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Virtual and Augmented Reality for Physical Function in Rehabilitation: An Umbrella Review of Evidence Synthesis

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I. INTRODUCTION

Virtual and augmented reality are increasingly integrated into rehabilitation to enhance physical function through immersive, interactive training. Despite numerous systematic reviews, inconsistencies in outcomes, heterogeneity, limited long-term data, and sparse safety reporting hinder definitive conclusions. This umbrella review synthesizes existing evidence to evaluate overall effectiveness, identify moderating factors, and assess personalization strategies influencing functional recovery and engagement in rehabilitation populations.

II. METHODS

An umbrella review was conducted following PRISMA guidelines. Eleven databases, including MEDLINE, EMBASE, CINAHL, CDSR, CENTRAL, Web of Science, Scopus, and IEEE Xplore, were searched from inception to May 2025. Eligible studies were systematic reviews and meta-analyses of VR/AR interventions targeting physical function. Methodological quality was appraised using AMSTAR 2, and evidence certainty was graded with GRADE. Random-effects re-analyses were performed where feasible.

III. RESULTS AND DISCUSSION

Synthesised evidence demonstrated generally positive but methodologically inconsistent effects of VR/AR on physical function. Improvements in gait, balance, and upper-limb performance were frequently reported, with some exceeding clinical significance thresholds. However, most outcomes were graded low to moderate certainty due to short follow-up, small samples, and substantial heterogeneity. Immersive VR showed stronger and more consistent functional gains than marker-based AR, particularly in neurological populations. Dose-response patterns suggested moderate-to-high session frequency and cumulative hours improved outcomes, though optimal parameters remain undefined. Baseline severity, age, and neurological diagnosis influenced responsiveness, with milder impairments demonstrating greater durability.

Personalized VR/AR interventions enhanced engagement, adherence, and task persistence through adaptive difficulty and feedback. Tailored programmes demonstrated superior motor gains and improved psychosocial indicators, including motivation and self-efficacy. Emotional relevance and goal alignment strengthened participation, suggesting personalization is a critical mediator of both functional and behavioural rehabilitation outcomes.

IV. CONCLUSIONS

Virtual and augmented reality demonstrate promising yet methodologically constrained benefits for physical rehabilitation. Immersive modalities, adequate dosing, and personalized delivery enhance functional and psychosocial outcomes. However, low-to-moderate evidence certainty, short follow-ups, and inconsistent safety reporting limit definitive guidance. Rigorous, theory-driven, long-term trials are essential to establish durable clinical value.

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