Effectiveness of Virtual Reality-Based Early Rehabilitation Strategies on Pain, Sleep, Anxiety, Balance, Cognition, and Quality of Life in Adult ICU Patients: A Systematic Review and Meta-Analysis of Randomized Controlled Trials

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Abstract

Background: Early rehabilitation strategies based on virtual reality (VR) technology offer a new perspective for the physical, psychological, and cognitive rehabilitation of critically ill patients, yet there are still discrepancies in the effectiveness of related interventions.

Objective: To explore evidence regarding the effectiveness of early VR-based interventions on physical, psychological, and cognitive function indicators in critically ill patients during ICU treatment, as well as during short-term (within 3 months) and long-term (6-12 months) follow-up.

Methods: We searched 10 international and Chinese databases, including PubMed, Embase, and Cochrane Library, for randomized controlled trials (RCTs) published up to May 11, 2025, that applied VR technology for early rehabilitation (within 72 hours of ICU admission). The Cochrane Risk of Bias tool was used to assess the methodological quality of the studies. RevMan 5.3 software was employed for meta-analysis, sensitivity analysis, and subgroup analysis, with standardized mean difference (SMD) and 95% confidence interval (CI) as the combined effect sizes. Stata 17.0 software was used to evaluate the risk of publication bias for relevant indicators. The Grading of Recommendations Assessment, Development, and Evaluation (GRADE) framework was applied to grade the quality of evidence for outcome measures.

Results: Fourteen RCTs involving 1,259 critically ill patients were included. Compared with conventional measures, VR therapy reduced anxiety levels during ICU treatment (SMD = -1.79, 95% CI -3.24 to -0.33; P =.02) and at short-term follow-up (SMD = -0.66, 95% CI -1.17 to -0.15; P =.01). It also improved sleep quality during ICU treatment (SMD = 2.20, 95% CI 0.74 to 3.65; P =.003) and at short-term follow-up (SMD = 0.51, 95% CI 0.15 to 0.88; P =.006), with subgroup analysis showing a better effect on improving sleep during ICU treatment (P =.03). Additionally, VR therapy enhanced balance ability (SMD = 0.88, 95% CI 0.53 to 1.24; P <.01) and quality of life (SMD = 1.27, 95% CI 0.09 to 2.44; P =.03) at short-term follow-up. No significant publication bias was observed for the outcome measures. Due to the lack of blinding of interveners and participants in the studies and substantial heterogeneity among them, the relevant evidence was of moderate to low quality.

Conclusions: Our results preliminarily suggest that early VR-based intervention strategies have positive impacts on relevant outcome measures in critically ill patients during ICU treatment and at short-term follow-up. However, the findings of this review are limited by the small number of included studies, small sample sizes, and substantial heterogeneity among studies. High-quality long-term follow-up studies are still needed to further validate the intervention effects. Clinical Trial: PROSPERO CRD420251114439.

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Review

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Conclusions: Our results preliminarily suggest that early VR-based intervention strategies have positive impacts on relevant outcome measures in critically ill patients during ICU treatment and at short-term follow-up. However, the findings of this review are limited by the small number of included studies, small sample sizes, and substantial heterogeneity among studies. High-quality long-term follow-up studies are still needed to further validate the intervention effects.
Trial Registration: PROSPERO CRD420251114439.

Keywords: Virtual Reality; Intensive Care Unit; Early Rehabilitation; Randomized Controlled Trial; Systematic Review; Meta-Analysis.

Introduction

Patients in the Intensive Care Unit (ICU) are affected by multiple factors, including physiological dysfunction, the use of sedative and analgesic drugs, surgical trauma, pain, limited physical activity, and reduced social interaction [1]. Consequently, they often experience a range of physical, cognitive, and mental health impairments after discharge. In 2010, the Society of Critical Care Medicine (SCCM) of the United States first introduced the term "Post-Intensive Care Syndrome (PICS)" at the Global Critical Care Conference to clearly define this phenomenon [2, 3]. Patients commonly exhibit symptoms such as weakness, pain, anxiety, depression, sleep disturbances, and cognitive dysfunction. These impairments can persist for months or even years. Specifically, 47.9% of patients continue to experience cognitive impairment 3 to 6 months after transfer from the ICU [4]; 68% of patients still suffer from persistent pain after ICU discharge, with pain intensity remaining at a moderate level even one year later [5]. Additionally, 55% of patients experience sleep disturbances within one month after ICU discharge [6]. Furthermore, 12.3% of critically ill patients are diagnosed with depression or anxiety after discharge, and those newly diagnosed with depression or anxiety demonstrate higher long-term mortality rates compared to ICU survivors without such diagnoses [7]. The occurrence of PICS severely compromises patients' quality of life, reduces functional independence, and may even be life-threatening, imposing a substantial caregiving burden on families and society [8].

The SCCM has explicitly pointed out [9] that to reduce long-term impairments following critical illness, healthcare professionals should conduct thorough assessments upon patients' admission to the ICU and develop corresponding nursing coordination strategies to identify and manage relevant impairments. With continuous improvements in clinical treatment, early functional recovery in critically ill patients has become a primary focus in the field of intensive care medicine for reducing the harms associated with PICS [10]. Early rehabilitation involves rehabilitation activities initiated within 72 hours after a patient's admission to the ICU [11, 12], typically commencing within 24-48 hours after achieving hemodynamic and respiratory stability [12]. An increasing number of researchers have implemented early rehabilitation programs during patients' ICU treatment to prevent long-term functional impairments during hospitalization and after discharge. These programs often include early physical activity [13, 14], early neurocognitive stimulation [15, 16], psychological interventions [17], and multimodal rehabilitation plans [18], among others. Existing meta-analytic results have confirmed [19] that initiating early rehabilitation for critically ill patients within 72 hours has the potential to improve physical and cognitive functions, thereby preventing PICS without increasing adverse events. Another related meta-analysis indicated [20] that routine early rehabilitation reduced the incidence of ICU-acquired weakness. However, no significant differences were observed between the two groups in terms of cognitive-related delirium-free days and scores on the mental health-related Hospital Anxiety and Depression Scale. Similarly, a meta-analysis examining the effectiveness of nurse-led routine early rehabilitation programs revealed [21] that such programs significantly reduced the length of ICU stay but did not demonstrate significant effects on mobility, physical function, muscle strength, or mortality. These findings may be attributed to factors such as the time-consuming and labor-intensive nature of existing routine measures, difficulties in standardized implementation by healthcare professionals, and poor active participation and adherence among patients.

Virtual reality (VR), a term first introduced by computer scientist Jaron Lanier in 1989, refers to a simulation technology providing users with an immersive environmental experience [22]. VR technology integrates computer, electronic information, and simulation technologies to enable users to interact with the virtual reality system and experience an immersive, tactile, visual, and multisensory environment via VR helmets, all-in-one devices, and other gadgets [23]. The system is known for its novelty, interactivity, and immersive qualities [24]. VR technology-based rehabilitation techniques have been widely adopted in clinical rehabilitation. There is evidence suggesting that these techniques can effectively improve cognitive function in stroke patients [25], reduce pain levels in patients with chronic low back pain and neck pain [26, 27], and alleviate anxiety and depression [28, 29].

Interventions based on VR technology, as a novel strategy for early rehabilitation in ICU patients, have garnered widespread attention globally and achieved preliminary application outcomes. Researchers often utilize VR technology to provide patients undergoing treatment in the ICU with specific virtual environments (such as viewing virtual natural landscapes [30, 31] or listening to meditation and relaxation music [32]) or virtual tasks (completing memory training games [33] or engaging in cognitive function exercises like "catching coconuts" and "avoiding obstacles" [34]). These approaches aim to enhance patients' rehabilitation motivation and participation while promoting improvements in physiological and psychological function indicators. The design of these contents features interactivity, immersion, and real-time feedback, making them promising tools for advancing personalized and early functional recovery in critically ill patients. However, existing primary studies have demonstrated variations in the effectiveness of early rehabilitation based on VR technology. For instance, one study effectively reduced patients' anxiety levels [33], whereas no significant differences were observed in two other studies [30, 35]. Such inconsistencies may undermine the certainty and consistency of clinical decision-making, hindering the application and promotion of VR technology in early rehabilitation for ICU patients.

To the best of our knowledge, some researchers [36] have explored the intervention effects of VR therapy on patients' PICS through a meta-analysis. However, this study had significant limitations in terms of the included population, as it did not specifically focus on early rehabilitation strategies implemented during ICU treatment. Specifically, the pooled analysis incorporated data from two distinct groups of patients: those receiving VR therapy while in the ICU and those receiving VR therapy during post-discharge follow-up. Nevertheless, there are fundamental differences in the intervention timing, environment, and influencing factors between these two groups. Directly combining data from these two types of studies may introduce clinical heterogeneity, thereby undermining the credibility of the results. Additionally, the findings of another meta-analysis [37] indicated that, compared with traditional rehabilitation techniques, early motor rehabilitation based on VR technology improved balance ability, functional walking, and upper and lower limb motor functions in critically ill patients. However, this review only focused on motor function as an outcome measure, and the effects of early rehabilitation on other functional indicators in patients were not further analyzed and validated.

