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APPLICATION OF VIRTUAL REALITY TECHNOLOGY TO SLEEP-DISORDERS: A SYSTEMATIC REVIEW OF DATABASES

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Abstract

Background and Objective: Insomnia is one of the most prevalent mental disorders that seriously threatens the lives of individuals. The aim of this systematic review is to evaluate the effectiveness of virtual reality (VR) technology in triggering and treating insomnia.

Methods: This systematic review was conducted by searching relevant articles from 2010 to the first half of 2023. The search strategy was based on the PICO (Population, Intervention, Comparison, Outcome) definition and MESH keywords related to insomnia, sleep disorders, and virtual reality in international electronic databases, including Google Scholar, PubMed, Scopus, Science Direct, ProQuest EMBASE, CINAHL, Magiran, and Iran Medex. A manual search of the reference list of related articles was also performed. The quality of the articles was assessed using the Joanna Briggs Institute (JBI) checklist by two researchers.

Results: Six articles met the inclusion criteria and were included in this review. Studies have shown that the use of novel technologies such as VR positively affects inducing sleep or reducing insomnia in various patient groups compared with control groups using relaxation and medication therapy.

Conclusions: Integrating and applying virtual reality technology in sleep medicine may provide a new solution for inducing, improving, and treating insomnia in various patient groups. Despite the limited studies in this field, the use of this technology can strengthen the knowledge base and contribute to the promotion of public health.

Keywords: Insomnia, sleep disorder, virtual reality, systematic review.

1. Background

Approximately one-third of our lifespan is spent asleep, and quality sleep plays a fundamental role in our health and well-being (1). In other words, sleep is a physiological mechanism of the body that

reflects the recovery of lost energy and fatigue resulting from brain and body activities throughout life, and is an important criterion for maintaining human physical and mental health (2). Falling asleep is a complex process that involves various mental-physiological changes, and disrupting these changes can lead to sleep disorders or insomnia. In other words, the symptoms of physiological changes in the brain cortex and cognitive and emotional arousal often manifest in individuals with insomnia (3,4). Insomnia is one of the most common psychological disorders that pose a serious threat to individuals' lives, both directly and indirectly, and not only affects the individual's life but also has an impact on their family, colleagues, and ultimately the community (5). Insomnia is now defined as an independent disorder and is classified separately in the Diagnostic and Statistical Manual of Mental Disorders, Fifth Edition (DSM-V) and the International Classification of Sleep Disorders, Third Edition (ICSD-3), with forms including difficulty initiating sleep, difficulty maintaining sleep with frequent awakenings, and difficulty returning to sleep and early morning awakening with inability to return to sleep. Insomnia is also classified based on its duration, as transient, short-term, or chronic (6,7). Insomnia is a complicated disorder that has observable effects on both structural and functional levels of the brain. Sleep disorders, insufficient sleep, and sleep deprivation cause neurological, behavioral, and physiological changes, and the consequences of insomnia reduce concentration and weaken problem-solving abilities (8). Insufficient sleep also leads to irritability and disruption of daily functioning, skin aging, and harmful consequences for the cardiovascular system, including high blood pressure, heart disease, arrhythmia, and stroke. In chronic insomnia, there is a disruption in immune system function, fatigue, depression, and an increased risk of suicide in patients with mental disorders (9- 14) Recent studies have shown that the incidence of insomnia has increased during and after the COVID-19 pandemic (2,15). A survey shows that around 30-50% of the world's adult population have reported symptoms of insomnia. This rate is higher in women, divorced individuals, those who have lost loved ones, and the elderly (4).

While the quality of sleep and the treatment of insomnia have become a global concern for community health, approaches such as sleep education, sleep restriction, psycho-pharmacotherapy, sleep hygiene, and relaxation exercises such as yoga and meditation are among the existing and utilized approaches in sleep medicine (16,17). In recent years, the use of virtual reality (VR) technology to improve sleep has become a research focus receiving special attention. These technologies provide new therapeutic solutions under specific conditions (18-21).

VR is a computer-based technology in which a virtual environment is presented to the user, and the user interacts with the virtual environment based on head and body movements (22). In other words, when a person wears a virtual reality headset, they see a space in front of them that changes based on hand and head movements, and the human mind eventually accepts that they are in a real environment (23). This technology allows for practice without time and space restrictions and can also decrease stress and psychological conditions (24). Due to recent advances in technology, virtual reality is introduced as a new phenomenon, referred to as a technological revolution, a complex technology that immerses the user in a virtual environment that is similar to reality. Technological advances have made VR more affordable and its use more common (25). The use of this innovative technology is expanding in various fields of science, and its expansion in the field of medicine and healthcare is also on the rise. Research shows that this emerging technology has been used to facilitate the treatment of cerebral palsy, Guillain-Barré syndrome, Parkinson's disease, phobias and environmental anxiety, clinical education of medical and nursing students, surgical, dentistry, nephrology, and anesthesia assistants (26-33).

