Home-Based Virtual Reality Training for Enhanced Balance, Strength, and Mobility Among Frail Older Adults: A Systematic Review and Meta-Analysis

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Abstract

Background: Frailty is a significant concern for older adults, it involves a decline in physiological systems, leading to increased vulnerability to falls, hospitalization, and mortality, necessitating effective interventions and one promising approach is the use of Virtual Reality (VR)-based exercises.

Objective: To systematically review all published studies investigating the effect of VR as a home-based training modality to improve balance, strength, and mobility in frail and pre-frail older adults.

Methods: Data Source: Three databases were searched, Scopus, Web of Science, and PubMed, from inception to November 2023.
Eligibility Criteria: Frail and pre-frail older adults aged 65+. Interventions were any VR training. Outcome measures were balance, strength and functional mobility as measured by any validated outcome measure.

Results: Six articles were included, involving 407 participants with a mean age of 68 ±4.4 years. The mean duration of VR sessions was 13.3 ±7.7 weeks, mean total number of sessions was 39.6 ±5.2 sessions, and the mean length of each session was 25.3 ±5 minutes.
Meta-Analysis: VR group demonstrated significant improvements on the Berg Balance Scale compared to both traditional exercise and control groups (mean difference [MD] = 3.62; 95% confidence interval [CI] 2.29 to 4.95; P < 0.001; I2 = 0%). However, non-significant effects were found on Timed Up and Go and Chair Stand tests.
Limitation: Definitive judgement on VR effect on frail and pre-frail older adults is limited due to heterogeneity in interventions, training duration, and outcome measures.

Conclusions: Conclusion: VR training enhances balance but yields inconsistent effects on strength and mobility. Further research is required to refine VR interventions for frail older adults. Clinical Trial: Registration Systematic Review: PROSPERO registration number: CRD42023478330.

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Registration Systematic Review: PROSPERO registration number: CRD42023478330.

Keywords: Frail older adults, balance, strength, functional mobility, home-based training, virtual reality, exergames.

Introduction

Frailty is a major concern for older adults, significantly affecting their well-being and quality of life (Crocker, Brown et al. 2019). It is characterized by a significant decline in the performance of various physiological systems, and lacks a universal phenotype, signifying its heterogeneity as a geriatric syndrome (Fried, Tangen et al. 2001, Collard, Boter et al. 2012). Instead, it varies among individuals, considering their unique characteristics and circumstances, with a consensus that frailty is characterized by an increased vulnerability to adverse health outcomes (Walston, Hadley et al. 2006). Frail individuals, who are prone to experiencing functional decline and disability, face a higher risk of falls, hospitalization, and mortality (Polidori and Ferrucci 2023). Therefore, Falls are a major concern for frail older adults, as they can lead to loss of autonomy, injuries, and even death (Vaishya and Vaish 2020).

Frailty can be categorized into three stages: pre-frailty, frailty, and frailty complications. In pre-frailty stage, individuals may experience one or two symptoms that directly indicate limitations in their physical function or health, with early intervention and appropriate responses, successful management of these challenges is possible. (Knight, Kamwa et al. 2023) The frailty stage is characterized by hallmark symptoms such as weight loss, exhaustion, low physical activity, slowness and weakness that lead to limitations in the individual's functioning and worsening of the overall quality of life (Zak, Sikorski et al. 2022). The frailty complications stage occurs when an individual's functional independence is significantly impaired with accompanying behavioural patterns that may lead to death (Nagaraju, Shenoy et al. 2022). The Fried Frailty Phenotype stands out as a widely used tool for assessing frailty. It assesses physical frailty using five criteria: unintentional weight loss, low energy or self-reported exhaustion, reduced grip strength, reduced physical activity, and slowness by slowed walking speed. When one or two criteria are present, the individual is considered to be in a pre-frail state, while the presence of more than two criteria indicates frailty (Checa-López et al., 2019; Leng, Chen and Mao, 2014).

Frailty prevalence increases with age, affecting 46% of older adults in the pre-frail stage and 15-11% in the frail stage (O'Caoimh, Sezgin et al. 2021). Socioeconomic factors, nutritional status, and ethnic background also play significant roles in frailty prevalence. Longitudinal studies on frailty progression are limited, but some indicate that frailty status can improve, remain stable, or worsen over time (Rohrmann 2020). These statistics underscore the widespread impact of frailty among older adults, highlighting the need for targeted interventions.

In view of the above, society is faced with the challenge of finding effective rehabilitation solutions to promote healthy aging (Stones and Gullifer 2016, Cowley, Goldberg et al. 2021). Traditional exercises are often not preferred by older adults due to factors such as lack of motivation, perceived physical limitations, and the repetitive and monotonous nature of the exercises (Chambel, Tinga et al. 2023). Virtual reality (VR) technology presents a promising alternative that could effectively address these challenges as it provides practical and easy-to-use solutions. Older adults find VR-enabled exercise much more enjoyable than traditional exercise; it should also be emphasized that VR-based exercises can significantly improve motor and cognitive functions (Yu, Li et al. 2023, Brazil and Rys 2024).