Objectives

Given the increasing number of trials on early rehabilitation treatment for patients using VR technology in critical care settings, there is a need for a systematic evaluation and analysis of the existing effects of VR-based early rehabilitation. This study aims to conduct a systematic review and meta-analysis of current research findings to investigate the impact of VR-based early rehabilitation strategies on physical, psychological, and cognitive function indicators in critically ill patients during ICU treatment, as well as in the short-term and long-term follow-up after ICU discharge, thereby providing evidence-based support for subsequent related research.

Methods

Study Protocol and Registration

The research protocol for this systematic review was registered in PROSPERO (ID: CRD420251114439). We conducted this systematic review in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA) statement [38] to ensure the transparency of the research. Details can be found in Supplementary File 1.

Data Sources and Search Strategy

The first (WF) and second authors (WYT) independently performed literature searches across six English-language databases, including PubMed, Embase, The Cochrane Library, Web of Science, Ovid Medline, and ProQuest, as well as four Chinese-language databases, namely China National Knowledge Infrastructure (CNKI), Wanfang Data, VIP Information (VIP), and the Chinese Biomedical Literature Service System (SinoMed). We employed a combination of Medical Subject Headings (MeSH) terms and free-text terms such as "virtual reality*", "delirium", "Anxiety", and "Depression" using Boolean operators for the searches. The search period spanned from the inception of each database to May 11, 2025 (to ensure comprehensive retrieval, searches were conducted up to the current date). The language was restricted to Chinese or English. The search strategies for each database are outlined in Multimedia Appendix 1. Additionally, a "snowballing" approach was adopted, which involved tracing the reference lists of included studies and relevant reviews in the field, as well as tracking the articles citing the included studies and the literature suggested by search engines to expand the search scope.

Study Selection

The rationale for formulating inclusion and exclusion criteria was based on the Population, Intervention, Comparison, Outcome, and Study Design (PICOS) framework: (1) Population: Adults aged ≥18 years receiving treatment in the ICU; (2) Intervention: Early intervention strategies based on VR technology (patients were required to receive the intervention within 72 hours of ICU admission); (3) Control: Non-treatment, conventional care measures, or interventions not based on VR technology; (4) Outcome: At least one physical, psychological, or cognitive function indicator (e.g., cognition, pain, delirium, anxiety, depression, post-traumatic stress disorder, sleep quality) reported during ICU treatment or after transfer out of the ICU; (5) Study Design: Randomized controlled trials (RCTs) published in Chinese or English were included to ensure that the study results were derived from the highest level of evidence, thereby minimizing potential bias in evaluating the early intervention effects of VR therapy. RCTs are considered the gold standard for assessing intervention effects because they can minimize confounding variables and bias, providing more reliable and valid results. The exclusion criteria were as follows: (1) Studies that did not report original outcome indicators and for which relevant outcome indicators could not be obtained after contacting the authors; (2) Duplicate publications; (3) Case reports, letters, conference abstracts, and review articles.

Screening and Data Extraction

The first (WF) and second authors (WYT) independently screened the literature, extracted data, and cross-checked the results. Any uncertainties during the screening and data extraction processes were resolved by the corresponding author (CWX). Literature screening was conducted by first reading the titles and abstracts. After excluding obviously irrelevant literature, full texts were further reviewed to determine inclusion. A standardized form was used for data extraction, and the following data were systematically extracted: (1) General information, including the first author, study country, and publication year; (2) Participant characteristics, including disease type, sample size, and baseline demographic and clinical characteristics; (3) Intervention characteristics, including the content of VR-based interventions, intervention duration, intervention frequency, outcome indicators, measurement tools for indicators, data collection periods, and original data such as means, standard deviations, medians, and interquartile ranges. In cases of missing, unclear, or incomplete data, attempts were made to contact the authors via email for further clarification. If the necessary information could not be obtained from the authors after two attempts, recommended formulas were used to calculate the means and standard deviations based on the available data (e.g., using sample size, median, and range) [39].

Risk-of-Bias Assessment

The third (XYN) and fourth authors (ZR) independently evaluated the quality of the included RCTs according to the assessment criteria for RCTs specified in the Cochrane Handbook [40]. Researchers were required to make judgments of "high risk of bias," "low risk of bias," or "unclear risk" for seven items: "Random sequence generation," "Allocation concealment," "Blinding of participants and researchers," "Blinding of outcome assessment," "Incomplete outcome data," "Selective reporting," and "Other bias." If all seven items in an included study exhibited a low risk of bias, it indicated an overall "Low risk of bias" for the study; if some items showed a low risk of bias and one or more items showed an "unclear risk," it indicated an overall "Unclear risk of bias"; if one or more items showed a high risk of bias, it indicated an overall "High risk of bias." In case of disagreements during the quality assessment process, the two researchers and the corresponding author jointly discussed and determined the quality rating.

Statistical Analysis

Review Manager 5.3 software was used for the pooled analysis. All the included outcome indicators were continuous variables, and we conducted a pooled analysis of the means and standard deviations of the two groups after intervention. Due to differences in the assessment tools for outcome indicators across studies, the outcome indicators in the meta-analysis were described using the Standard Mean Difference (SMD) and 95% Confidence Interval (95% CI), with a significance level of $P < 0.05$. Additionally, to reduce bias, we classified the outcome indicators according to the time of collection into three categories: indicators during the patient's ICU treatment, indicators from 2 weeks to 3 months after the patient's transfer out of the ICU, and indicators from 6 months to 12 months after the patient's transfer out of the ICU. To ensure consistent interpretation of the outcome indicators, we reverse-scored the quality-of-life scores assessed by the EuroQol-5 dimension (EQ-5D) and the sleep-quality scores assessed by the Pittsburgh Sleep Quality Index (PSQI) according to the Cochrane Handbook (Version 6.5) [41]. Therefore, higher scores in the pooled results indicated better quality of life and sleep quality for the corresponding patients.

The Cochran Q test and I^2 statistic were used to assess heterogeneity [41], taking into account whether the included studies shared a common true effect size. If there was significant heterogeneity among the studies ($P \leq .1$, $I^2 \geq 50\%$), a random-effects model was used for analysis; if the heterogeneity among the studies was small ($P > .1$, $I^2 < 50\%$) and the studies shared a relatively large common true effect, a fixed-effects model was considered for analysis. Furthermore, a leave-one-out sensitivity analysis was conducted to identify potential sources of heterogeneity and determine the stability of the pooled results. Due to the limited number of included studies, subgroup analyses were only performed for the anxiety and sleep indicators based on the time of indicator collection (during ICU treatment and short-term follow-up after transfer out of the ICU). Descriptive analyses were conducted for outcome indicators with fewer than two included studies. Begg's test and Egger's test in Stata 17.0 were used to assess publication bias.

Evidence Quality

To evaluate the quality of evidence, we used the GRADE approach [42]. A total of two independent assessors used GRADE pro GDT software to assess the evidence quality, and any disagreements were resolved by the corresponding author (CWX). The evidence quality was classified as very low, low, moderate, or high. Footnotes were provided to clarify the reasons for any downgrading of the evidence, including considerations of risk of bias, inconsistency, indirectness, imprecision, and publication bias.

Ethical Considerations

This study used literature data and did not require approval from an ethics review committee or patient consent.

Results

Search Results

A total of 2,853 studies were identified from 10 searched databases. After removing 197 duplicate articles, the titles and abstracts of the studies were initially screened, and 60 full-text manuscripts relevant to this study were identified. Following full-text reading and quality assessment, 14 randomized controlled trials were ultimately included for analysis. The specific search and inclusion process is shown in (Figure 1), and the excluded articles after re-screening along with the reasons are detailed in Multimedia Appendix 2.

Figure 1: Flowchart of literature screening.

Characteristics of the Studies

The basic characteristics of these studies are presented in (Table 1) (at the end of the article). The 14 included randomized controlled trials were published between 2020 and 2025, with research conducted in Italy [44], Turkey [30], South Korea [45, 46], France [17, 35], Spain [47], and China [33, 34, 48 - 52]. A total of 1,259 participants were involved. The sample size of participants recruited in each study ranged from 24 to 180. The types of patient diseases included cardiovascular diseases [31, 35, 49, 51], post-craniocerebral injury surgery [34, 44], post-liver transplantation [52], post-laparoscopic sleeve gastrectomy [30], and post-routine oncological surgery [33], among others. The average age of the included patients generally fell within the range of 60 - 70 years.