A systematic review of the structured analysis of various dimensions of the use of innovative technologies, such as VR, in sleep disorders can lead to the production of theoretical knowledge in the field of medical virtual reality, especially in sleep disorders. The aim of this systematic review is

to summarize evidence relevant to the use of virtual reality in insomnia and to evaluate the effectiveness of this technology in inducing and treating insomnia.

2. Methods

2.1 Search Strategy

The present study is a systematic review of the use of virtual reality in the induction and treatment of insomnia in various population groups compared to other available methods. The review was conducted in accordance with the PRISMA checklist, and a search strategy was developed based on the study objectives and the PICO system (34). The population included all individuals with insomnia in the community, while the intervention involved the use of VR for insomnia in the community. The comparison was made with studies that had a control group, and the outcome was the impact of virtual reality intervention on insomnia in affected individuals in the community. Electronic databases such as Google Scholar, PubMed, Scopus, Science Direct, Magiran, Iran Medex, ProQuest, EMBASE, and CINAHL were searched, and a manual search of the reference lists was also conducted. Suitable and relevant keywords for the search were selected using Mesh or medical and technological subject headings, including both English and Persian keywords such as sleep disorders, insomnia, and virtual reality. Boolean operators (AND, OR) and * were used to combine these keywords for possible search combinations.

2.2 Study Selection and Data Extraction

All available studies on the use of VR in insomnia, including randomized and non-randomized, quasi-experimental, case study, and case series designs, were included in this study from 2010 to mid-2023. The study population included all individuals with insomnia in the community and hospitals from different age groups. The exclusion criteria were conference abstracts, letters to the editor, non-English and non-Persian language studies, and non-interventional studies. In the review process, two independent researchers (S.S.M, SH. S) evaluated the titles, abstracts, and full texts of the studies that combined the keywords of sleep disorders and virtual reality. In case of disagreement between the researchers, the final decision was made by the sleep medicine group manager at Tehran University of Medical Sciences. The final studies were classified based on author information, year of publication, location of the study, study objective, study design, sampling method and characteristics, data collection method, findings, and results after peer review by the researchers.

2.3 Quality Assessment

The JBI checklist was used to assess the quality of the included studies. Each item on the checklist had four response options: yes, unclear, no, and not applicable. Based on this, the studies were categorized into strong (scored over 75%), moderate (scored over 50%), and weak (scored less than 50%) levels after evaluation (35). Articles that were based on the JBI quality appraisal checklist and were categorized as weak based on the researchers' scoring were excluded from the list of studies under consideration in this study.

2.4 Data Analysis

Data analysis was conducted using qualitative content analysis throughout the study. Descriptive statistics were also provided when necessary. After repeated evaluation of the results, primary codes were identified and classified.

3. Results

3.1 Study Characteristics

In the conducted research in Iran, no studies have been performed in the field of utilizing new technologies such as VR for addressing sleep disorders, specifically insomnia. However, a limited number of studies have been carried out in other countries, which we briefly summarize. Based on the PRISMA guideline, six articles were extracted from the total number of articles retrieved, which

investigated the effectiveness of using virtual reality in treating insomnia in various groups. Out of the 40 articles extracted from databases and other sources, 28 articles were removed due to being repetitive, not matching the study objective, submitting abstracts to conferences, or obtaining low-quality assessment scores according to the JBI checklist. The remaining 12 articles underwent quality appraisal and received low-quality assessment scores, resulting in six articles being included in the systematic review (Figure 1).