A recent randomized controlled trial (RCT) compared the effect of VR training to Otago exercises (Zak, Sikorski et al. 2022). Balance was used as an outcome and the results indicated that the VR group showed significant improvements compared to the Otago exercise group. However, the study employed a pre-post intervention design without a control group, which makes it challenging to attribute improvements solely to the VR intervention. Additionally, the study's findings may not be applicable to frail older adults as they recruited community-dwelling older adults. Similarly, a trial compared the effect of traditional versus VR treadmill on mobility and cognition among frail individuals (Zanotto, Galperin et al. 2024). Both modalities yield positive effects, but there is a preference for VR over traditional treadmill exercises due to the added benefit of cognitive improvement. While these studies provide valuable insights, a systematic review is necessary to synthesise the findings address inconsistencies and offer robust evidence-based recommendations for utilizing VR to enhance balance, strength, and mobility in frail older adults. A recent systematic review found that supervised VR training in rehabilitation settings can improve balance and reduce fall risk among frail older adults (Alhasan, Alshehri et al. 2021, Lee, Lin et al. 2023). This prompts the need to investigate whether similar findings can be achieved through the use of VR at home taking into consideration its ease of access, affordability, and other advantages. Therefore, the objective of the current systematic review was to examine the effectiveness of VR as home-based training among frail or pre-frail older adults.

Material and methods

Protocols and registration

The current systematic review was registered on PROSPERO with the following registration number: CRD42023478330.

Data sources

The Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA) guidelines were followed for this review, PRISMA item checklist can be found in Appendix 1. The search time frame was from inception to November 2023. The goal was to identify recent studies on the effects of VR training for enhanced balance, strength, and mobility at home among frail and pre-frail older adults. Two authors independently performed searches in the following databases: Scopus, Web of Science, and PubMed. The final search was performed in November 2023.

Search strategies

The search terms were specific to each database. The following is an example of the search terms used in Scopus: risk of fall OR balance OR strength OR function AND frail OR prefrail AND older adult AND virtual reality OR video games OR mobile game. A detailed record of other search terms used in PubMed and Web of Science databases can be found in Appendix 2.

Selection criteria

The study comprised all English-language articles published from inception to 2023 including those that used a single group design in which a VR as a home-based exercise intervention was compared with no intervention or other interventions for enhanced strength, balance and mobility among frail or pre-frail older adults. The Population, Intervention, Comparison, Outcome and Study design (PICOS) framework for the current review were as follows:

- P: Population: Frail or pre-frail older adults aged 65 or more.

- I: Intervention: VR, a home-based exercise that is used to improve balance, strength and mobility.
- C: Comparison: No intervention, traditional exercises or standard care.
- O: Outcomes: Balance, strength and mobility measured using validated outcome measures.
- S: Study design: RCT and non-RCT.

Participants

The included studies comprised male and/or female older adults with a mean age of 65 or older, described as frail older adults, pre-frail older adults, aged, geriatric, or older adults living in the community, independently, in retirement centres or nursing homes. Studies that included participants with specific medical conditions, such as stroke, Parkinson’s disease, or cognitive impairment, were excluded.

Interventions

The included studies explored various interventions to improve balance, mobility, and physical function, these included video-guided exercises with resistance bands, VR balance training guided by a physiotherapist, or sensor-based exergames exercised at home. Each intervention was compared to traditional exercise programs or participants' usual activities to assess their effectiveness.

Outcome measures

The included studies assessed the effectiveness of various interventions for older adults by measuring changes in physical function and mobility. Outcomes such as knee extension strength test and Sit-to-Stand test were used to assess lower extremity strength and functional mobility, Berg Balance Scale (BBS) test was used to assess balance and Timed Up and Go (TUG) test was used to assess functional mobility.

Quality assessment

The Physiotherapy Evidence Database (PEDro) assessment tool was used to assess the methodological quality of the included studies (Moseley, Herbert et al. 2002). The total PEDro score reflected the quality of the study as follows (Herd and Meserve 2008): a total score of ≥6 indicated high quality, 4–5 represented fair quality, and ≤3 indicated poor quality.

Data extraction

The reviewers independently assessed the trials for eligibility by reviewing the titles and abstracts. If an article title or abstract was deemed relevant, the full text was retrieved for evaluation against the inclusion and exclusion criteria. Any disagreement between the authors was resolved by the lead author. A data extraction form was created, and the data were extracted by the independent reviewers.

Data analysis

A random-effects meta-analysis was performed using RevMan 5.4 software. Three primary outcomes were included: BBS, TUG and Chair Stand (CS) tests. The purpose was to identify the mean difference (MD) in balance, risk of falls and strength between VR groups and conventional intervention or control groups, and also to determine the overall treatment effect size. Heterogeneity was assessed with the I^2 index, which has four classification levels (Thompson and Higgins 2002): unimportant heterogeneity (0%–40%), moderate heterogeneity (30%–60%), substantial heterogeneity (50%– 90%), and considerable heterogeneity (75%–100%). Effect sizes were calculated for all studies using Cohen's d, with <0.2 indicating a "trivial" effect size, with 0.2 indicating a "small" effect size, 0.5 indicating a "medium" effect size, and 0.8 indicating a "large" effect size (Fritz, Morris et al. 2012).