The forms of VR technology included fully immersive and non-immersive types. The main content focused on patients' physical exercises [34, 44, 50, 52], where patients were required to complete virtual training tasks such as "catching birds," "playing the piano," "catching coconuts," and "avoiding obstacles" during exercise. Three studies [30, 35, 47] mainly focused on using VR technology to create fully immersive relaxing virtual natural scenes for patients, such as snow-capped mountains, wheat fields, forests, oceans, and mountains, to promote physical and mental relaxation. Four studies [17, 31, 45, 49] mainly focused on using VR technology to facilitate patient meditation, thereby improving sleep quality, including breathing training, hypnotherapy, relaxation therapy, and mindfulness-based cognitive therapy. Three studies [33, 48, 51] included multiple training content scenarios, such as cognitive training, activities of daily living training, psychological relaxation therapy, and family emotional support. The intervention periods and frequencies varied among the 14 included studies, encompassing short-term interventions during ICU treatment and long-term interventions extending beyond patients' transfer out of the ICU. The included studies comprised a total of 15 outcome observation indicators, such as cognitive function, delirium, anxiety, depression, post-traumatic stress disorder, pain, sleep quality, and quality of life. There were also differences in the outcome assessment tools and observation windows used by the researchers.

Risk of Bias

According to the Cochrane criteria, the risk of bias assessments are presented in (Figure 2) and (Figure 3). Due to the nature and setting of VR interventions, it was impossible to blind patients or researchers providing the interventions, resulting in insufficient information for blinding assessment. Overall, the included studies exhibited a relatively high risk of bias. In the domain of "random sequence generation," 13 studies (92.86%) had a low risk of bias, while only one study [51] had an unclear risk. In the domain of "allocation concealment," 7 studies (50%) [17, 31, 44, 45, 47, 49, 50] had a low risk of bias, and 7 studies (50%) [30, 33 - 35, 48, 51, 52] had an unclear risk of bias. In the domain of "blinding of participants and personnel," all 14 studies (100%) had a high risk of bias. In the domain of "blinding of outcome assessment," 4 studies (28.57%) [30, 45, 49, 50] had a low risk of bias, 9 studies (64.29%) [17, 31, 33 - 35, 44, 48, 51, 52] had an unclear risk of bias, and 1 study [47] had a high risk of bias. In the domains of "incomplete outcome data," "selective reporting," and other biases, all 14 included studies (100%) demonstrated a low risk of bias.

Figure2: Risk of bias graph: Proportion of judgements per item in included studies.

Figure3: Risk of bias summary: Items assessed in each included study.

Results of the Meta-analysis

Among the included trials, due to the limited number of studies, we conducted meta-analyses on outcome indicators with at least 2 studies. The specific analysis results are as follows.

Anxiety

A total of 7 studies (35.71%), involving 754 participants, used anxiety as an observed outcome indicator. Among them, 5 studies [17, 30, 33, 35, 49] reported anxiety levels during ICU treatment. Three studies [47, 49, 51] evaluated anxiety levels within 3 months after patients were transferred out of the ICU, and we conducted a subgroup analysis based on the assessment periods in these studies. The results showed substantial overall heterogeneity among the included studies (I^2 = 97%, P < .01), which might be attributed to differences in study populations and assessment tools. After performing a sensitivity analysis using the leave-one-out method, we still did not identify a significant source of heterogeneity, and the combined results across studies were stable. Therefore, a random-effects model was used for result analysis. The meta-analysis indicated that early rehabilitation strategies based on VR technology not only significantly reduced anxiety levels during patients' ICU treatment (SMD = -1.79, 95% CI -3.24 to -0.33; P = .02) but also improved anxiety levels within the period from 2 weeks to 3 months after patients were transferred out of the ICU (SMD = -0.66, 95% CI -1.17 to -0.15; P = .01). However, the difference between the two groups was not statistically significant (P = .15; Figure 4), indicating that it was not possible to conclude which period showed better improvement. Due to the risk of bias and inconsistency caused by insufficient blinding information, the quality of evidence during the ICU stay was rated as moderate, and the quality of evidence after leaving the ICU was rated as low (Multimedia Appendix 3).

Figure 4: Forest plot of subgroup analysis for anxiety.

Sleep Quality

A total of 5 studies (35.71%), involving 453 participants, used sleep quality as an outcome observation indicator. Among them, 4 studies [31, 33, 45, 49] reported sleep outcomes during patients' ICU treatment. Two studies [49, 51] tracked sleep quality outcomes within 3 months after patients were transferred out of the ICU. We conducted a subgroup analysis based on the assessment periods of the indicators. The results showed substantial overall heterogeneity among the included studies (I^2 = 97%, P < .01), which might be attributed to differences in populations and assessment tools. After performing a sensitivity analysis using the leave-one-out method, we did not identify a significant source of heterogeneity, and the combined results across studies were stable. Therefore, a random-effects model was used for result analysis. The meta-analysis indicated (Figure 5) that early rehabilitation strategies based on VR technology not only significantly improved sleep quality during patients' ICU treatment (SMD = 2.20, 95% CI 0.74 to 3.65; P = .003) but also enhanced sleep quality within the period from 2 weeks to 3 months after patients were transferred out of the ICU (SMD = 0.51, 95% CI 0.15 to 0.88; P = .006). Moreover, the difference between the two groups was statistically significant (P = .03), suggesting that early intervention strategies based on VR technology had a greater advantage in improving sleep quality during patients' ICU treatment. Due to insufficient blinding information and inconsistency, there was a certain risk of bias, and the quality of evidence for both was rated as moderate (Multimedia Appendix 3).

Figure 5: Forest plot of subgroup analysis for sleep quality.

Pain

Only 3 studies (21.43%) [17, 30, 35], involving 400 patients, used pain levels during patients' ICU treatment as an outcome indicator. There was substantial heterogeneity among the included studies (I^2 = 94%, P < .01), which might be attributed to differences in study populations and assessment tools. After performing a sensitivity analysis using the leave-one-out method, we still did not identify a significant source of heterogeneity, and the combined results across studies were stable. Therefore, a random-effects model was used for result analysis. The meta-analysis indicated that the early rehabilitation strategy based on VR technology had no statistically significant impact on pain during patients' ICU treatment (SMD = 0.08, 95% CI -0.75 to 0.91; P = .85; Figure 6). Due to insufficient blinding information leading to a risk of bias and inconsistency, the quality of evidence was rated as low (Multimedia Appendix 3).

Balance

A total of 2 studies (14.29%) [34, 52], involving 136 patients, assessed patients' quality of life after they were transferred out of the ICU. There was no heterogeneity among the included studies (I^2 = 0, P = .40). However, due to differences in outcome assessment tools and patient populations among the studies, it was less likely that the included studies shared a common true effect. Therefore, a random-effects model was used for result analysis. After conducting a sensitivity analysis using the leave-one-out method, we did not find a significant source of heterogeneity, and the combined results across studies were stable. The meta-analysis showed that the early rehabilitation strategy based on VR technology improved balance ability within the period from 2 weeks to 3 months after patients were transferred out of the ICU (SMD = 0.88, 95% CI 0.53 to 1.24; P < .01; Figure 6). Due to insufficient blinding information leading to a risk of bias, the quality of evidence was rated as moderate (Multimedia Appendix 3).

Quality of Life

A total of 2 studies (14.29%) [44, 49], involving 172 patients, assessed patients' quality of life after they were transferred out of the ICU. There was substantial heterogeneity among the included studies (I^2 = 85%, P = .009), which might be attributed to differences in assessment tools. After performing a sensitivity analysis using the leave-one-out method, we did not identify a significant source of heterogeneity, and the combined results across studies were stable. Therefore, a random-effects model was used for result analysis. The meta-analysis indicated that the early rehabilitation strategy based on VR technology improved patients' quality of life within 2 weeks to 3 months after they were transferred out of the ICU (SMD = 1.27, 95% CI 0.09 to 2.44; P = .03, Figure 6). Due to insufficient blinding information leading to a risk of bias and inconsistency, the quality of evidence was rated as moderate (Multimedia Appendix 3).

Cognitive Function

A total of 2 studies (14.29%) [47, 48], involving 178 patients, tracked the long-term impact on patients' cognitive function after they were transferred out of the ICU. There was substantial heterogeneity among the included studies (I^2 = 76%, P = .04), which might be attributed to differences in study populations, assessment time points, and assessment tools. After performing a sensitivity analysis using the leave-one-out method, we did not identify a significant source of heterogeneity, and the combined results across studies were stable. Therefore, a random-effects model was used for result analysis. The meta-analysis showed that the early rehabilitation strategy based on VR technology had no statistically significant impact on cognitive function within 6 months to 12 months after patients were transferred out of the ICU (SMD = 0.67, 95% CI -0.04 to 1.37; P

= .07, Figure 6). Due to insufficient blinding information leading to a risk of bias and inconsistency, the quality of evidence was rated as low (Multimedia Appendix 3).

Figure 6: Forest plot for pain, balance ability, quality of life, and cognitive function.