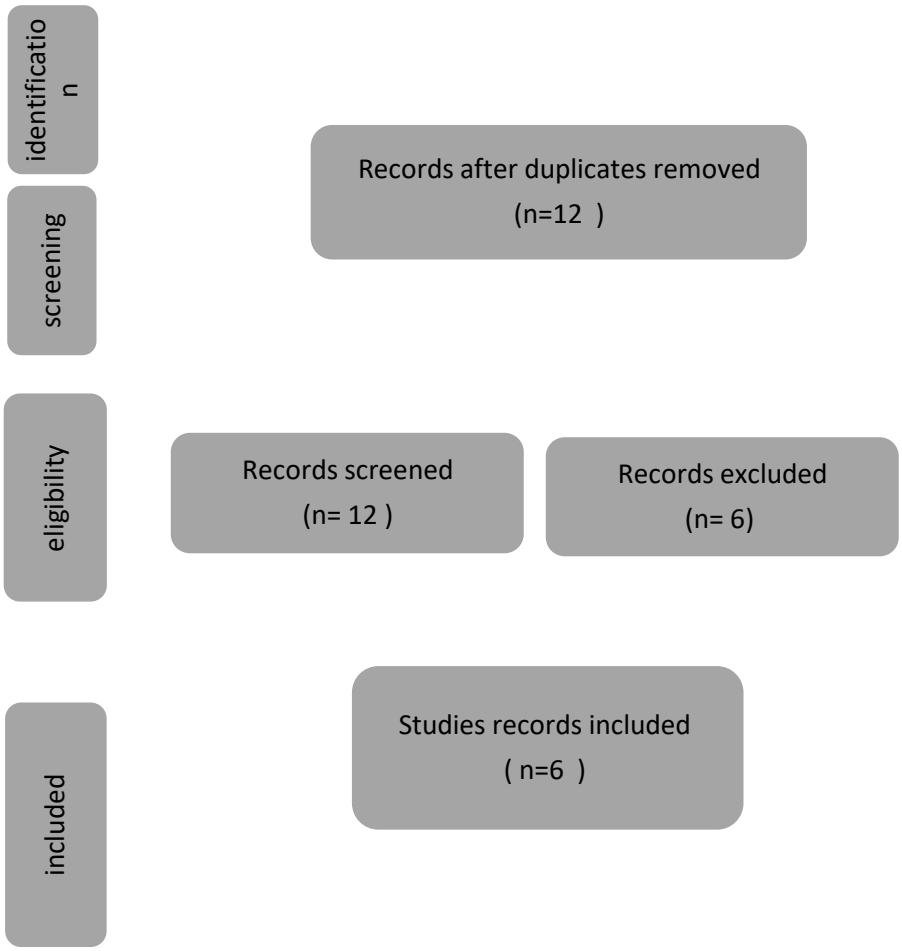

Figure 1. Articles selecting process based on PRISMA

Of the six studies, two investigated the effect of virtual reality on insomnia in cancer patients, one on insomnia in frontline workers facing COVID-19, one on insomnia in ICU patients, one on insomnia in adolescents with a psychophysiological approach to reducing arousal, and one on insomnia in patients with low back pain and sciatica. Various measuring tools were used to assess sleep quality in these studies, with PSG, PHQ, AIS, and ISI being the most commonly used tools. The characteristics of the included studies are presented in Table 1. These studies were extracted from the period between 2010 and mid-2023, and all available studies on the use of VR for treating insomnia were included, whether randomized or non-randomized, quasi-experimental or pre-and post-tests, case studies, or case series. The participants were 152 individuals, including all individuals suffering from insomnia in the community and hospitals from various age groups. The studies showed that the use of new technologies such as VR had a positive effect on inducing sleep or reducing insomnia in various groups of patients.

Table 1. The characteristics of the included studies

Author	Title	Journal name & status	Year and study area	participants	design	Control group	Intervention group	measure	RESULT	Conclusion
Orakpo N, Yuan C, Olukitibi O,Burdette J and Arrington K	Does Virtual Reality Feedback at Infra-Low Frequency Improve Centralized Pain With Comorbid Insomnia While Mitigating	Frontiers in Human Neuroscience Open access	(2022 United States	a patient with clinically diagnosed moderate-severe insomniasecondary to chronic lower back pain and sciatica	Case study	treated with hydrocodone,	(twice weekly for situationPlacing the patient in a 20-session test 10 weeks) in virtual reality neu rofeedback therapy (VR-NFB). Sub-low frequency And follow up inar	ISI	In the present case, secondary insomnia was reduced VR-NFB and dependence on sedatives was eliminated. The patient showed significant improvement in insomnia (70%) through complete cessation of sedative use in the middle of the trial. In the intermediate stage of the trial (10 sessions), with the cooperation of the primary care physician, the patient discontinued the use of	Compared to other biofeedback methods, the VR-NFB approach has an advantage in that it provides a simulation of real life