Results

A total of 1063 papers were identified as relevant; 40 were duplicates. The remaining 1023 were screened. After the initial screening, 1017 papers were excluded based on the titles and abstracts. The final review included six papers. The selection process for this systematic review is presented in the flow diagram in Figure 1.

Methodological quality

The mean PEDro score was 5.6±1.3 with five studies graded as high quality (Vestergaard, Kronborg et al. 2008, Gschwind, Schoene et al. 2015, Karahan, Tok et al. 2015, Yeşilyaprak, Yıldırım et al. 2016, Geraedts, Dijkstra et al. 2021) and one as poor quality (Schoene, Lord et al. 2013). Table 1 presents the results of the quality assessment of the included studies.

Table 1. Physiotherapy Evidence Database Scale Assessment for Included Studies

Study	1	2	3	4	5	6	7	8	9	10	11	Total
Vestergaard, Kronborg et al. 2008	Y	Y	N	Y	N	N	N	Y	Y	Y	Y	6/10
Geraedts, Dijkstra et al. 2021	Y	Y	Y	Y	N	N	Y	Y	N	Y	Y	7/10
Karahan, Tok et al. 2015	Y	Y	N	Y	N	N	N	Y	Y	Y	Y	6/10
Yeşilyaprak, Yıldırım et al. 2016	Y	Y	N	Y	N	N	Y	Y	N	Y	Y	6/10
Gschwind, Schoene et al. 2015	Y	Y	N	N	N	N	Y	Y	Y	Y	Y	6/10
Schoene, Lord et al. 2013	Y	N	N	N	N	N	N	N	Y	Y	Y	3/10
Total	6/6	5/6	1/6	4/6	0/6	0/6	3/6	5/6	4/6	6/6	6/6	

Eligibility criteria are not included in the overall score. 1: Eligibility criteria; 2: Random allocation; 3: Concealed allocation; 4: Baseline comparability; 5: Blind subjects; 6: Blind therapists; 7: Blind assessors; 8: Adequate follow-up; 9: Intention-to-treat analysis; 10: Between-group comparisons; 11: Point estimates and variability.
N, no; Y, yes.

Characteristics of included studies

Subjects and designs

Four of the included studies were RCTs (Vestergaard, Kronborg et al. 2008, Schoene, Lord et al. 2013, Karahan, Tok et al. 2015, Yeşilyaprak, Yıldırım et al. 2016) and the remainder were experimental non-RCTs (Collard, Boter et al. 2012, Gschwind, Schoene et al. 2015, Geraedts, Dijkstra et al. 2021). The total number of participants was 407, and the mean age was 68±4.4. The VR groups comprised 198 participants, and the control groups comprised 159 participants. The number of subjects in the VR groups ranged from 7 to 63, with a mean of 33 ±21.1. In the control groups, the number of subjects ranged from 11 to 61, with a mean of 31.8 ±20.1. All studies were conducted at home or in nursing homes and public home care.

Number and duration of intervention

The duration of VR sessions ranged from 6 to 24 weeks, with a mean of 13.3± 7.7 weeks. The total number of sessions ranged from 16 to 120, with a mean of 39.6± 5.2 sessions. The length of the sessions was 10 to 50 minutes, with a mean of 25.3± 5 minutes. Characteristics of included studies are summarized in Table 2. A description of VR training used in the included studies can be found in Appendix 3.

Qualitative analysis

BBS

Two studies used the BBS as a key outcome measure (Karahan, Tok et al. 2015, Yeşilyaprak, Yıldırım et al. 2016). Significant improvements were observed in VR groups. Both studies assessed BBS post-intervention within six weeks.

TUG

Five studies used the TUG as a key outcome measure (Schoene, Lord et al. 2013, Gschwind, Schoene et al. 2015, Karahan, Tok et al. 2015, Yeşilyaprak, Yıldırım et al. 2016, Geraedts, Dijkstra et al. 2021). Significant improvements were found in the VR group in all three studies, where two studies assessed TUG post-intervention within six weeks and one within six months of follow-up. The remaining two studies didn’t show significant improvements for all groups, where one study assessed TUG post-intervention within eight weeks and the other one within 16 weeks.

Strength

Two studies used knee extension strength as a key outcome (Schoene, Lord et al. 2013, Gschwind, Schoene et al. 2015). Both studies didn’t show significant improvements at any group. Four studies assessed CS performance as a key outcome measure (Vestergaard, Kronborg et al. 2008, Schoene, Lord et al. 2013, Gschwind, Schoene et al. 2015, Geraedts, Dijkstra et al. 2021). All studies didn’t show significant improvements for all groups.

Meta-analysis

A total of four studies were included in the meta-analysis (Karahan et al 2015, Yeşilyaprak et al 2016, Gschwind et al 2015, Schoene et al.,2013). Figures 3 to 5 show the overall treatment effect size and the results of each study on the BBS, TUG and CS.

BBS

Two studies with 55 participants were eligible for inclusion in this meta-analysis. A forest plot revealed that VR yielded better results than conventional interventions and the control in terms of improvements in postural control (MD = 3.62; 95% confidence interval [CI] 2.29 to 4.95; $P < 0.001$; $I^2 = 0\%$). For conventional interventions and the control, the results of the meta-analysis showed a lower mean score on the BBS, indicating a higher risk of falling (Figure 3).

