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**EXTENDED
ABSTRACT**

Effectiveness of Virtual or Augmented Reality Therapy in Improving Physical Functionality in Physical Rehabilitation: A Systematic Review

Ily Insyirah Aishah¹, Razif Sazali¹, Yusandra Md Yusoff¹, Muhammad Zulqarnain¹, Amrun Haziq¹, Aizzat Adnan¹, & Adam Linoby^{1*}

¹Faculty of Sports Science and Recreation, Universiti Teknologi MARA, Negeri Sembilan Branch, Seremban Campus, Negeri Sembilan, MALAYSIA

*Corresponding author: linoby@uitm.edu.my

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I. INTRODUCTION

Virtual and augmented reality (VR/AR) technologies are emerging adjuncts in physiotherapy, promising immersive task-oriented practice that could accelerate functional recovery [1]. However, evidence remains fragmented: reviews typically separate VR from AR, focus on narrow conditions, and exclude many clinical populations [2]. This systematic review synthesizes and appraises all available VR/AR rehabilitation trials, maps their clinical applications, and examines the devices, dosages, and variables associated with superior physical functionality outcomes [3].

II. METHODS

With the assistance of a health sciences librarian [4], we searched the Web of Science, PubMed, Scopus, and OVID MEDLINE databases from their inception to January 10, 2025. Search blocks combined “virtual reality” OR “augmented reality” with physiotherapy/rehabilitation terms and randomized-controlled-trial filters. Forward- and backward-citation chasing of pertinent reviews captured additional records [5] on the same date.

We retained peer-reviewed RCTs enrolling ≥ 20 adults (≥ 18 y) with musculoskeletal or neurological functional deficits, comparing immersive or semi-immersive VR/AR-assisted physiotherapy plus standard care against dose-matched conventional therapy or sham digital exercise. Discrepancies were resolved through discussion or third-party adjudication; Cohen κ quantified agreement [6].

Methodological quality was assessed using the 11-item PEDro scale [7], and the risk of bias was evaluated using the Cochrane RoB 2 tool across five domains [8]. All trials were included, but sensitivity analyses excluded PEDro ≤ 3 or high-risk studies [9]. Pooled effects were calculated in Comprehensive Meta-Analysis v4 using Hedges g (continuous) or risk ratios (binary) [10]. Random-effects models were applied when $I^2 > 50\%$ [11]; subgroup analyses explored immersion level, diagnosis, and total VR/AR dose (< 8 h vs ≥ 8 h). Publication bias was assessed using funnel plots, Egger tests, and Duval–Tweedie trim-and-fill methods;

narrative synthesis was employed when pooling proved inappropriate [12].

III. RESULTS AND DISCUSSION

A. Evidence Synthesis & Appraisal

Twelve eligible RCTs (306 participants) show VR/AR-assisted physiotherapy yields moderate-to-large functional gains versus dose-matched conventional care (Hedges g 0.45–1.0, ≈ 10 –20 % extra improvement). Trial quality was acceptable: eight high-PEDro, four moderate; RoB-2 flagged only minor concerns. Overall, evidence supports VR/AR as an efficacious rehabilitation adjunct across heterogeneous musculoskeletal and neurological conditions [2]. Each of the subject characteristics for this study is shown in Table 1.

TABLE I
SUBJECT CHARACTERISTICS

Characteristics	Mean	Median	Min	Max
Age (yrs)	60.5	59.7	47.4	72.9
Height (cm)	162.4	164.8	150.5	179.7
Weight (kg)	63.6	64.6	57.5	69.7
BMI (kg/m ²)	24.8	24.9	21.6	27.4

B. Clinical Fields & Populations

Most studies targeted stroke recovery, geriatric fall-prevention, or Parkinsonian gait, representing 75 % of trials. Participants averaged 60 years (47–73), with balanced sex distribution and stable chronic disease stages. Semi-immersive camera systems led device use, followed by head-mounted displays; AR via tablets or smart-glasses appeared sporadically, indicating early adoption curves in clinical practice.

C. Effective Devices, Dose & Features

Greatest benefits emerged from Kinect balance games and EMG-triggered AR-FES delivered 20–45 min, 3–5 times weekly for ≥ 4 –8 weeks (≥ 8 h total). Effective programmes featured high-repetition [13], task-specific stepping or reaching, real-time multimodal feedback, progressive

difficulty, and simple gamification, all driving adherence and enhancing neuroplasticity-linked functional recovery. Figure 1 shows the study design distribution for included studies, while Figure 2 shows the country distribution.

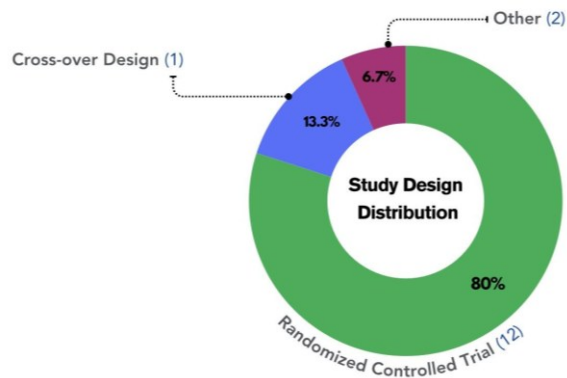


Fig. 1 A donut chart in distinct grey shades that separates Randomized Controlled Trial, Cross-over Design, and Other designs.



Fig. 2 Map showing the geographic origin of the 11 studies included in this systematic review. Colour intensity reflects the number of studies per country (scale 1–11).

IV. CONCLUSIONS

VR/AR-integrated physiotherapy confers moderate-to-large functional benefits across stroke, balance, and Parkinson's cohorts [14], driven by semi-immersive cameras and EMG-linked AR protocols at cumulative doses of ≥ 8 hours. High methodological quality and low bias support effectiveness, yet limited sample sizes [15] and sparse AR trials warrant larger, condition-specific RCTs to confirm durability.

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