–1,32). On the other hand, Nusser et al. reported a significant improvement in cervical flexion-extension (SMD = 0,70; 95 % CI: 0,03–1,37). All these confidence intervals exclude the null value, suggesting that the observed effects are statistically significant.

Taken together, these findings suggest that immersive virtual reality generates clinically relevant improvements in cervical mobility, especially during rotation-related tasks, which could have important functional implications for rehabilitating students suffering from neck pain. Figure 2 illustrates the forest plot graph showing individual effect sizes and their respective confidence intervals, while table 1 summarizes the methodological characteristics of each of the two included studies.

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Tabla 2. Results

AUTHOR/YEAR	TYPE	POPULATION	INTERVENTION	RESULTS
Cetin et al.[19]	Randomized clinical trial single-blind	n= 41 (RG= 15; CG= 13; EXERCISE= 13	10 sessions, 2 or 3 times per week for 4 weeks. Group with traditional exercise for 20 min with 10 repetitions of each exercise. Diaphragmatic breathing (10 repetitions) Stretching of the pectoral, trapezius, and scalene muscles. Postural education + strengthening exercises (shoulder add and scapular descent + craniocervical flexion + shoulder rotation) GRV: VR + traditional exercise for 20 min each session. RV: Oculus Go device + Ocean Rift app with mechanism for tracking and catching sea creatures GCM: Therapist applied CM (manual cervical traction + bridge technique + lateral sliding + mobilization with rotation and traction, all using the Cyriax technique) + traditional exercise, for 20 minutes with 10 repetitions and 1 minute of rest between each technique.	The JPSE values in neck movements were not significant in any intervention group (p>0,005). GRV and GCM showed irrelevant values with JPSE-flexion 0,01, JPSE extension 0,02, JPSE right rotation 0,12, and left rotation 0,16. In addition, there is a moderate difference between LLF and RLF of 0,54 and 0,53. In terms of VAS values, there was a small to moderate effect of 0,44 when comparing GRV and GCM. Likewise, the NDI values were not statistically significant, nor were the GPE values (p>0,005); however, in the SF-36 results, there was a significant improvement in the CM Group with 21,15.
Kragting et al.[20]	Experimental study with crossover design	n= 54 (RV EFT=27; RV IFT= 27)	Intervention: Seated position + VR headset + shoulder restraint belt (prevents trunk movement) + noise-canceling headphones. Strategies used: VR EFT: Projection of two forest environments, searching for hidden birds for 90 seconds with 2-minute breaks. IFT VR: First, in a dark environment, the patient performed maximum neck rotation to the right and left, maximum neck flexion-extension. Movements performed for 90 seconds, repeating each movement 3 times with 2-minute breaks (during the break, they closed their eyes and kept the VR glasses on).	The range of rotation with VR EFT (mean = 162,1º, CI = 95 %) was greater compared to the range of RV IFT (mean = 135,6º, CI = 95º), registering a significant difference of 27,4º (P<0,001, t(53) = 9,07) and a large effect (d = 1,24). In contrast, the maximum flexion-extension range with RV EFT (mean = 100,4º, CI = 95 %) was lower than that with RV IFT (mean = 108,6º, CI = 95 %), identifying a significant difference of 8,2º (P = 0,018, t(53) = -2,45) with a mild to moderate effect. Regarding Person's r tests, no significant aspects were identified between the range of motion values (RV EFT and RV IFT), and fear of movement related to range of motion also showed no significant results (p ≥ 0,197). Therefore, the differences in RV IFT and EFT performance cannot be explained by differences in fear of movement.
Gavish et al.[21]	Prospective single-visit clinical trial	n= 20	Recorded sessions, use of VR glasses + XRHealth, results evaluated using VRPhysio software. Movements performed: Flexion, extension, rotations, and combinations of both, for a total of 8 movements repeated twice, randomly and each at a speed of 25 seconds.	Main result: movements evaluated by 4 certified physical therapists + VRPhysio software show that 80 % of movements are suitable for cervical rehabilitation. The exact bilateral test reached a real significance of 0,0414 (p<0,001).