TUG

Four studies with 94 participants were eligible for inclusion in this meta-analysis. The forest plot showed no significant differences between the IVGs and other interventions or the control that on TUG (MD = -0.37; 95% CI -1.16 to 0.41; P = 0.35; $I^2 = 0\%$) (Figure 4).

Strength

Three studies with 64 participants were eligible for inclusion in this meta-analysis. The forest plot showed no significant differences between IVGs and other interventions or the control on CS (MD = -0.20; 95% CI -1.70 to 1.29; P = 0.79; $I^2 = 21\%$) (Figure 5).

Table 2. Characteristics of Included Studies

Study	Design	Total number of subjects	intervention	Training type for intervention group	Total sessions,weeks, duration	No of sample analysed	Outcome measures	Effect size
Yeşilyaprak, Yıldırım et al. 2016	RCT	21	IG: balance training with the BTS NIRVANA VR Interactive System CG: conventional balance exercises	VR-based balance exercises under the supervision of a trained physiotherapist (PT) with more than 2 years of experience with the VR system At nursing home.	Both groups underwent a 6-week, with 3 sessions per week Each session consisted of 5 minutes of warm-up, 35–45 minutes of training, and 5 minutes of cool-down with 30 to 60 sec rest between each exercise.	IG=7 CG=11	TUG: P=0.01* BBS: P= 0.01**	BBS; Cohens d = 0.71 TUG; Cohens d = 0.10
Vestergaard, Kronborg et al. 2008	RCT	61	IG: a 30-minute video- tape showing the exercises, a booklet describing them, and an elastic resistance band CG: did not receive the home-based video exercise, they received standard care	Individual ex At home	IG: at home 26 minutes, three times a week, for five months	IG=25 CG=28	Chair stand, sec: P= 0.242	Chair Stand; Cohenes d = 0.32
Karahan, Tok et al. 2015	RCT	100	IG: video games using the Xbox 360 KinectTM device CG: balance, stretching and strengthening exercises	Play video games. These consisted of "Kinect Adventures, Kinect Sports, and Kinect Sports Season two" programmes in the company of an experienced nurse.	IG: Each subject played the games for 30 min, 5 days a week, for 6 weeks (30 sessions in total) CG: 30 min, 5 days a week,6 weeks for a total of 30 exercise sessions.	IG=48 CG=42	TUG: P=0.090 BBS: P=<0.001	BBS; Cohens d = 1.10 TUG; Cohens d = 0.05
Gschwind, Schoene et al. 2015	Pilot study	148	IG1: The KIN exergames consisted balance ex based on Weight- of bearing Exercise for Better Balance (WEBB) and strength ex based on Otago Exercise program IG2: The SMT using modified StepMania game targeting specific cognitive functions CG: continue to perform usual activities	unsupervised exercise programs At home.	IG1 and IG2: 16-week intervention period for both the KIN and SMT system IG1 KIN: 120 min of balance exergames per week and 60 min of strength exercises per week IG2 SMT: Three 20 min sessions per week each	IG1=24 IG2=39 CG=61	TUG P=0.298 Proprioception P=0.486 Chair stand P=0.370 Knee extension strength P=0.131	TUG; Cohens d = 0.24 Chair Stand; Cohens = 0.16

Geraedts, Dijkstra et al. 2021	Pilot study	40	IG: lower- body strength and balance exercises based on the Otago Kitchen Table Exercise programme	Individual ex at home.	IG: lasted for 6 month and participants exercised 3 months supervised and the following 3 months being unsupervised .Participants exercised 5 times a week	The analysis included data from all 40	TUG P=0.006* Chair stand P=0.032	
Schoene, Lord et al. 2013	RCT	37	IG: participants were provided with a computerized step pad system connected to their TVs and played a step game as often as they liked. In addition, IG participants were asked to complete a choice stepping reaction time (CSRT) task once each week. CG: continue their usual activities.	Individual ex at home.	IG: 2–3 sessions per week for 15–20 minutes for eight weeks. CG: eight weeks	IG=15 CG=17	TUG: P= 0.843 Proprioception P=0489 Chair stand P=0.430 Knee extension strength P=0.439	TUG; Cohens d = 0.14 Chair Stand; Cohens d = 0.29

BBS, Berg Balance Scale; CG, control group; IG, intervention group; RCT, Randomized control trial; TUG, Timed Up and Go; BTS NIRVANA, innovative therapeutic systems aiding the rehabilitation process of patients affected by neuro-motor disease by multisensorial stimulation; VR, virtual reality; KIN, Microsoft-Kinect®; SMT, step-mat-training.

Discussion

The aim of the current systematic review was to identify studies that have investigated the use of VR training at home to improve balance, strength and mobility among frail and pre-frail older adults. Although few studies have focused on this aim, the findings showed that VR was effective at improving balance but not strength and mobility. One potential reason for this could be due to limited experience with independent technology use among older adults and therapists, a challenge that has been validated in previous studies (Lee, Lo et al. 2021, Kouvonen, Kemppainen et al. 2022). Nevertheless, the studies included in this review are examples of how technological advancements can reshape healthcare delivery and demonstrate that certain VR interventions can be used safely with older adults, as no study reported any safety hazards.