Massimiliano de Zambotti, Dilara Yuksel, Orsolya Kiss, Giacinto Barresi, Nicole Arra, Laila Volpe1, Christopher King
A virtual reality-based mind–body approach to downregulate psychophysiological arousal in adolescent insomnia
Digital Health
2022community of the San Francisco Bay Area via flyers
Fifty-two 10–12th grade Junior and Senior highschool students (16–20 years; 32 female) were recruited from local high schools the insomnia sufferers' group (N = 18) the good sleepers' group (N = 34)
Experimental Original Research
quiet activity of their choice (e.g. watching TV or reading)
Prior to the main study, all participants underwent an in-lab full clinical polysomnography assessment. On that night, standard EEG, electromyography,bilateral electrooculography, ECG, finger oximetry, nasal airflow, thoracic and abdominal breathing (piezoelectric bands) and leg movement measurements were taken via Compumedics Grael® system(Compumedics, Abbotsford, Victoria, Australia) min of nature-based VR-guided meditation and paced breathing (intervention session) or 20 min without an intervention Before, 20 during and after the 20 min intervention or Control sessions, measures of psychophysiological arousalwere taken
Self-report Cognitive arousal. The Pre-Sleep Arousal Scale (PSAS) The Daytime Insomnia Symptom Scale (DISS), visual analog scale (VAS), ECG and EEG data
significantly higher subjective sleep quality than the control group. Evaluation of activity tracking showed no difference in total sleep time and time spent in light sleep between the groups. The experimental group had significantly shorter wake-up time, longer deep sleep time, and better sleep efficiency. Scores on the four-factor scale of sleep quality (sleep pattern, sleep evaluation, sleep outcome, and sleep disturbance) were higher in the experimental group. significant differences were observed between the groups in wake-up time, deep sleep time, and sleep efficiency.
This study provides evidence for the use of digital technology based on VR for regulating levels of psychological and physiological arousal by acting on cognitive and autonomic neural pathways in adolescent insomnia. Further studies, such as randomized controlled

Yingchun Zeng a, Linghui Zeng a, Andy S.K. Cheng b, Xijun Wei c, Boran Wang d, Jingchi Jiang e, Jin Zhou f	Soon Young Lee a, Jiyeon Kang
The use of immersive virtual reality for cancer-related cognitive impairment	Effect of virtual reality meditation on sleep quality of intensive care unit patients: A randomised controlled trial
Asia-Pacific Journal of Oncology Nursing 9 (2022)	Intensive & Critical Care Nursing
2022 China	2020
Nine subjects with mean age 43.3 years	48 cardiac intensive care unit patients in a university hospital in Korea randomly allocated to the experimental (24) and the control group (24). The mean age of study participants was 66.42 years. Most of them were male and married and about half were diagnosed with myocardial infarction
A single group of pre-test and post-test study	randomised controlled trial experimental group,
---	eye mask, earplugs, massage, meditation, relaxation therapy, footbath, music, acupuncture
The intervention was designed to be administered in approximately ten 30-min VR sessions over a period of 2 weeks	meditation was provided for 30 minutes using a head-mounted display for virtual reality,on the evening of the admission day ICU with cardiovascular diseaseThe study began on the day of admission to the ICU. participants completed (PSQI) questionnaire on their usual sleep and the activity tracker band was placed on their wrist to record theirmovements. The minutes before bedtime (9–11 PM) (WASO) experimental group used the VR meditation programme fo30
(PHQ-9). The Insomnia Severity Index (ISI)	usual sleep quality: PSQI Subjective sleep assessment: Korean Sleep Scale A’ Objective sleep assessment: activity tracker FitBit Charge 2
the VR psychological intervention significantly reduced the severity of sleep disorders ($P < 0.01$)	The experimental group reported significantly higher subjective sleep quality than the control group. The mean score of subjective sleep quality in the experimental group with VR meditation after the intervention (2.25±0.19) was significantly higher than that of the control group (2.06± 0.21) ($t = 3.34$, $p = 0.002$). Evaluation of activity tracking showed no difference in total sleep time and time spent in light sleep between the groups. However, the experimental group had significantly shorter wake-up time, longer deep sleep time, and better sleep efficiency than the control group. Scores on the four-factor scale of sleep quality (sleep pattern, sleep evaluation, sleep outcome, and sleep disturbance) were higher
With the recent advances in artificial intelligence technology and the use of advanced VR, more patients are	Virtual reality meditation had a positive effect on the sleep quality of patients in the intensive care unit. It also reduced wake-up time and increased deep sleep time and sleep efficiency. In future studies, it is necessary to investigate the effects