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Santos et al.[22]	Development and reliability study	n= 30 (ages 18 to 65)	Instrument: 1 HTC Vive Pro Eye + 1 Vive Tracker + 2 HTC Vive Controllers + 2 Lighthouse base stations + Back movement tracker attached with harness (to measure trunk compensations at T4 vertebra)	Shapiro-Wilk test demonstrates normality in all CROM movements (P>0,05). Of all movements, more compensation is recorded in lateral flexion (variation of 10,61° in Evaluator A and 10,78° in Evaluator B). Intra-evaluator reliability analysis in the measurement without compensation ranges between ICC= 0,86 and 0,96; with compensation ICC= 0,79 and 0,96, and Evaluator A records lower flexion values. Inter-evaluator reliability of CROM: values without compensation between ICC= 0,81 and 0,97 and with compensation ICC= 0,82 and 0,97. SEM and MDC were lower in measurements with compensation correction compared to measurements without correction. As an instrument for evaluating CROM, the application of RV recorded a SD=11 with a total score of 86.
Tejera et al.[23]	Randomized clinical trial Single-blind	n= 44 (GRV= 22; GC= 22)	8 sessions, twice a week for 4 weeks. GRV = Vox Play VR glasses + LG Q6 phone First stage (Fulldive VR): View images, name them, and change them by bending your neck sideways. At the end, they rested for 1 min. Second stage (VR Ocean Aquarium 3D + Sea sounds): Search and identification of marine animals using neck movements (fl, ext, rot) + auditory stimuli from the sound of the sea. In the first interventions, the participants first performed a craniocervical flexion, then the physical therapist used their hands to control the superficial muscle contraction. Gradually, the examiner's assistance was withdrawn to promote correct craniocervical position and deep muscle contraction. Dosage: 3 sets of 10 repetitions, with 30-second breaks between exercises. CG = Traditional exercise In a seated position leaning against the wall + ball, they performed a cervical flexion + sustained craniocervical flexion. In a seated position, cervical extension + craniocervical flexion Craniocervical flexion + rotations + inclinations. Dosage: Same as RV intervention.	GRV= Significant reduction in pain after the intervention (p= 0,01; d= 0,121), at the first month of treatment (p < 0,01, d = 1,12) and at the third month of monitoring (p < 0,01, d = 1,44) CG = Significant reduction in pain after intervention (p < 0,01, d = 0,82), at one month (p < 0,01, d = 1,53) and at three months (p < 0,01, d = 1,44). Statistically significant differences in rotation over time (F= 4,23, p < 0,01, ηp2 = 0,09), however there were no significant effects on: group-time relationship (F= 0,49, p= 0,63, η(p) (2) = 0,01), time factor in flexion-extension and lateral flexion movements (F/E ROM F= 0,32, p= 0,71, η(p) (2) < 0,01; lateral flexion F = 0,86, p = 0,46, η(p)(2) = 0,02), in the time-group relationship (F/E ROM F= 0,03, p= 0,99, η(p) (2)< 0,01; lateral flexion F = 1,65, p= 0,18, η(p) (2) = 0,04) No significant differences were found in the post hoc analysis between the intervention groups in their initial measurements and the follow-up of rotation evolution. Statistically significant differences in the group-time relationship (F=3,89, p=0,01, ηp2=0,08) and over time (F= 16,40, p<0,01, ηp2=0,28). Post hoc analysis revealed significant differences only in GRV: between baseline and 3-month follow-up (p=0,020, d=0,67), baseline and first month (p=0,001, d=−0,90), and baseline and third month (p=0,001, d=−1,42). No significant differences were found in the group-time relationship (F= 0,64, p= 0,58, ηp2 = 0,01), but there were differences over time (F = 24,18, p< 0,01, ηp2 = 0,37). Post hoc analysis showed a moderate-large effect in the GRV: after treatment (p< 0,01, d = 0,54), 1 month of evolution (p<0,01, d= 0,70), 3 months of evolution (p<0,01, d= 0,82). In addition, a moderate effect was observed in the CG: post-treatment (p< 0,01, d= 0,82), 1 month (p< 0,01, d= 0,72), and 3 months (p< 0,01, d= 0,75).