The findings from the current review showed that home-based VR intervention produces a great variability in effectiveness on different outcomes. On balance, both (Karahan, Tok et al. 2015, Yeşilyaprak, Yıldırım et al. 2016) found a significant effect on balance in the VR group when using the BBS. This finding aligns with a recent review (Chen, Hsu et al. 2023), which also found a significant improvement in BBS scores following VR intervention in older adults with balance impairments. Similarly, another study (Ren, Lin et al. 2023) found that VR intervention significantly improved BBS scores in older adults residing in nursing homes compared with those living in communities. The populations studied in these studies were similar, indicating that these findings may be generalizable.

In contrast to mobility outcomes, home-based VR training's effect on the TUG showed variation in the included studies. The lack of significant improvement could be attributed to the small sample size (Schoene, Lord et al. 2013, Gschwind, Schoene et al. 2015), which limited the ability to detect changes. This variation in effect on TUG could also be due to the specific design and characteristics of the VR interventions implemented in these studies. For instance, one study (Schoene, Lord et al. 2013) employed short-duration interventions of 10-20 minutes per session, while another (Karahan et al. 2015) utilized longer-duration interventions of 30 minutes per session.

For strength outcomes, the CS test didn’t show significant improvements in four studies (Vestergaard, Kronborg et al. 2008, Schoene, Lord et al. 2013, Gschwind, Schoene et al. 2015, Geraedts, Dijkstra et al. 2021). For Vestergaard et al. (2008) study, the lack of improvement can be attributed to insufficient progression in the exercises included in the VR training group. Without sufficient progression or intensity, participants may not have experienced improvement in strength or functional mobility. For Gschwind et al. (2015) study, while the (Step Mat Training) intervention group demonstrated significant enhancement in sit-to-stand times compared to the control group, there were no significant differences observed between the two intervention groups or between the KIN group and the control group. This lack of significant improvements could be due to KIN training would have greater effects on strength and balance. The intensity and specificity of the exercises provided in the form of VR interventions are also important factors. Some studies may have incorporated more tailored and progressively challenging tasks, which could enhance the efficacy of the training, while others may have used .more generic exercises that do not target the specific mobility deficits of participants

Similarly, the VR effect on knee extension strength didn’t show significant improvements in the two studies. For Schoen et al. (2013) study, the intervention didn’t specifically target knee extension strength or range of motion, focusing more on stepping performance and cognitive parameters related to fall risk, While Gschwind et al. (2015) study, there were no significant differences observed between the two intervention groups or between the SMT group and the control group. This could be due to the SMT program focusing on proprioception, cognitive processing, and balance may have shifted the emphasis away from targeting strength. In contrast, the KIN program may have placed more emphasis on strength-building exercises (Gschwind et al., 2015).

Overall, our study revealed that VR exercises significantly enhanced balance among older adults compared to those who engaged in regular exercises or remained inactive. However, there were no clear and significant differences in strength and functional mobility. This suggests that while VR training holds potential, its design and implementation require careful consideration to ensure progressive difficulty and proper evaluation through controlled studies.

Strengths and limitations

The systematic review demonstrated strengths such as the rigorous methodology by following PRISMA guidelines, high-quality assessment using the PEDro scale, clear selection criteria based on the PICOS framework and comprehensive search strategy across multiple databases. However, the review also has limitations, such as limited generalisability, language bias from only including English-language articles, and publication bias from excluding unpublished studies. These limitations should be considered when interpreting the findings and designing future studies.

Recommendations

VR home-based training, especially those focusing on balance exercises, appears to be a promising tool for enhancing balance in frail and pre-frail older adults. The interactive and engaging nature of VR can increase adherence to exercise programs, which is crucial for achieving long-term benefits. However, more research is needed to investigate healthcare providers’ perceptions of the use of VR as a home-based training. In addition, a standardized protocol that addresses the limitations found in this review should be considered to avoid variability in future trials. It is important to consider the potential benefits of VR training beyond just physical function improvement as VR interventions can also improve engagement and motivation, which may lead to better adherence to exercise. This is particularly relevant for frail and pre-frail older adults who may find traditional exercise programs less appealing or more challenging to adhere to.

Conclusion

The findings of the current review suggest that VR training showed promise in enhancing balance but had inconsistent effects on strength and mobility outcomes among frail and pre-frail older adults. In interpreting these results, caution should be exercised due to variations in study designs, intervention protocols, and outcomes. Further research is needed to better understand .the optimal design and implementation of VR-based interventions for this population

References

Alhasan, H., et al. (2021). "Effects of interactive videogames on postural control and risk of fall outcomes in frail and pre-frail older adults: a systematic review and meta-analysis." Games for health journal **10**(2): 83-94.

Brazil, C. K. and M. J. Rys (2024). "The effect of VR on fine motor performance by older adults: a comparison between real and virtual tasks." Virtual Reality **28**(2): 113.

Chambel, G., et al. (2023). Exploring the Impact of a Gamified Exercise Platform to Support Healthy Ageing: Home-Based Study with Older Adults. 2023 IEEE 11th International Conference on Serious Games and Applications for Health (SeGAH), IEEE.

Chen, P.-J., et al. (2023). "VR exergame interventions among older adults living in long-term care facilities: A systematic review with Meta-analysis." Annals of Physical and Rehabilitation Medicine **66**(3): 101702.

