**Title: Exploring the Potential of Virtual Reality in Knee Therapeutic Exercises: An Umbrella Review**

**Abstract:**

**Backgrounds:**

Musculoskeletal disorders of the knee pose a significant health challenge, requiring effective interventions to enhance patient outcomes. However, conventional therapeutic exercises encounter issues related to adherence and motivation. Therefore, Virtual Reality (VR) has emerged as a promising approach, leveraging immersive experiences to develop rehabilitation. This umbrella review was conducted to comply evidence from the existing systematic reviews on the effectiveness of VR therapeutic exercises while considering technology variations and outcome measures. Our objective is to offer practical recommendations for incorporating VR into physiotherapy and to promote robust studies in this field.

**Methods:**

A protocol was developed by following the Joanna Briggs Institute (JBI) manual for evidence synthesis and registered in the International Prospective Register of Systematic Reviews (PROSPERO) (CRD42022323746). A thorough search was conducted across reputable databases, such as AMED, CINAHL, EMBASE, MEDLINE, IEEE Explore, PubMed, PEDro, Scopus, and Web of Science. The search strategy combined the following keywords {Knee AND Virtual reality AND Rehabilitation OR therapeutic Exercise} with subject heading terms. Following the same strategy, the grey literature was also searched (e.g., Google Scholar).

**Eligibility Criteria:**

Inclusion criteria: Systematic reviews, with or without meta-analyses on the effectiveness of VR-based therapeutic exercises for adults aged 18 years or older with knee musculoskeletal disorders and had Evaluated function, pain severity and quality of life as outcomes.

Exclusion criteria: Systematic reviews that do not have a clear focus on or sub-analysis of knee musculoskeletal disorders or used off-the-shelf commercial games.

**Data Extraction and Quality Assessment:**

Data extraction was based on the standardised JBI data extraction tool. The two reviewers (AAM and AP) conducted the data extraction independently, and any disagreements that arose during the extraction process were referred to the third reviewer (MAA). At the final data extraction stage, a new reviewer (DS) joined the team to continue extracting the data from the reviews. The methodological quality of the reviews was critically assessed using the AMSTAR-2 tool.

**Results:**

Out of 513 systematic reviews, only 8 reviews met the inclusion criteria and formed the foundation for this narrative synthesis figure 1.
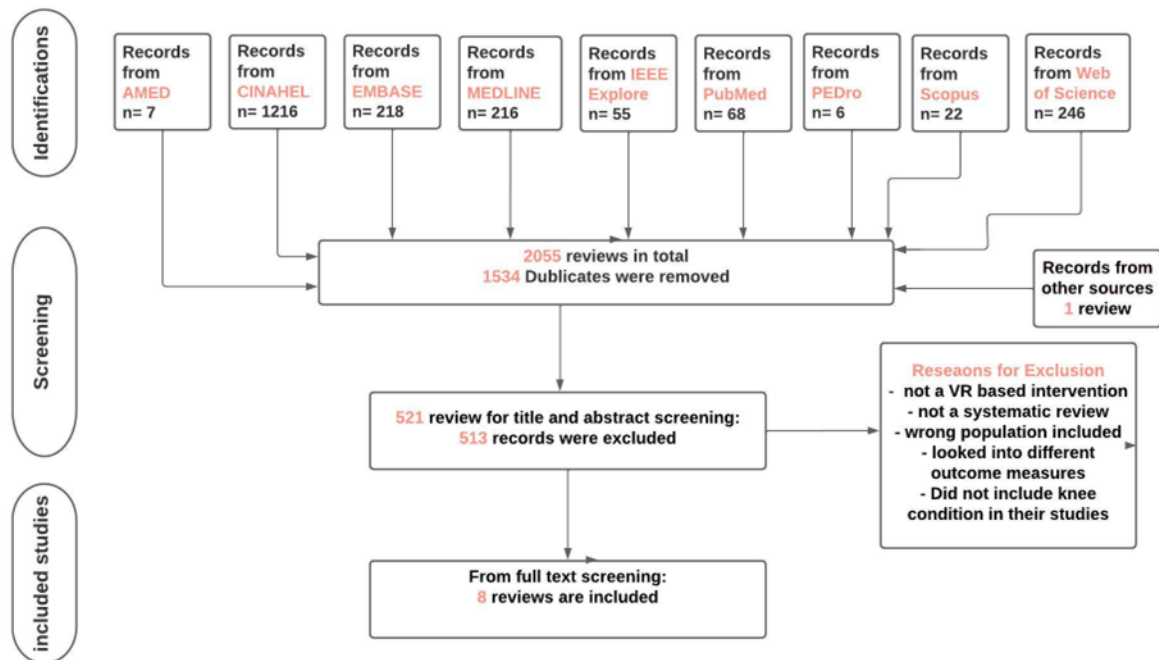