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Emedoli et al.[24]	Randomized controlled trial	n= 50 (GRV= 21; GC= 19)	12 sesiones 2 veces a la semana durante 6 semanas. Sesión 45 min (15 min terapia manual + GRV (30 min RV / GC (30 min ejercicios) GC= 15 min terapia manual + 30 min de ejercicios Ejercicios simples (flexo-extensión cráneo-cervical + flexiones laterales + rotaciones) + ejercicios con movimientos multiplanares + ejercicios de control motor (dibujar figuras geométricas, letras o números en el aire con movimientos en los tres planos, la velocidad iba cambiando según el terapeuta) GRV= 15 min terapia manual + 30 min terapia sensoriomotor con RV + 2 sensores UMI (frente y manubrio del esternón) + ejercicios del GC	GRV revealed significant values in terms of NDI (p< 0,001), NPDS (p< 0,001), NRS (p< 0,001), TSK (p= 0,018) and effects on maximum flexion-extension CROM (p= 0,009), inclination (p< 0,001), craniocervical rotation (p= 0,039). In the comparison between groups, the NDI, NPDS, NRS, and TSK variables did not report significant values, meaning that both treatments presented results of the same magnitude. However, the kinematic results documented notable findings in craniocervical rotations in the VR intervention (p= 0,021).
Nusser et al.	Randomized controlled pilot trial	n= 51 (CG= 20; GSM= 18; GVR= 17)	CG= Traditional rehabilitation (neck exercises, mobilization, strengthening, gymnastics, hydrotherapy, back school technique. SMR= Traditional rehabilitation + 30 min of skill exercises (obstacle course, jumping rope, shooting hoops), balance (standing with eyes closed, single-leg exercises), games (throwing and catching, juggling, curling), and partner activities (ping-pong, badminton). Duration: 4 sessions totaling 120 min. GRV = Traditional rehabilitation + 20 min sensorimotor training for the neck + VR (headset + monitor + 5DT HMD 800-26 2D). They had to move their heads following the orbital trajectories of a globe and keep a white circle as close to the globe as possible; in the virtual projection, this was the orientation of the head. Duration: 120 min of intervention	GRV showed a reduction in head and neck pain both at rest and in motion; in the between-group analysis, GRV had a greater effect on reducing headache pain at rest compared to CG (p = 0,008) and in motion (p = 0,023). VRG showed improvement in all the most significant movements in flexion-extension and left rotation. In the between-group analysis, VRG revealed intermediate and large effects in terms of flexion and extension compared to CG (p=0,041) (p=0,007) and compared to GSM in extension (p=0,031).

Notes: Number of participants; VR: Virtual reality; CM: Cervical mobilization; VRG: Virtual reality group; CMG: Cervical mobilization group; min: Minutes; JPSE: Joint Position Sensing Error; LLF: Left LateralFlexion; RFL: Right Lateral Flexion; VAS: Visual Analogue Scale; NDI: Neck Disability Index; GPE: Global Perceived Effect; SF-36: Short form-36; pcte: Patient; RV EFT: Virtual reality with external focus task; RV IFT: Virtual reality with internal focus task; s: seconds; CROM: Cervical range of motion; SEM: Standard error of measurement; MDC: Minimum detectable change; GRV: Virtual reality group; GC: Control group; SD: Standard deviation; ANOVA: Analysis of variance; minute; NDI: Neck Disability Index; NPDS: Neck Pain and Disability Scale; NRS: Numerical Rating Scale; TSK: Tampa Scale of Kinesiophobia; GSM: Sensory-motor group.

Table 3. Meta-analysis results

Study	Movement	SMD	95 % CI	Interpretation
Kragting et al.	Cervical rotation	2,47	[1,76, 3,18]	Very large effect
Emedoli et al.	Craniocervical rotation	0,68	[0,04, 1,32]	Moderate effect
Nusser et al.	Flexion-extension	0,70	[0,03, 1,37]	Moderate effect