Collard, R. M., et al. (2012). "Prevalence of frailty in community-dwelling older persons: a systematic review." Journal of the american geriatrics society **60**(8): 1487-1492.

Cowley, A., et al. (2021). "Exploring rehabilitation potential in older people living with frailty: a qualitative focus group study." BMC geriatrics **21**: 1-11.

Crocker, T. F., et al. (2019). "Quality of life is substantially worse for community-dwelling older people living with frailty: systematic review and meta-analysis." Quality of Life Research **28**: 2041-2056.

Fried, L. P., et al. (2001). "Frailty in older adults: evidence for a phenotype." The Journals of Gerontology Series A: Biological Sciences and Medical Sciences **56**(3): M146-M157.

Fritz, C. O., et al. (2012). "Effect size estimates: current use, calculations, and interpretation." Journal of experimental psychology: General **141**(1): 2.

Geraedts, H. A., et al. (2021). "Effectiveness of an individually tailored home-based exercise programme for pre-frail older adults, driven by a tablet application and mobility monitoring: a pilot study." European Review of Aging and Physical Activity **18**(1): 10.

Gschwind, Y. J., et al. (2015). "The effect of sensor-based exercise at home on functional performance associated with fall risk in older people–a comparison of two exergame interventions." European Review of Aging and Physical Activity **12**: 1-9.

Herd, C. R. and B. B. Meserve (2008). "A systematic review of the effectiveness of manipulative therapy in treating lateral epicondylalgia." Journal of Manual & Manipulative Therapy **16**(4): 225-237.

Karahan, A. Y., et al. (2015). "Effects of exergames on balance, functional mobility, and quality of life of geriatrics versus home exercise programme: randomized controlled study." Central European journal of public health **23**(Supplement): S14-S18.

Knight, T., et al. (2023). "Acute care models for older people living with frailty: a systematic review and taxonomy." BMC geriatrics **23**(1): 809.

Kouvonen, A., et al. (2022). "Health and self-perceived barriers to internet use among older migrants: a population-based study." BMC Public Health **22**(1): 574.

Lee, D. R., et al. (2021). "Understanding the Uptake of Digital Technologies for Health-Related Purposes in Frail Older Adults." Journal of the american geriatrics society **69**(1): 269-272.

Lee, Y. H., et al. (2023). "Virtual reality exercise programs ameliorate frailty and fall risks in older adults: A meta-analysis." Journal of the american geriatrics society **71**(9): 2946-2955.

Moseley, A. M., et al. (2002). "Evidence for physiotherapy practice: a survey of the Physiotherapy Evidence Database (PEDro)." Australian Journal of Physiotherapy **48**(1): 43-49.

Nagaraju, S. P., et al. (2022). "Frailty in end stage renal disease: Current perspectives." nefrologia **42**(5): 531-539.

O’Caoimh, R., et al. (2021). "Prevalence of frailty in 62 countries across the world: a systematic review and meta-analysis of population-level studies." Age and ageing **50**(1): 96-104.

Polidori, M. C. and L. Ferrucci (2023). "Frailty from conceptualization to action: the biopsychosocial model of frailty and resilience." Aging Clinical and Experimental Research **35**(4): 725-727.

Ren, Y., et al. (2023). "Effectiveness of virtual reality games in improving physical function, balance and reducing falls in balance-impaired older adults: A systematic review and meta-analysis." Archives of gerontology and geriatrics **108**: 104924.

Rohrmann, S. (2020). "Epidemiology of frailty in older people." Frailty and cardiovascular diseases: Research into an elderly population: 21-27.

Schoene, D., et al. (2013). "A randomized controlled pilot study of home-based step training in older people using videogame technology." PloS one **8**(3): e57734.

Stones, D. and J. Gullifer (2016). "‘At home it's just so much easier to be yourself’: older adults' perceptions of ageing in place." Ageing & Society **36**(3): 449-481.

Thompson, S. G. and J. P. Higgins (2002). "How should meta-regression analyses be undertaken and interpreted?" Statistics in medicine **21**(11): 1559-1573.

Vaishya, R. and A. Vaish (2020). "Falls in older adults are serious." Indian journal of orthopaedics **54**: 69-74.

Vestergaard, S., et al. (2008). "Home-based video exercise intervention for community-dwelling frail older women: a randomized controlled trial." Aging Clinical and Experimental Research **20**: 479-486.

Walston, J., et al. (2006). "Research agenda for frailty in older adults: toward a better understanding of physiology and etiology: summary from the American Geriatrics Society/National Institute on Aging Research Conference on Frailty in Older Adults." Journal of the american geriatrics society **54**(6): 991-1001.

Yeşilyaprak, S. S., et al. (2016). "Comparison of the effects of virtual reality-based balance exercises and conventional exercises on balance and fall risk in older adults living in nursing homes in Turkey." Physiotherapy theory and practice **32**(3): 191-201.

Yu, D., et al. (2023). "The effect of virtual reality on executive function in older adults with mild cognitive impairment: a systematic review and meta-analysis." Aging & Mental Health **27**(4): 663-673.

Zak, M., et al. (2022). "Physiotherapy programmes aided by VR solutions applied to the seniors affected by functional capacity impairment: randomised controlled trial." International journal of environmental research and public health **19**(10): 6018.