Tanriverdi M, Cakir E,Akkoyunlu ME, Cakir FB	Xiao Pan, Ying-Cheng Zhang, , Ding Ren, Li Lu, Yi-Hao Wang, Guan-Xiong Li, Ying Xiao, , Hong-Yu Zhou, and Yong-Hai Bai,
Effect of virtual reality-based exercise intervention on sleep quality in children with acute lymphoblastic leukemia and healthy siblings: A	Virtual Reality in Treatment for Psychological Problems in First-Line
Palliative and Supportive Care	The Journal of Nervous and Mental Disease
University, Istanbul, Turkey; Bezmialem Vakif University2022	2022
38 participants. Before intervention, ALL patients (n = 24) and healthy siblings (n = 14	four cases of first-line health care professionals with emerging clinically significant early psychological problems during the COVID-19 outbreak, and specifically received the VRT treatment
randomized controlled tria	Case series participants were the following: a) first-line professionals directly work with patients with COVID-19 at the hospital woman(surgical nurse.) year-old-31 :Case A . Case B : a 30-year-old woman (osteological specialist).
control group were managed	----
The initial PSG and CSHQ of all ALL patients and healthy siblings were recorded. After 12 weeks, only the PSG and CSHQ measurements of the exercise group comprised of 11 ALL patients and 6 healthy siblings were recorded .All recordings started at the child' s usual bedtime and ended at the usual time of getting up in the morning (between pm and 06:00 am). School children were studied on days 09:30	The VRT device which contained a total 12 different virtual scenarios, including grassland, seabed, beach, forest, etc. The setting of therapy was designed to receive 30 minutes of VRT psychological intervention at a specific location, every day for a week, in total seven times In the total seven sessions, all participants followed according to
The initial PSG and CSHQ measurements	Athens Insomnia Scale before and after Sessions PHQ AIS was introduced to evaluate sleep disturbance.
After intervention, total time asleep (p = 0.023), respiratory disturbance index of hypopnea (p = 0.005), apnea/hypopnea index (p = 0.008), and number of apnea (p = 0.028) statistically significant improved	All four cases showed a reduction in scale comparison. General scores ofthe PHQ-9 reduced 65%, , PHQ-15 decreased 38.17%, and scores of the Athens Insomnia Scale reduced 67.44%. For case A, the scores for PHQ-15 and AISdecreased to an underdelimitation level. For case B, PHQ-9, GAD-7, andAIS dropped to an underdelimitation level. PHQ-9, PHQ-15, and AISof case C reduced
The VRBE intervention resulted in improved sleep quality in both patients and their healthy siblings. Game-based exercises using virtual	VR, along with mindfulness-based approaches, has been effective in improving sleep quality. The main limitations are the small

4. Discussion

This study presents a systematic review aimed at evaluating the effectiveness of VR technology in inducing sleep and reducing insomnia among different populations. Among the articles screened, six studies met the eligibility criteria for inclusion in the systematic review. Virtual reality was used to induce or treat insomnia in various groups, including hospitalized patients, adolescents, and professionals. In the control group, other methods for inducing or treating insomnia, such as relaxation, music, games, therapeutic massage, eye masks, watching television, reading, and medication, were employed. The studies revealed that the use of medication for treating insomnia may lead to adverse effects, such as rebound insomnia and anterograde amnesia (36). The results of this systematic review suggest that VR technology may be an effective intervention for improving sleep outcomes in individuals with insomnia.

4.1 Insomnia during childhood and adolescence

Insomnia during adolescence is a complex disorder with multiple causes, including the interplay of normal biological growth behaviors (such as maturation and shifting in circadian preferences) and psychosocial factors (such as increased autonomy, independence, and peer relationships). While the pathophysiology of insomnia is not fully understood, it can lead to disturbances in the cognitive, emotional, autonomic nervous system (ANS), and central nervous system (CNS) functions, resulting in excessive worrying, anxiety, intrusive thoughts, muscle tension, rapid heart rate, and increased activation and metabolism of the brain during sleep when individuals attempt to fall asleep (37-39). The primary cause of insomnia in adolescents is stress, psychological and physiological arousal before sleep, which can lead to delayed sleep onset and/or poor sleep quality. Researchers have suggested the potential use of virtual VR as a tool for facilitating sleep in individuals with insomnia. VR may reduce excessive worry, intrusive thoughts, negative cognition, anxiety, and induce calming and sleep-facilitating effects in adolescents with insomnia (18,40,41). In one study, 20-minute VR meditation sessions were designed to reduce psychological and physiological arousal in adolescents, leading to a decrease in physiological arousal (heart rate and cortisol) compared to the control group. However, no significant change in cognitive arousal levels was observed (36).