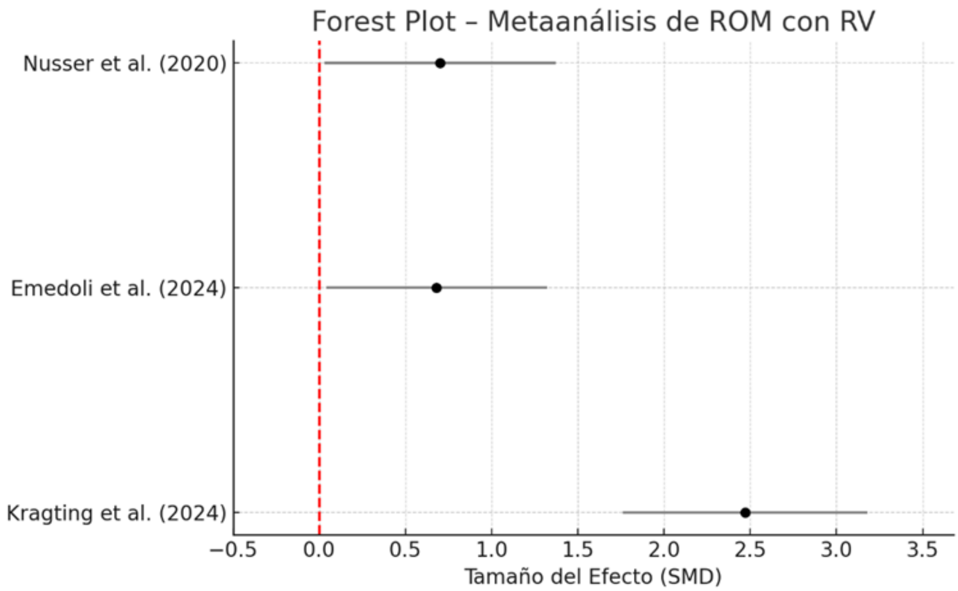

Figure 2. Forest plot

DISCUSSION

Virtual reality is considered to be the distraction that acts as the main analgesic mechanism because the painful sensation is a multifactorial neurophysiological combination generated in the brain in response to different stimuli, It can be modified according to each individual's perception, which, due to its approach to pain processing and diversion of attention from unpleasant sensations, produces a slower response to pain signals, thus acting directly and indirectly on pain signals and perceptions.[(]

According to Tejera et al.[23] and Cioeta et al.[26], there is a significant reduction in pain after the implementation of VR through the attentional distraction mechanism. Neuroimaging studies have shown a reduction in metabolic activity in the areas of the brain linked to pain during VR interventions.[27,28] Other studies that corroborate pain attenuation are Gray et al.[29] and Pandrangui et al.[30] which establish that highly significant values were recorded in terms of pain reduction after the application of interventions with virtual environments during outpatient procedures (debridement and nasal endoscopy) and postoperative procedures (head and neck).

On the other hand, in the study conducted by Cetin et al.[19] the pain factor showed mild and moderate effects in terms of reduction, similar values obtained by Slatman et al.[31] where limited effectiveness is justified due to high expectations of the population, exclusively digital intervention, or insufficient duration/dosage of the intervention. The suggested dose in that study was 200 minutes for the entire intervention, while in the research by Cetin et al.[19] its limited results can be attributed to the fact that the primary purpose of this research was to assess the usability of VR and did not place as much emphasis on other variables.[31]

Likewise, in the projection of virtual environments, the more immersion and interaction VR resources provide, the greater the analgesic effect they will demonstrate, This is because the inclusion of improvements when using VR (use of headsets with a wider field of view, eye tracking, controls, sound, and immersive animation) generates a greater attentional mechanism for the activity being performed, distraction from painful sensations, and greater treatment efficacy. In turn, the inclusion of more immersive resources does not show any side effects. Thedoesshowinclusion of more immersive resources not any side effects.

Cetin et al.[19] and Tejera[23] present statistically significant values in terms of pain reduction which can be associated with the implementation of accessories such as specific headphones, auditory stimuli of the sound of the sea, and the use of the VR Ocean Aquarium 3D app. Similarly, the inclusion of external implements such as interactive VR avatars with immersive interactive cyberhands,[32]as well as Pandrangui,[30] who presented better results when using VR with sound and immersive animation compared to 2D intervention.

Feeling part of the visual illusion makes people more engaged and involved, as they perceive the activities

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as enjoyable, attractive, and innovative, diverting their attention from pain, improving their motivation, and reducing negative states such as anxiety and stress.[33,34] This therapy strategy can also be used when traditional treatment has been applied but the individual is uncomfortable or dissatisfied with the program, in which case VR training will be incorporated to promote adherence to exercise programs while using immersive technology.