*Figure 1The search result reported by PRISMA guidelines.*

Three themes have emerged from the narrative synthesis; details of these themes are in Table 1. The quality assessment revealed a mixture of reviews, ranging from low to critically low quality; details for the methodological quality in the third theme are in Table 1.

*Table 1 Themes emerged from Narrative synthesis.*

| Main Themes | Description |
|---|---|
| **Diversity of VR Interventions and how closely it relates to the VR definition.** | The diversity in VR interventions, ranging from custom-made systems to interactive toolkits is evident across the reviews. They generally align with the stated definition in this umbrella review as the use of VR-enabled rowing exercises and a custom-built device with tailored computer games suggests the creation of a simulated environment (Gumaa and Youssef (2019), Wang et al. (2019), Byra et al. (2020), Peng et al. (2022)). Moreover, Interactive virtual toolkits with wireless sensors, a 3D avatar, and a web portal for therapists indicate a form of digital interaction in a virtual space (Wang et al. (2019), Blasco et al. (2021), Peng et al. (2022), Chen et al. (2021)). And finally, Custom-made VR systems for rowing exercises and robot-assisted training combined with a VR environment contribute to the simulated environment (Wang et al. (2019); Fernandes et al. (2022); Gazendam et al. (2022)). This |

| | diversity underscores the growing nature of VR applications in rehabilitation. |
|---|---|
| **Effectiveness of VR Outcomes measures** | VR interventions for knee musculoskeletal disorders have shown positive outcomes comparable to traditional exercises in terms of pain reduction and functional improvement. Gumaa and Youssef's review (2019) suggests that VR interventions yield outcomes comparable to traditional exercises in terms of pain reduction and functional improvement. This was repeatedly illustrated by Wang et al. (2019), Byra et al. (2020), Blasco et al. (2021), Chen et al. (2021) Fernandes et al. (2022) and Peng et al. (2022). However, Gazendam et al. (2022) review stated that VR-based rehabilitation may offer advantages over traditional therapy as functional outcomes were improved at 12 weeks and 6 months postoperatively compared to traditional rehabilitation, and there were no differences in pain scores at 2 weeks and 3 months postoperatively. |
| **Methodological Robust Evidence** | Despite the positive outcomes, the effectiveness of VR interventions is limited due to uncertainties and limited clinical significance. Methodological weaknesses also raise doubts about the reliability of the synthesized evidence (Gumaa and Youssef 2019; Blasco et al. 2021; Chen et al. 2021). While Gazendam et al. (2022) and Peng et al. (2022) suggest the potential benefits of VR-based rehabilitation over traditional therapy for certain patients' post-total knee arthroplasty, their reviews' critically low based on AMSTAR 2 scores call for cautious interpretation. This highlights the importance of addressing methodological flaws. Overall, the synthesis emphasizes the need for more conclusive and robust evidence. |

**Conclusion:**

VR has emerged as a promising therapeutic exercise modality for knee musculoskeletal disorders. Its potential is evident from the diverse applications and outcomes across different populations. However, our comprehensive narrative synthesis of eight systematic

reviews reveals that the existing evidence base is not robust enough to draw reliable and generalizable conclusions. The methodological quality of the systematic reviews, as assessed by the AMSTAR-2 checklist, raises concerns about their reliability and validity.

In order to ensure the effectiveness of VR-based rehabilitation, it is crucial to investigate how patients perceive it and how motivation affects their progress. Additionally, it is equally important to provide proper training to therapists on how to incorporate this modality into treatment plans, establish clear guidelines on equipment operation, and data interpretation, and customize VR experiences based on individual strengths. As we move forward, research should prioritize methodological rigour, intervention diversity, and the creation of guidelines to ensure the safe and effective integration of VR into rehabilitation practices.