Sleep plays a fundamental role in natural growth and development, as well as psychological well-being in children (38). Sleep disorders in healthy and sick children can affect their sleep quality and growth. Engaging methods tailored to children's interests, such as games and exercise, may improve children's sleep (37,42). In a study, various exercise methods in virtual reality were used for 12 weeks in a group of children with acute lymphoblastic leukemia (ALL) and their healthy siblings. The children showed more interest and participation in this method compared to other methods. Furthermore, after the VR intervention, sleep quality improved in all patients and healthy siblings, and sleep anxiety, insomnia, delayed sleep onset, nighttime awakenings, and daytime sleepiness improved (43).

4.2 Insomnia in hospitalized patients

Evidence has shown that sleep disorders and insomnia can lead to a decrease in pain threshold in patients with chronic pain, and conversely, studies have shown that 67 to 88 percent of individuals experiencing chronic pain also complain of insomnia and resort to the use of sedatives (44). Orakpo and colleagues, in their study, used 20 sessions of low-frequency virtual reality neuro feedback designed to distract patients, calm their brains, reduce restlessness, and improve sleep onset in a patient with chronic low back pain and sciatica. The 31-year-old patient reported significant improvements in pain (60%) and insomnia (70%) with discontinuation of the use of cyclobenzaprine sedatives during mid-trial and also discontinued diazepam at the end of the trial (45). Improving sleep quality in cancer patients also helps reduce anxiety and pain (46,47). Lee and Kang found in their randomized controlled trial on 48 patients hospitalized in the cardiac intensive care unit of a university hospital in Korea that 30 minutes of VR meditation had no significant difference in total sleep time and light sleep time between groups. However, the experimental group had significantly shorter wake-up time, longer deep sleep time, and better sleep efficiency than the control group. The use of VR meditation had a positive impact on the sleep quality of patients in the intensive care unit (48). Moreover, describing the experience of patients who have directly used the VR relaxation content and their feedback would be very helpful (49) In their study, Huang and colleagues first defined three levels of insomnia (more than three days in a week, between one to three days in a week, and less than three days) based on information provided by patients and their EEG, and used VR relaxation content to improve sleep quality. Participants reported feeling more relaxed during sleep and described their experience as good and enjoyable, although they found the VR headset uncomfortable (19).

4.3 Insomnia in healthcare workers

Insomnia in healthcare workers during the COVID-19 pandemic has become a significant problem (50). To address this issue, Pan and colleagues conducted a case series study on four first-line healthcare workers with primary clinical psychological problems, including insomnia, who received virtual reality therapy (VRT). They designed a 30-minute psychological intervention using VRT in a specific location, seven times a week for one week. In this study, participants voluntarily chose VR scenarios for 30 minutes. VR combined with mindfulness-based approaches effectively improved the quality of sleep and reduced insomnia in healthcare workers facing COVID-19. The main limitations of this study were the small sample size and the absence of a control group (51).

This study is limited by the small and heterogeneous sample size, methodological heterogeneity among studies, and the lack of meta-analysis. Furthermore, patients mentioned the positive effects of using VR for insomnia, but also negative effects such as discomfort due to the headset and VR equipment, and limited movement during sleep. These issues should be considered in future VR design and production. Most of the studies included in this systematic review had short-term follow-up periods, limiting the ability to evaluate the long-term effectiveness of VR technology in treating insomnia.

5. Conclusions

The findings of this systematic review indicate that virtual reality technology has the potential to be a non-pharmacological intervention for improving sleep outcomes in individuals with insomnia. This systematic review has identified the gap in clinical trials and research focused on the application of novel technologies in improving and treating insomnia. Virtual reality technology may provide a promising non-invasive, cost-effective, and accessible alternative or adjunctive treatment for insomnia. However, further research is needed to determine the efficacy and long-term effects of virtual reality interventions on sleep outcomes.

This study was conducted as part of a research project approved by the Research Deputy of the Sleep Disorders Research Center, Tehran University of Medical Sciences, with project ID 4957-455-4-1401 and ethics code IR.TUMS.IKHC.REC.1401.408. Additionally, this study was registered on the PROSPERO website with registration number CRD42023402861.

Contributors

All authors contributed equally to writing this article.

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