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Effects of Virtual Reality Based on Fall Prevention Intervention: A Systematic Review and Meta-analysis

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ADMINISTRATIVE INFORMATION

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Amendments - This protocol was registered with the International Platform of Registered Systematic Review and Meta-Analysis Protocols (INPLASY) on 11 June 2025 and was last updated on 11 June 2025.

INTRODUCTION

Review question / Objective We conducted a systematic review and meta-analysis of international and Korean studies on the effectiveness of VR-based fall prevention programs using the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) reporting guideline.

Condition being studied Falls are the most common cause of injury among adults aged 65 and older, with one out of every ten falls resulting in an injury. Approximately 3 million emergency department visits occur annually due to falls in the elderly, and approximately 319,000 older adults are hospitalized each year due to hip fractures. Additionally, falls frequently occur in patients with various conditions such as Parkinson's disease, multiple sclerosis, and stroke. Falls cause significant injuries such as dislocations or fractures, often resulting in hospitalization for moderate-to-severe injuries. Furthermore, prolonged hospitalization can lead to secondary complications, such as pressure ulcers and delirium, which can result in death. Even if death does not occur, many individuals are unable to engage in activities on their own after discharge or are readmitted for institutional care rather than returning home.

Consequently, the importance of balance exercises for fall prevention has recently been emphasized, and methods for balance exercises that are easy and simple to per-form independently have been introduced. Moreover, virtual reality (VR) technology is widely used in the medical field, providing environments that are difficult to experience in real life and allowing interaction with the surrounding environment without direct experience . This technology is used to implement innovative rehabilitation therapies in the cognitive and motor domains.

VR is a form of digital therapy that integrates multiple stimuli through the visual, auditory, tactile, and proprioceptive systems, providing an opportunity for practice in a realistic environment resembling actual objects and events. Repetitive training and simulations have shown significant

potential for advancement in the field of rehabilitation. As a result, VR technology has expanded across the entire healthcare sector, including treatment and rehabilitation.

Recent studies have explored not only traditional fall prevention programs, such as fall prevention, Otago exercise, and self-management, but also the use of VR technology in rehabilitation and exercise therapy. In particular, VR technologies such as the C-Mill (treadmill), Nintendo Wii, and Microsoft Xbox (Kinect)-based gait and balance training have been actively researched for their effects on various fall-related variables, including the Falls Efficacy Scale-International (FES-I), Fall Risk Index (FRI), Fall Risk Assessment Tool (FRAT), Berg Balance Scale (BBS), and Timed Up and Go). In addition, an increase in studies focusing on conditions such as Parkinson's disease (PD), stroke, dizziness, and multiple sclerosis (MS) has been witnessed. These studies suggest that VR technology can be used to effectively prevent falls in individuals with specific diseases.

Although various studies using VR programs have been conducted both domestically and internationally, there is a lack of systematic reviews and meta-analyses on the outcomes of VR-based fall interventions, particularly regarding fall-related variables commonly addressed in nursing, such as the number of falls, FES, FRI, and FRAT. Therefore, this study aimed to comprehensively review recent studies on VR-based fall prevention interventions, evaluate their effectiveness on outcome variables and populations, and propose efficient VR intervention strategies. This study can serve as an important foundation for the development of fall prevention programs in the future and is expected to contribute to the development of policies and frameworks for fall prevention.

METHODS

Search strategy The search terms VR or virtual realt*, accidental falls, fall, or fall prevention were used. Boolean operators OR and AND were applied.

Participant or population Population: This study included all Korean and international participants.

Intervention Intervention: The intervention was fall prevention utilizing on virtual reality (VR).

Comparator Comparison: The control groups received either no intervention or maintenance of the existing program.

Study designs to be included Study design: Randomised and Non-randomzised controlled trials were included.

Eligibility criteria The inclusion criteria were studies that included falls as outcome variables.

The exclusion criteria were as follows: (1) literature for which the original text was unavailable, (2) literature published in a language other than English or Korean, and (3) literature written in the form of qualitative studies, reviews, dissertations, and conference presentation abstracts.

Information sources Literature searches were conducted in PubMed, EMBASE, Cumulative Index to Nursing and Allied Health Literature (CINAHL), Cochrane Library, and Korean data-bases (Research Information Sharing Service (RISS), Korean Studies Information Service System (KISS), Database Periodical Information Academic (DBpia), and KoreaMed).

Main outcome(s) Data collection for systematic literature review and meta-analysis was conducted by three researchers, coding author (year), design, country, age, disease, sample size, duration, frequency, cycle, follow-up, technology, control, outcome, and cross-checking a total of original texts to reach a consensus.

Quality assessment / Risk of bias analysis Assessment of Evidence Quality

The certainty of evidence was assessed using the Grading of Recommendations, Assessment, Development, and Evaluation (GRADE) system, which allows for the evaluation of the following five domains: (i) risk of bias, (ii) inconsistency, (iii) indirectness, (iv) imprecision, and (v) overall quality of evidence.

. After reviewing the data, publication bias analysis was conducted to check for errors and consider their impact [28]. Publication bias was visually assessed using a funnel plot, and asymmetry was evaluated. Additionally, for statistical analysis of publication bias, Egger's regression intercept, and trim-and-fill method developed by Duval and Tweedie [29] were used to assess the extent to which publication bias might have affected the study results.

Strategy of data synthesis The collected data were organized and collated using EndNote X9 and Excel 2024 programs.

Effect size analysis

The effect size and publication bias were calculated using the meta-analysis packages "meta" and "metafor" of the R program. The effect size was calculated using the mean and standard

deviation of the fall variable or the suggested effect size. In cases where the results were presented as odds ratios, the results were converted, and the final results were analyzed using “metagen“. Additionally, analysis was conducted immediately after the intervention and during the follow-up period.

Subgroup analysis Subgroup analysis based on disease, number of interventions, and time immediately after follow-up.

Sensitivity analysis Sensitivity analysis was performed to assess the robustness of the findings, using visual tools such as Baujat plots and influence plots.

Language restriction English and Korean.

Country(ies) involved Korea of Republic.

Keywords virtual reality; fall prevention; fall efficacy scale; number of fall; fear of fal;falls rate to activity; fall risk index.

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