Descriptive Integration Results

We conducted descriptive analyses on outcome indicators for which fewer than 2 studies were included and those that could not be combined for analysis due to differing assessment methods. However, given the limited number of studies, there are currently no additional studies to validate the intervention effects of the aforementioned outcome indicators, and the research results should still be approached with caution. More high-quality randomized controlled trials are needed in the future to evaluate the intervention effects of these indicators.

Assessment Indicators of Motor Function (Disability, Grip Strength, Muscle Strength)

One researcher [44] tracked the impact on patients' disability after providing early physical exercise. The results showed that patients in the experimental group achieved greater improvements in disability (*P* = .001). Xia et al. [50] also evaluated the preventive effect of VR therapy on ICU-acquired weakness in patients. The results indicated that the incidence of ICU-acquired weakness in the experimental group (13.50%) was lower than that in the control group (35.50%), with a statistically significant difference. Additionally, they used an electronic grip strength meter to assess patients' grip strength, but there was no statistically significant difference in grip strength between the experimental group and the control group (*P* = .393). Zhu et al. [52] also used the Manual Muscle Testing (MMT) scale to assess patients' muscle strength. The results showed that after the intervention, the muscle strength scores of the experimental group were higher than those of the conventional control group, with a statistically significant difference (*P* = .023), suggesting that VR-based interventions are one of the promising ways to improve patients' muscle strength.

Assessment Indicators of Psychological Function (Depression, Post-Traumatic Stress Disorder, Somatic Symptoms, Perceived Well-being)

Ventura [47] evaluated the impact of VR therapy on two psychological indicators, depression and post-traumatic stress disorder, in patients one month and 12 months after they left the ICU. However, the results showed that at both one month and 12 months, VR therapy had no statistically significant impact on patients' depression and post-traumatic stress disorder. Li et al. [49] evaluated the impact on patients' somatic symptoms and perceived well-being, in addition to assessing anxiety. The results showed that at one week of ICU hospitalization, compared with the control group, the experimental group was more effective in improving patients' somatic symptoms and increasing perceived well-being scores. However, one month after leaving the ICU, there were no statistically significant differences, indicating that the long-term intervention effects on psychological function indicators still need to be further tracked in the future.

Assessment Indicators of Cognitive Function (Delirium)

Kim et al. [45] used the Confusion Assessment Method for the ICU (CAM-ICU) scale to evaluate the impact of VR treatment on the incidence of delirium in patients. The results indicated that the incidence of delirium was similar between the two groups, with no statistically significant difference (12.2% vs 12.8%, *P* = .938). Weng et al. [33] used the Confusion Assessment Method (CAM) scale to evaluate the severity of delirium in patients. The results showed a statistically significant difference in CAM scores between the two groups (2.25 ± .44 vs 6.37 ± 1.05, *P* < .05). It is recommended that more high-quality studies be conducted in the future with unified assessment standards to validate the intervention effects.

Publication Bias

Although the outcome indicators in this review did not reach the recommended threshold of 10 studies for a reliable interpretation of publication bias assessment, we still conducted a quantitative assessment of publication bias (Egger's test and Begg's test) for the relevant outcome indicators. Although this method falls below the conventional threshold, it still provides valuable preliminary insights into the potential publication bias of these outcomes. The results showed that none of the aforementioned outcome indicators had a significant risk of publication bias ($P > .05$). Specific results are detailed in the Multimedia Appendix 4.

Discussion

Principal Results

This review incorporated 14 eligible randomized controlled trials, summarizing evidence on the short-term effects during ICU treatment and long-term effects after leaving the ICU of early intervention strategies based on VR technology for critically ill patients. The results revealed that, compared with conventional measures in the control group, early rehabilitation programs based on VR technology could reduce patients' anxiety levels and improve sleep quality during ICU treatment. However, the impact on pain requires further observation. Meanwhile, early VR rehabilitation strategies could also lower anxiety levels, enhance sleep quality, quality of life, and balance ability within 2 weeks to 3 months after patients were transferred out of the ICU. Nevertheless, regarding the improvement of cognitive function 6 to 12 months after transfer, the effects of relevant strategies were not yet significant.

Anxiety is a crucial psychological issue among ICU patients. It generates psychological and physiological stress, leading to related surgical complications and prolonged recovery time [53], and increasing the risk of postoperative mortality in patients [54]. Our integrated results show that early interventions based on VR technology can effectively reduce patients' anxiety levels, which is consistent with the findings of Liu et al. [36]. The stress recovery theory may well explain this phenomenon [55]. This theory posits that natural environments (such as landscapes, vegetation, and oceans) can promote relaxation of the parasympathetic nervous system, thereby facilitating positive changes in emotional states. Research has validated that biophilic design elements influence stress recovery and anxiety [56]. In this study, natural landscapes like mountains, rivers, trees, and lakes were predominantly selected as the main content of VR interventions. During the intervention process, patients' blood pressure and respiratory rate significantly decreased [57, 58], which may indirectly confirm the relaxing effect of natural landscapes on the parasympathetic nervous system as proposed in the stress recovery theory. This suggests that early VR intervention therapy may effectively reduce negative feelings caused by stressors such as lighting, noise, and relative isolation in patients, and its intervention may have certain long-term effects, holding potential as an effective measure to improve anxiety in ICU patients during treatment and after leaving the ICU.

Critically ill patients experience fragmented sleep cycles and are unable to effectively transition from light sleep stages to deep sleep stages [59], which is closely related to pain, anxiety/fear, noise, light, and ICU care-related activities [60]. Interventions based on VR technology represent a new strategy, but the effectiveness of VR therapy in improving sleep has been controversial so far [61, 62]. Our review results initially indicate that early VR treatment strategies can improve patients' sleep quality during ICU treatment and in the short term after leaving the ICU. This may be because the protocols of the three studies [31, 45, 49] included in our analysis were designed around VR meditation and VR hypnosis, with the primary research objective of improving patients' sleep quality, which may have achieved better sleep intervention effects. Additionally, given the limited number of studies included and the subjectivity of sleep evaluation tools, as well as the significant heterogeneity in VR intervention frequency and duration, the research results should be viewed with caution. Future studies should further develop standardized VR intervention content, incorporate intervention modules specifically targeting sleep promotion such as VR meditation or hypnosis into the protocols, and adopt more precise and objective sleep measurement and assessment tools, such as polysomnography and wearable devices, to improve research quality and the accuracy of result assessment, and further explore the impact of interventions based on VR technology on sleep quality in critically ill patients.

The short-term effect of early interventions based on VR technology on pain in critically ill patients has not yet reached statistical significance, which may be related to factors such as the limited number of relevant studies, insufficient sample sizes, and inadequate specific content, duration, and intensity of VR interventions. For critically ill patients, frequent threats to mental and physical integrity result in complex and difficult-to-manage pain experiences [63]. Hoffman et al. [64] used functional magnetic resonance imaging to observe that VR intervention during painful stimulation could significantly reduce the excitability of five pain-related regions in the brain, and the higher the level of VR immersion, the stronger the effect of inhibiting activity in brain pain regions. Furthermore, VR devices with immersive experiences can block patients' audiovisual contact with the external environment, diverting their attention away from harmful stimuli that trigger pain [65]. The small number of studies included in our analysis and the relatively low pain report scores in both groups of patients may be related to the use of analgesic drugs, which could be one of the reasons why we did not observe significant differences between the two groups. We believe that early interventions based on VR technology have the potential to become a new attempt at non-pharmacological analgesia measures for critically ill patients.

The formation of balance dysfunction is associated with mechanisms such as muscle atrophy, diminished proprioception, and decreased neuromuscular control resulting from prolonged bed rest, which restricts patients' early mobility and subsequent rehabilitation progress. Our meta-analysis results indicate that, compared with conventional rehabilitation nursing, early intervention based on VR technology improves the short-term balance ability of critically ill patients after they leave the ICU. This finding is consistent with the results of a review by He [37], which explored the effects of VR therapy on early exercise intervention in critically ill patients. Leveraging its immersive environment, VR technology effectively compensates for the sensory interaction deficits in critically ill patients caused by prolonged immobilization and social isolation. Interventions based on VR technology strengthen balance-related sensorimotor pathways and neural plasticity through visual-vestibular-proprioceptive integration [66]. Moreover, intervention strategies based on VR technology facilitate the simultaneous engagement of cognitive and motor functions [67] and employ feedback-driven learning and task-specific adaptation to promote cortical activation [68, 69]. Furthermore, the engaging and gamified design of VR interventions may enhance patient adherence to treatment, which might also be one of the key factors contributing to their superior efficacy compared to traditional rehabilitation approaches. In the future, it is recommended to extensively develop and validate standardized VR intervention protocols in the field of critical care rehabilitation, with particular attention to personalized parameter settings for different populations, while also tracking the long-term efficacy of VR interventions.