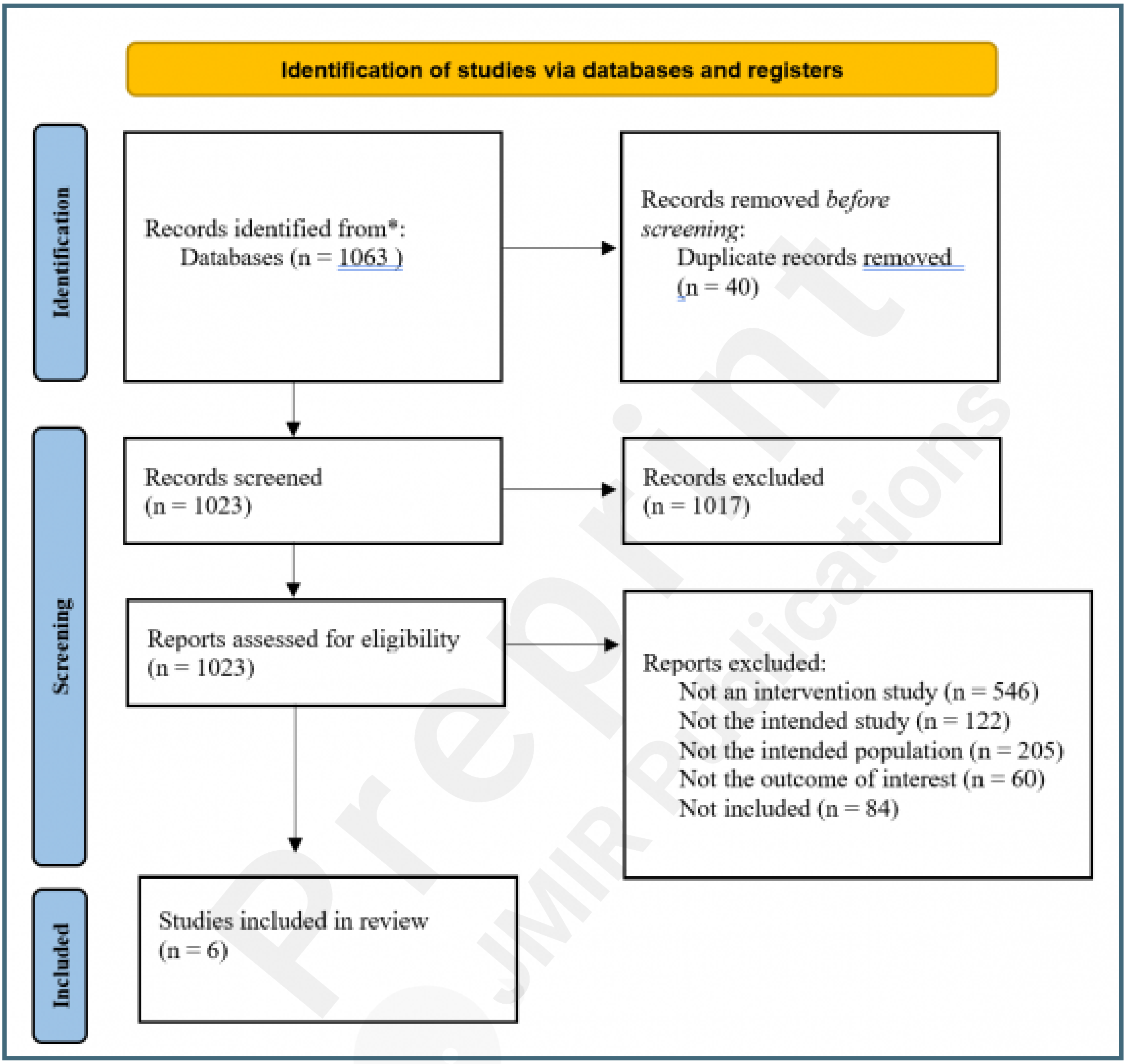
Zak, M., et al. (2022). "Frailty Syndrome—Fall Risk and Rehabilitation Management Aided by Virtual Reality (VR) Technology Solutions: A Narrative Review of the Current Literature." International journal of environmental research and public health **19**(5): 2985.

Zanotto, T., et al. (2024). "Effects of a 6-week treadmill training with and without virtual reality on frailty in people with multiple sclerosis: a randomized controlled trial." Archives of Physical Medicine and Rehabilitation **105**(4): e140.

Supplementary Files

Figures

Results of the literature search conducted in November 2023.

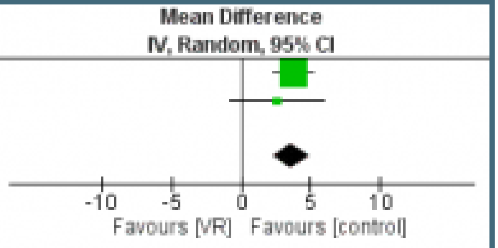


Forest plot for the mean difference of the effect of VR compared with conventional interventions and control on the BBS; lower BBS mean score indicates higher risk of falling.