In addition, the VR approaches included in this research have demonstrated beneficial effects in terms of improving ROM, with favorable results recorded in active cervical movements in all directions, having a greater impact on maximum ranges of rotation and a lesser effect on flexion-extension. This progress is a result of the visual modulation provided by VR, which improves degrees of range of motion, with greater results in rotation, because the projection of images activates the pyramidal tract, which generates muscle recruitment and subsequently triggers movements with greater amplitude (more intense ROM). According to Harvie and Kragting, discrete or subtle visual feedback will also provide confidence in the execution of movements and transform a painful movement into one without pain and with a greater range of motion.[35] .

The meta-analysis carried out in this systematic review provides quantitative data on the effectiveness of immersive virtual reality (IVR) in increasing cervical range of motion (ROM) among university students experiencing cervical pain. The three studies analyzed reported statistically significant results, with effect sizes ranging from moderate to very large, underscoring the therapeutic potential of this technology in rehabilitation interventions targeting young populations.

The study conducted by Kragting in 2023, showed a considerably large effect size (SMD = 2,47), evidencing a notable difference in cervical rotation in favor of the group that used IVR together with external projection tasks. This finding suggests that immersive environments not only promote active patient participation but also facilitate broader and more functional motor patterns through an external attentional focus, aligned with fundamental principles of motor control and neuroplasticity.[20]

On the other hand, research conducted by Emedoli in 2024 and Nusser et al. in 2020, demonstrated moderate effects on both craniocervical rotation and flexion-extension, respectively. These results support the complementary use of VR combined with traditional methods such as motor control-oriented exercises or manual therapy; this reinforces the idea that integrating immersive technologies into conventional treatment can generate beneficial synergies to facilitate effective functional recovery.[24,25]

Despite the positive effects observed in all the studies included, it is crucial to recognize the clinical and methodological heterogeneity between them—in terms of both the devices used and the doses applied, specific types of virtual tasks, and evaluation variables. However, the statistical model used allowed this variability to be managed and indicated a generally favorable trend toward the effective use of IVR.

Although all three studies presented positive results, it is crucial to note the clinical and methodological diversity that exists between them. This variability encompasses not only the different types of devices used, but also the doses administered, the type of virtual tasks implemented, and the specific variables observed as a result. However, the use of a random effects statistical model allowed this heterogeneity to be managed and corroborated a general favorable trend toward the use of IVR.

Overall, the findings of the meta-analysis support the hypothesis that immersive virtual reality is an effective tool for improving cervical range of motion in students with neck pain; its application could be incorporated into rehabilitation programs for university students. Furthermore, it should be noted that cervical rotation appears to be the movement most susceptible to immersive training, possibly due to its relationship with visual activities and orientation in virtual environments.

However, it is essential to consider certain limitations: the small number of studies included in this meta-analysis restricts the possibility of broadly generalizing its conclusions; in addition, long-term follow-up is needed to better understand how these effects are maintained. Future clinical trials with robust designs, larger samples, and standardized functional assessments are recommended to further strengthen the scientific evidence related to this novel intervention. Furthermore, the review was not extended to other databases.

CONCLUSION

The preliminary evidence from the systematic review presented, supplemented by an exploratory meta-analysis, demonstrates that immersive virtual reality (IVR) is an effective therapeutic strategy for improving cervical range of motion (ROM) in university students suffering from neck pain. The studies evaluated showed effect sizes ranging from moderate to very large, especially in rotational movements. This suggests that immersive experiences can facilitate significant functional recovery within this population.

The use of IVR has notable advantages over traditional methods by integrating elements such as multisensory interaction, playful motivation, and external attention. These characteristics not only improve treatment adherence but also stimulate processes related to neuroplasticity. This issue is particularly important in academic settings where factors such as student stress, poor posture, and low continuity in conventional treatments effectively hinder the rehabilitation of neck pain.

Although the results of the meta-analysis are consistent, caution should be exercised when interpreting them due to the small number of studies analyzed and the differences observed in the protocols used. Therefore, it is recommended that randomized clinical trials with larger samples be conducted and that clinically validated personalized virtual environments be developed to standardize their application within the university physiotherapy setting.

In conclusion, this study provides substantial evidence to support the incorporation of immersive virtual reality into programs aimed at rehabilitating neck pain among students, thus representing an innovative, safe alternative for improving both mobility and cervical functionality in young populations.

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CONFLICT OF INTEREST

The authors declare that there is no conflict of interest.

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