Intervention strategies based on VR technology have demonstrated potential in improving cognitive abilities in neurodegenerative diseases [70]. Firstly, interventions based on VR therapy can enhance patients' cognitive reserve, which may then strengthen functional outcomes and mitigate the cognitive impact of gray matter atrophy and brain damage on patients [71]. It has also been proposed [72] that training based on VR technology can stimulate neuroplasticity and improve hippocampal function and hippocampus-mediated memory function, potentially enhancing the therapeutic effects on cognitive function. However, our review results have not yet demonstrated the long-term improvement effect of VR rehabilitation on patients' cognitive function after leaving the ICU. This may be due to the small number of trials included and the heterogeneity among studies, which limit our interpretation of the results. Secondly, all the studies included in our analysis explored the long-term impact of VR therapy on patients' cognitive function after leaving the ICU, which may differ from the results after short-term interventions. The effects on long-term cognitive outcomes still require further exploration.

Quality of life has become one of the important indicators for evaluating the efficacy of rehabilitation exercises in critically ill patients. Our meta-analysis results indicate that early rehabilitation strategies based on VR technology have a positive impact on patients' quality of life within 3 months after leaving the ICU, which is consistent with the results of multiple related reviews [73, 74]. Patients' quality of life after discharge is related to motor ability, activities of daily living, psychological well-being, and sleep quality. Our results suggest that intervention strategies based on VR technology can directly improve the above indicators, which may also be important factors contributing to the improvement of patients' quality of life after leaving the ICU. This provides reference and a basis for medical staff to adopt intervention strategies based on VR technology to improve patients' quality of life after leaving the ICU in the later stage.

Strengths, Limitations, and Future Recommendations

This review has several strengths. Firstly, it represents the latest exploration of evidence regarding the short- and long-term intervention effects of early VR-based treatment protocols on critically ill patients, incorporating a rigorous search across 10 internationally recognized databases. Secondly, stringent inclusion and exclusion criteria were applied, with only studies implementing early intervention within 72 hours of ICU treatment being included, while studies on VR intervention for ICU survivors after discharge were excluded, enhancing the comparability of intervention effects across studies. Additionally, sensitivity analysis using the leave-one-out method was conducted to identify potential sources of heterogeneity, ensuring the robustness of the pooled results.

However, there are also limitations to consider. Firstly, only 14 studies were eligible for inclusion, limiting the interpretation of our results. Moreover, due to variations in intervention modalities, disease types, and measurement tools across included studies, a high degree of heterogeneity and unavoidable potential bias existed. Given the limited number of included studies, subgroup analyses were only performed for anxiety and sleep indicators, and future efforts will focus on collecting more high-quality studies for secondary analysis. Secondly, due to the nature of VR interventions, blinding of intervention providers or participants was not feasible, introducing potential methodological bias and resulting in generally low evidence quality. Therefore, the conclusions of this study should be interpreted with caution.

For future research, it is recommended to conduct high-quality randomized controlled trials with larger sample sizes and longer follow-up periods to investigate the intervention effects of early VR rehabilitation on relevant indicators in critically ill patients. Secondly, the development of standardized early VR intervention protocols, including intervention intensity, frequency, and duration, will help reduce inter-study heterogeneity and improve the comparability of results. Additionally, to mitigate the risk of bias associated with the inability to blind intervention providers and participants, strategies such as blinding outcome assessors, increasing the diversity of control groups, using objective indicators, and conducting long-term follow-up should be employed to ensure the credibility of study results. Finally, fostering interdisciplinary collaboration represents an important direction for future research. The development of large language model (LLM) technology holds potential positive implications for early VR intervention content [75, 76]. With its ability to rapidly integrate and analyze vast amounts of complex text, image, and 3D information, LLM technology can be leveraged to consistently constrain and model the emotions and full-body movements of virtual avatars across multiple dimensions, including visual, auditory, tactile, and perceptual psychology. This will enhance the expressiveness and realism of virtual avatars in various VR scenarios, enabling the generation of high-quality, rich content within VR systems and providing more immersive, present, and intelligent metaverse experiences, thereby further improving user engagement and overall experience.

Conclusions

Our review results indicate that early VR-based intervention strategies are safe and effective for critically ill patients. Despite the limited number of existing studies, our findings preliminarily support the positive impact of early VR-based intervention strategies on anxiety, sleep, and quality of life during and shortly after ICU treatment. It is recommended that healthcare professionals implement early rehabilitation strategies for critically ill patients to mitigate adverse effects during and after ICU treatment in the short and long term. However, there is currently insufficient evidence to demonstrate the long-term effects of this strategy on cognitive function after ICU discharge, and more high-quality randomized controlled trials are needed to track long-term benefits.

Abbreviations

ICU Intensive care units
PRISMA Preferred Reporting Items for Systematic Reviews and Meta-Analysis
RCT Randomized controlled trials
SMD Standardized mean difference
VR Virtual reality
95%CI 95% confidence interval
CNKI China National Knowledge Internet
VIP Chinese Journal Service Platform (Weipu)
SinoMed Chinese Biomedical Literature Service System
PICOS Participants, Intervention, Control, Outcome, and Study Type
MoCA Montreal Cognitive Assessment
EQ-5D-5L European Quality of Life Five Dimension Five Level Scale Questionnaire
HADS Hospital Anxiety and Depression Scale
SAS Self-rating Anxiety Scale
NRS Numeric Rating Scale
PDQ-D Parkinson's Disease Questionnaire – Depression
NPRS Numeric Pain Rating Scale
VAS Visual Analog Scale
CAM-ICU Confusion Assessment Method for the Intensive Care Unit
RCSQ Richards-Campbell Sleep Questionnaire
PSQI Pittsburgh Sleep Quality Index
DTS Davidson Trauma Scale
IES-R Impact of Event Scale - Revised
DASS-21 Depression Anxiety Stress Scales - 21 Items
RFS Revised Fatigue Scale
Berg Berg Balance Scale

Conflicts of Interest

None declared

Data Availability

The data sets generated and analyzed during this study are available from the corresponding author on reasonable request.

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Table 1. Characteristics of studies identified from the literature search.