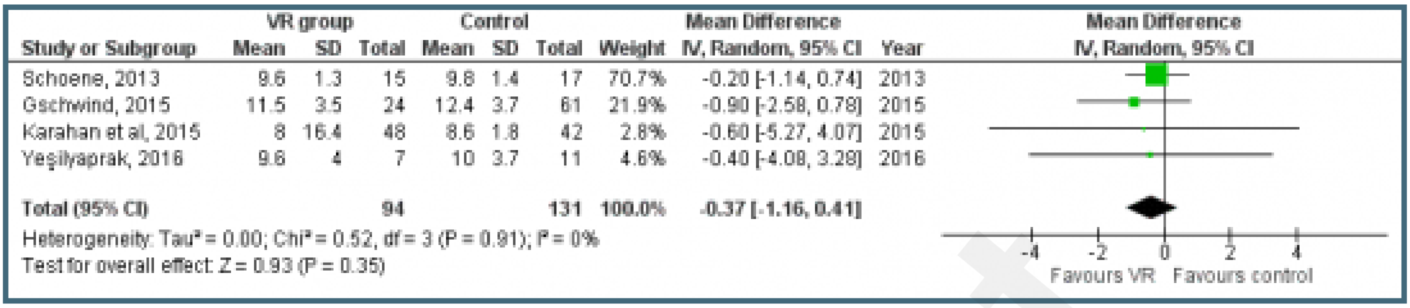
	Experimental			Control				Mean Difference
Study or Subgroup	Mean	SD	Total	Mean	SD	Total	Weight	IV, Random, 95% CI
Karahan et al, 2015	54.9	2.6	48	51.1	4.1	42	84.9%	3.80 [2.36, 5.24]
Yeşilyaprak, 2016	54.4	3.4	7	51.8	3.9	11	15.1%	2.60 [-0.81, 6.01]
Total (95% CI)			**55**			**53**	**100.0%**	**3.62 [2.29, 4.95]**

Heterogeneity: Tau² = 0.00; Chi² = 0.40, df = 1 (P = 0.53); I² = 0%

Test for overall effect: Z = 5.34 (P < 0.00001)



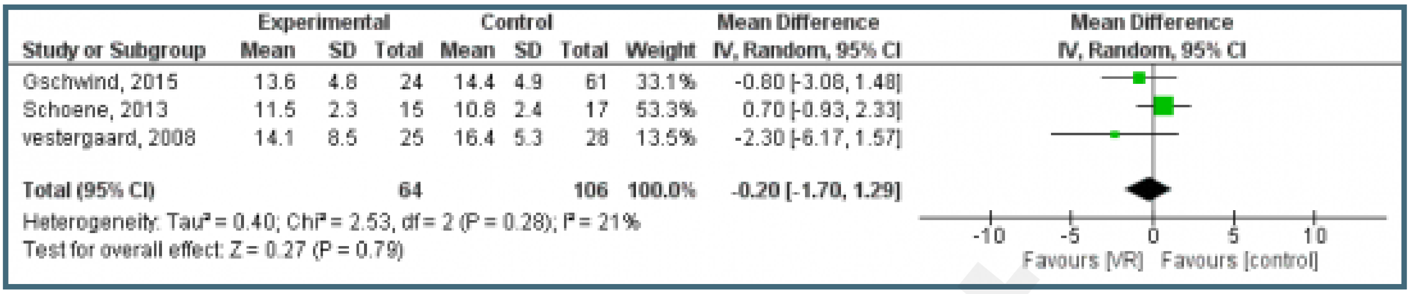
Forest plot for the mean difference of the effect of VR compared with conventional interventions and control on the time (in seconds) of the TUG; lower TUG mean score indicates better mobility performance.



	VR group			Control				Mean Difference		Mean Difference
Study or Subgroup	**Mean**	**SD**	**Total**	**Mean**	**SD**	**Total**	**Weight**	**IV, Random, 95% CI**	**Year**	**IV, Random, 95% CI**
Schoene, 2013	9.6	1.3	15	9.8	1.4	17	70.7%	-0.20 [-1.14, 0.74]	2013	
Gschwind, 2015	11.5	3.5	24	12.4	3.7	61	21.9%	-0.90 [-2.58, 0.78]	2015	
Karahan et al, 2015	8	16.4	48	8.6	1.8	42	2.8%	-0.60 [-5.27, 4.07]	2015	
Yeşilyaprak, 2016	9.6	4	7	10	3.7	11	4.6%	-0.40 [-4.08, 3.28]	2016	
Total (95% CI)			**94**			**131**	**100.0%**	**-0.37 [-1.16, 0.41]**		

Heterogeneity: Tau² = 0.00; Chi² = 0.52, df = 3 (P = 0.91); I² = 0%
Test for overall effect: Z = 0.93 (P = 0.35)

Forest plot for the mean difference of the effect of VR compared with conventional interventions and control on Chair Stand test; lower mean score indicates better mobility performance.



Multimedia Appendixes

PRISMA 2020 item checklist.
URL: http://asset.jmir.pub/assets/d25369fdae8db73f02f209428f9da64d.docx

Search terms used.
URL: http://asset.jmir.pub/assets/ad548a51af376dde17057973dee78cc3.docx

Description of VR used in included studies.
URL: http://asset.jmir.pub/assets/1cd62346f16cd02d672cf7266bfe5594.docx