Study (Author, year)	Country	Types of Diseases	Sample size (Interventio n /Control)	Age	Intervention		Duration and frequency of interventions	Outcome indicator	ICU length of stay(day)
				Intervention/ Control	Intervention group	Control group			
Castelli,2023	Italy	Severe acquired brain injury and Intensive-Care-Unit-acquired weakness	12/12	63.75±12.29/ 62.75 ± 8.29	Using non-immersive VR technology, patients complete corresponding lower limb rehabilitation tasks by viewing virtual scenes displayed on a monitor. Meanwhile, their nerves and muscles are stimulated through the non-invasive device EVM EVO.	Routine care (including passive rehabilitation performed in bed, use of a cycle ergometer, and sitting in a chair)	5 times a week for 3 weeks	① ②	Not Specified
Dong,2023	China	Critically ill patients with cognitive impairment.	68/68	65.8 ± 14.4/ 63.9 ± 12.7	Utilizing VR and human-computer scene interaction technology to deliver motor-cognitive and activities of daily living training, incorporating music therapy, aerobic exercise, and psychological interventions.	No cognitive interventions were administered	Twice weekly for 30 minutes per session, lasting 6 months	① ③	Intervention: 13.8±2.9 Control: 13.1±3.0
Kim,2025	South Korea	Patients with routine general surgical ICU admission	49/47	67.63 ± 11.31/ 66.28 ± 12.5	Patients received standard sleep intervention along with a 20-minute VR meditation session of their choice, which included nature environments, focused meditation, breathing exercises, and tree mindfulness practices.	Routine care (including noise and light reduction, with provision of eye masks and earplugs as required)	Nightly 20-minute interventions at 9:00 PM, continuing until ICU discharge	④ ⑤	Intervention: 2.28 ± 1.23 Control: 2.36 ± 1.45
Laghlam,2021	French	Undergo drain removal after cardiac surgery	90/90	68.0±10/ 68±10.96	Patients experience a choice of five different immersive environments (360° video): snow-capped mountains, landscapes of India or the French Camargue, a balloon ride, or a canoe descent.	Routine care (The therapy utilizing an equimolar mixture of oxygen and nitrous oxide (Kalinox®).)	5 min before 10 min after drain removal, 24 weeks of intervention.	⑥ ⑦	Not Specified
Lee, 2020	South Korea	Cardiovascular diseases (angina, myocardial infarction, heart failure, and cardiomyopathy)	24/24	69.46 ± 16.27/ 63.38 ± 16.53	The patient wears a head-mounted monitor to autonomously select a meditation video that includes nature scenes such as mountains, oceans, or lakes while background sounds and calming music play.	Routine sleep hygiene protocol (including provision of eye masks/earplugs upon request)	30-minute intervention period prior to bedtime on ICU admission day	④	Mean: 2.79 days
Li, 2024	China	Acute myocardial infarction Cardiac ICU	70/78	58.3 ±9.3/ 59.9±9.5	Participants wore head-mounted displays hypnotherapy (day 1), positive cognition (days 2 and 3), music therapy (days 4 and 5) and relaxation therapy (days 6 and 7). Each module contains several scenarios from which participants can choose 1-2 each day.	Mental health support (Mental health support, including brief mental health-related education and daily mental health care provided by nurses.)	Approximately 30 minutes of intervention per day for a total of 7 days.	① ④ ⑦ ⑧ ⑨	Not Specified
Merliot,2022	French		56/54	-/-	Patients were able to use VR goggles to watch real movies, perform breathing exercises, and listen to hypnotic voice guidance.	A 15-minute period for relaxation and distraction, utilizing methods such as television or radio, during which no medical care procedures are to be performed.	Administered once, with each session lasting approximately 15 minutes	⑥ ⑦	8.0 [5.2–12.1]
Ventura, 2021	Spanish	Patients in the combined medical-surgical ICU	21/21	69.1±37.19/ 67.7±36.07	The patient is placed in a relaxation environment (tropical island) consisting of 4 scenes with realistic natural sounds (wheat field, beach, forest, and mountain landscape), where the patient can walk accompanied by a virtual avatar, who promptly orientates the patient and provides instructions to encourage cognitive exercises and relaxation.	Conventional cognitive exercises (i.e., exercises where patients lift each arm against gravity for cognitive interaction training).	Minimum two interventions of 15-20 min each during ICU care, with follow-up after 1 month.	③ ⑦ ⑩ ⑪	Intervention: 16 [6–76] Control: 10 [5–73]
Weng, 2023	China	Patients undergoing tumor surgery, including those with esophageal cancer, gastric cancer, ovarian cancer, brain tumors, and lymphoma	42/42	59.13±5.21/ 58.62±5.18	Provide an immersive audio-visual experience, listen to or watch music, episodes, etc.; hear and see family members record videos, simulate family moments, but also access to the virtual seabed, forest or countryside scenery, etc.; play memory games, intellectual challenges, and other cognitive stimulation.	Routine care(including scheduled turning, intermittent pneumatic compression therapy, endotracheal suctioning, and twice-daily active-assisted/passive range-of-motion rehabilitation exercises.)	Twice daily throughout the entire ICU admission	④ ⑤ ⑦	Not Specified
Xia,2023	China	Patients with routine ICU admission	37/31	62.46±13.95/ 62.58±14.74	Utilize VR technology to simulate interactive scenarios including bird-catching, piano-playing, block-building, as well as calisthenics in a virtual park and tennis matches, enabling patients to complete	Routine early mobilization protocol involves daily exercise sessions at 10:00 AM, comprising pre-activity preparation and a 6-section rehabilitation	Once daily at 10:00 AM, spanning from 24 hours post-ICU admission until ICU	⑫ ⑬	Intervention: 4.65±2.82 Control: 6.90±2.40

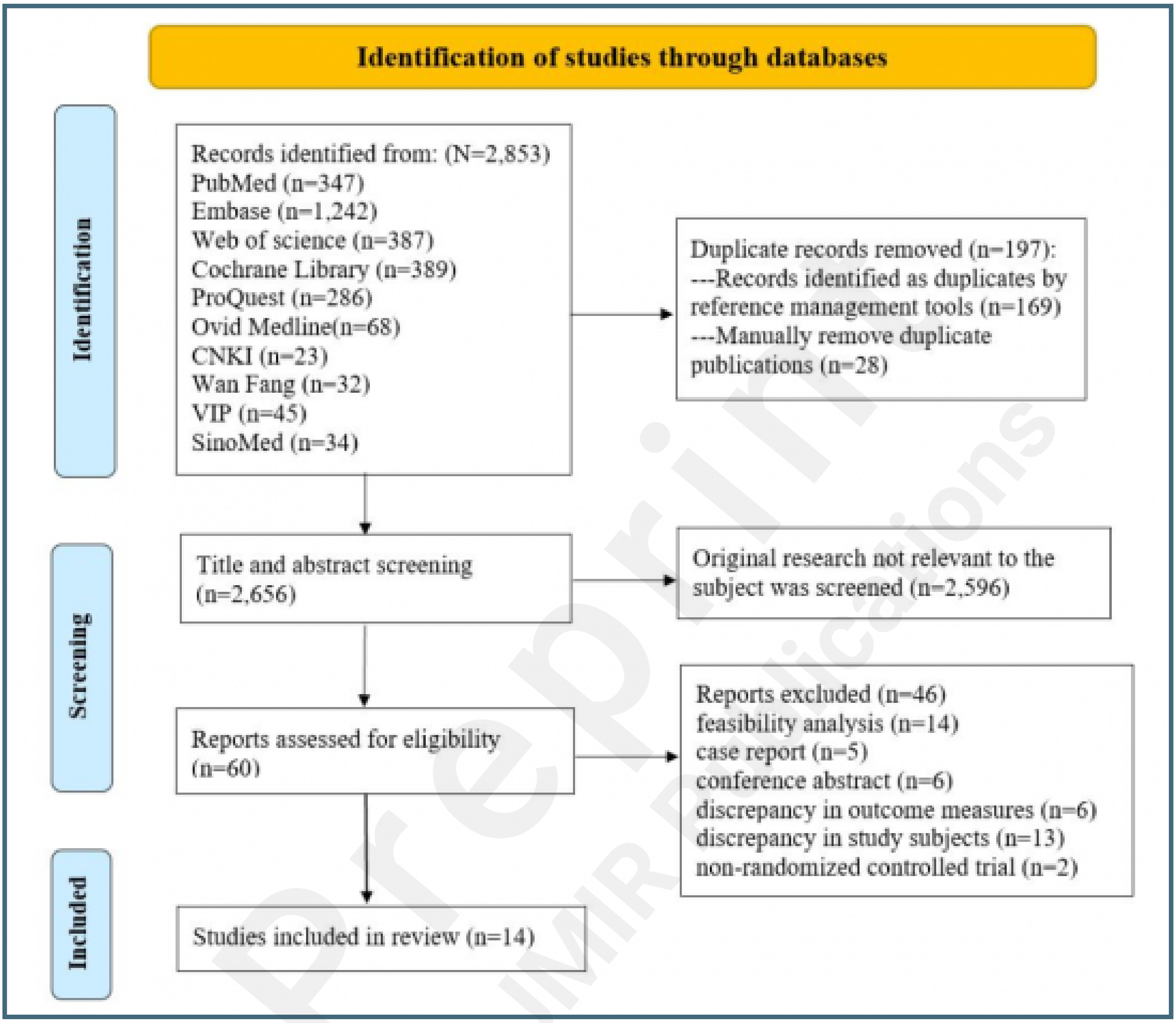
					corresponding exercise tasks.	routine	discharge		
Yesilot, 2022	Turkish	Post-laparoscopic sleeve gastrectomy	55/55	36.62 ± 9.65/ 37.35 ± 12.35	Lie back and watch virtual videos that include images of nature, such as mountains, seas and forests, accompanied by relaxing music.	The patient received pharmacological treatment and remained supine in bed for rest.	A single intervention lasting 30 minutes.	⑥ ⑦	Not Specified
Yan,2024	China	Cardiac surgery patients	39/41	59.26±10.01 / 61.00±10.71	Using VR to introduce ICU environmental information, ICU healthcare team composition and nurse-to-patient ratios, postoperative catheter/tube management, potential postoperative discomforts and coping strategies, respiratory function training, sleep health guidance, postoperative activity and rehabilitation instructions, and family support.	Routine care: Written materials supplemented by verbal explanation of medical risks, anesthesia methods, respiratory function recovery training, key points of catheter/tube care, and early rehabilitation exercise protocols.	A single intervention	④ ⑦	Not Specified
Zeng,2021	China	Postoperative patients with traumatic brain injuries	38/38	48.75 ± 4.19/ 48.52 ±4.36	Patients interact within a virtual environment by moving their upper limbs to catch falling coconuts, accurately avoiding obstacles, and classifying/assembling various household items displayed on the screen.	Routine cognitive-behavioral intervention, encompassing cognitive restructuring, behavioral strategies, and physical functional exercises.	5 days per week	③ ⑭	Not Specified
Zhu,2023	China	Postoperative patients in the intensive care unit following liver transplantation.	30/30	57.33±4.39/ 57.91±4.26	Early-stage bedridden rehabilitation employs low-energy expenditure programs, including simulated penguin-tapping, fruit-slicing, and remote-controlled car racing games; later-stage programs focus on enhancing muscular endurance and active motor control through simulated table tennis, skiing, and other dynamic exercises.	Standard care and rehabilitation training encompass routine health education, dietary guidance, respiratory exercises, bedside defecation/cough training, motor exercises, scheduled repositioning, and pain management strategies.	Once daily for a total of 2 weeks.	① ⑭ ⑮	Not Specified

Note: ① Quality of life (assessed by EQ-5D/SF-36/SF-12); ② Degree of disability (assessed by Disability Rating Scale); ③ Cognitive function (assessed by MoCA scale/ 14 neu-ro psychological measures); ④ Sleep quality (assessed by RCSQ/ PSQI scales); ⑤ Delirium (assessed by CAM-ICU scale); ⑥ Pain (assessed by Numeric Pain Rating Scale (NPRS) / Visual Analog Scale (VAS)/ Numeric Pain Rating Scale (NPRS).; ⑦ Anxiety (assessed by HAM-A/NRS/HADS scales); ⑧ Somatic symptom; (assessed by PHQ-15, patient health questionnaire-15); ⑨ Perceived well-being; (assessed by SF-12 MCS, 12-Item Short Form Health Survey Mental Component Score); ⑩ Depression (assessed by HADS/ PDQ-D scales); ⑪ post-traumatic stress disorder (assessed by DTS scales); ⑫ ICU-acquired weakness (assessed by Medical Research Council Score); ⑬ Grip strength (measured by electronic dynamometer); ⑭ Balance ability (assessed by Berg scale); ⑮ Muscle strength(assessed by Manual Muscle Testing (MMT) Scale).

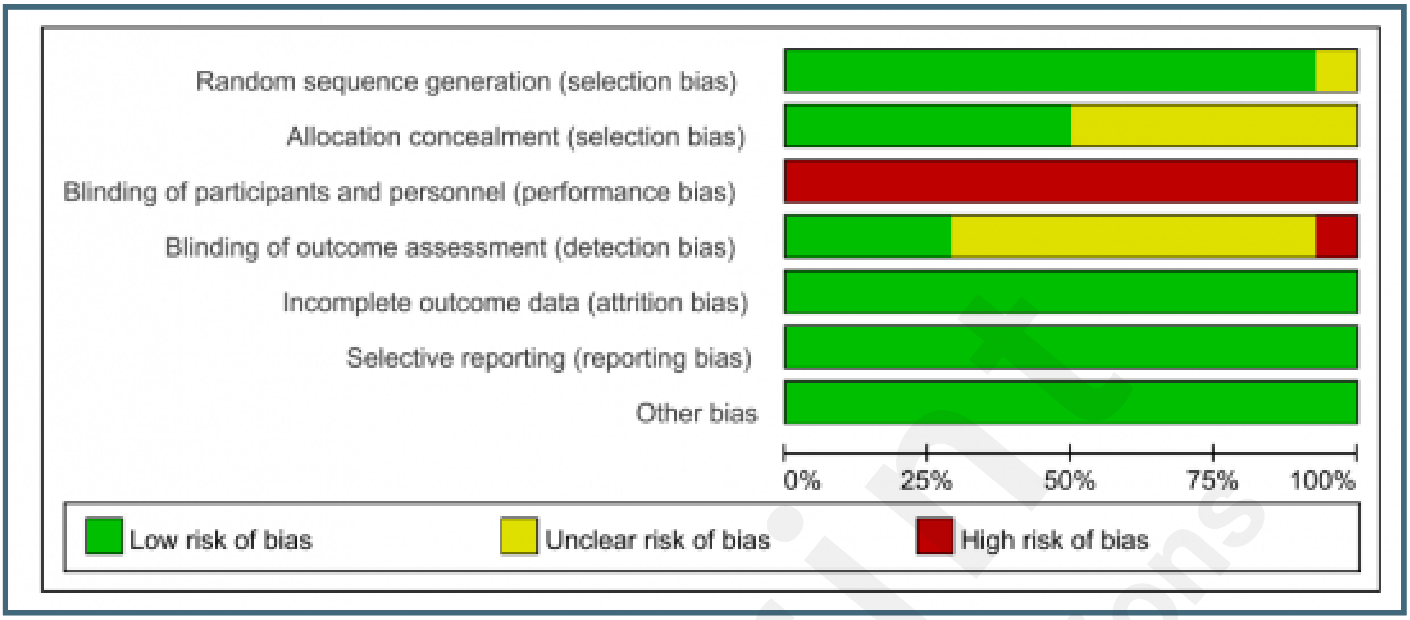
Supplementary Files

Figures

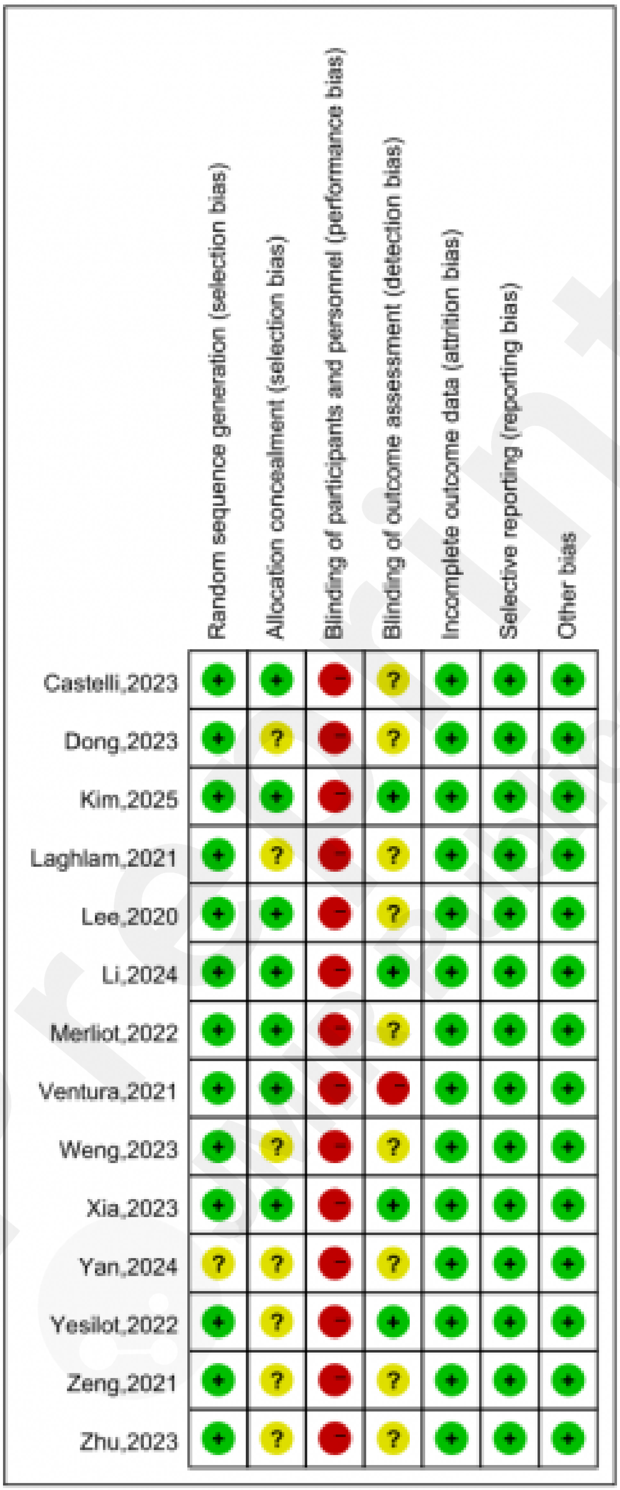
Flowchart of literature screening.



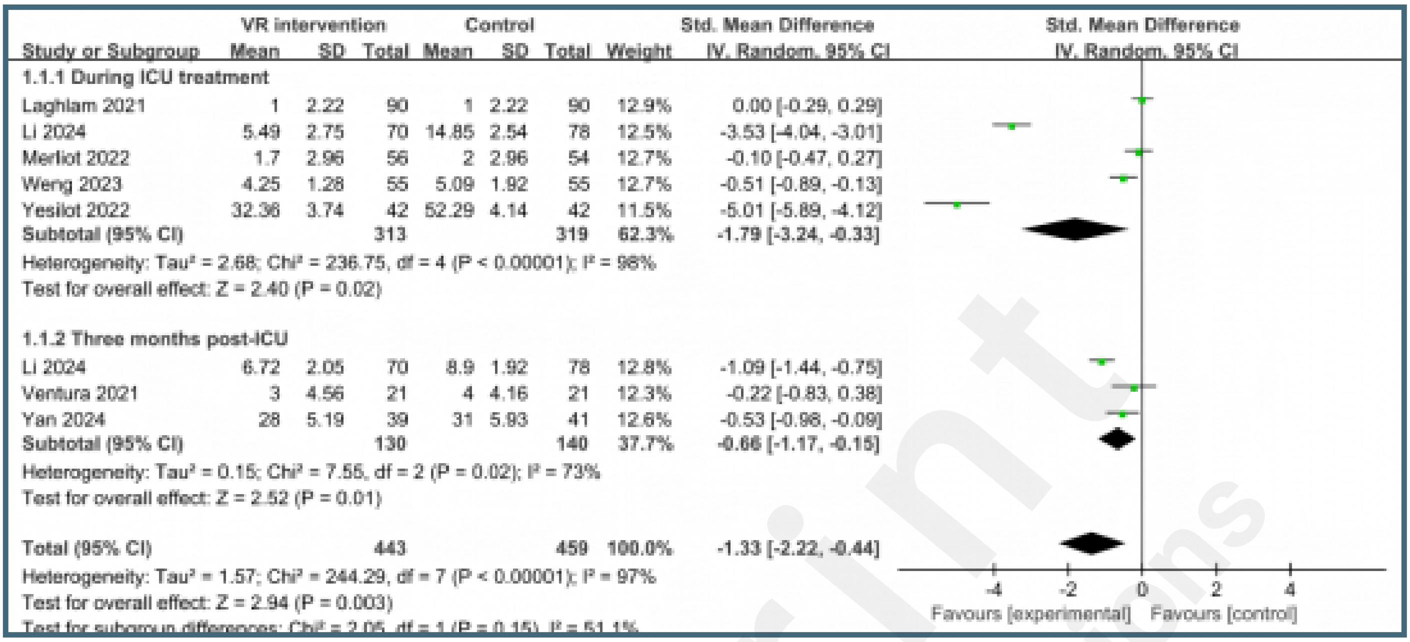
Risk of bias graph Proportion of judgements per item in included studies.



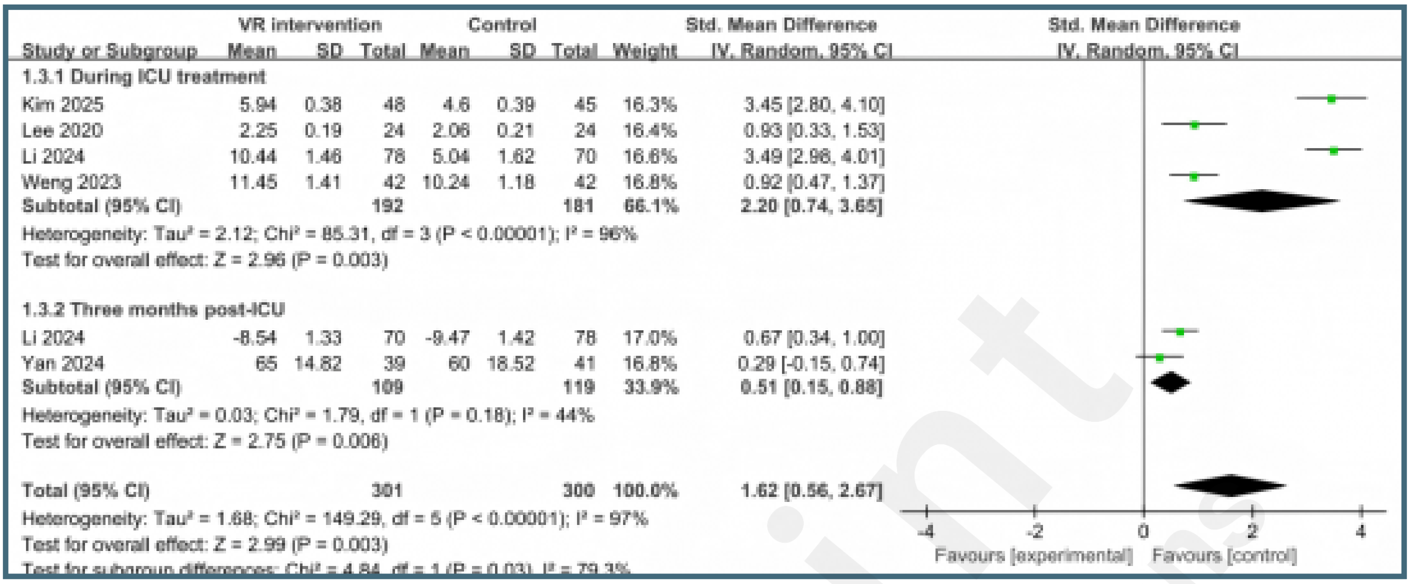
Risk of bias summary Items assessed in each included study.



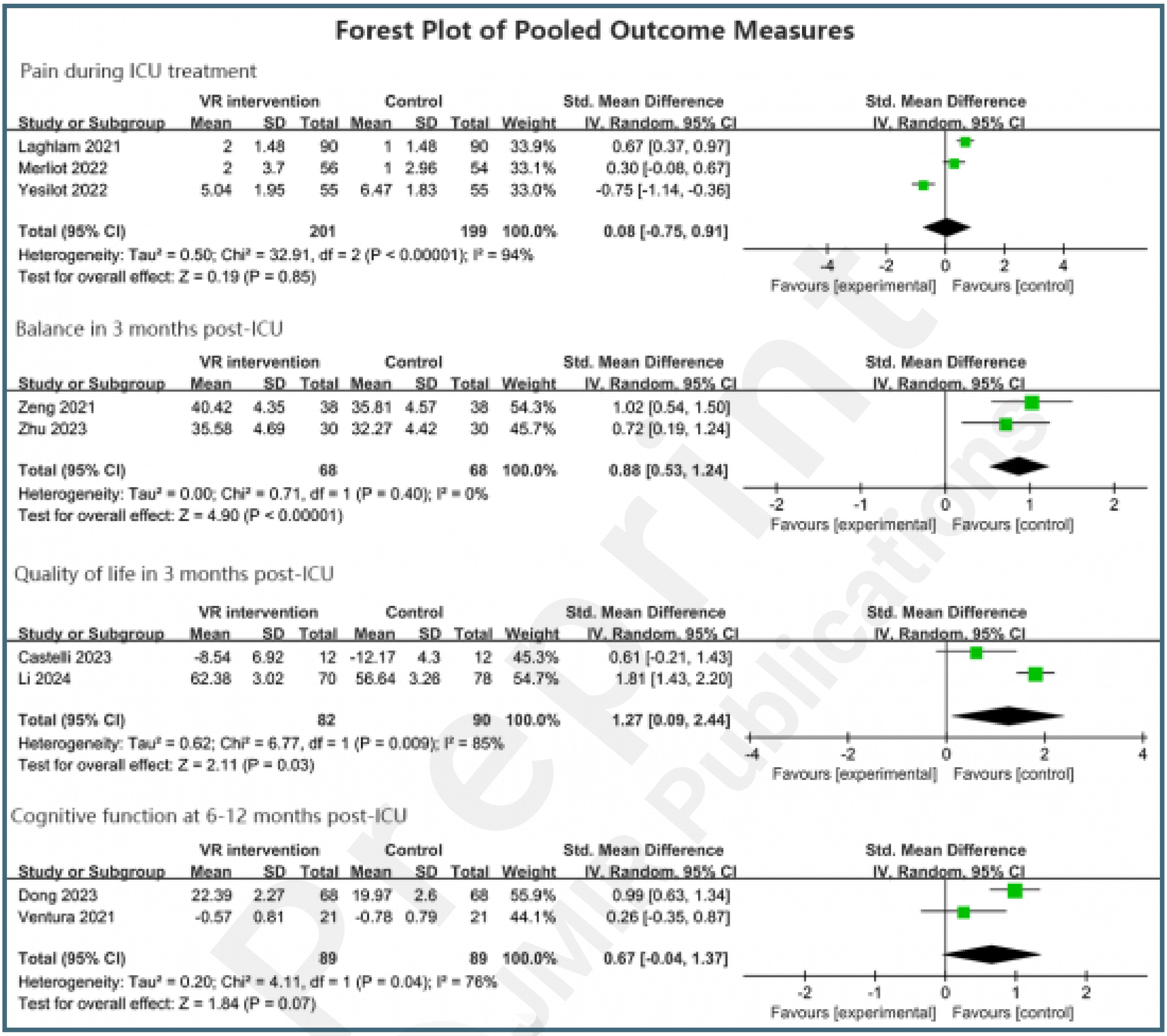
Forest plot of subgroup analysis for anxiety.



Forest plot of subgroup analysis for sleep quality.



Forest plot for pain, balance ability, quality of life, and cognitive function.



Multimedia Appendixes

Detailed search strategy.
URL: http://asset.jmir.pub/assets/f86e8cc3a5b9bcaa52e0c3cd651927b7.docx

Excluded literature and reasons.
URL: http://asset.jmir.pub/assets/5e704e92afa363853f07ee4380f3e230.docx

GRADE Assessment Results.
URL: http://asset.jmir.pub/assets/8447c8ab24c8ec12fe80be376d15bd56.docx

Publication Bias.
URL: http://asset.jmir.pub/assets/53d31ae319b1606af03b118875623abc.pdf

CONSORT (or other) checklists

PRISMA Checklist.
URL: http://asset.jmir.pub/assets/d51ee3114044ff0e88855d7316e7615a.pdf