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The effect of eHealth-delivered exercise programmes on balance in people aged 65 years and over living in the community: A systematic review & meta-analysis of randomised controlled trials.

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The effect of eHealth-delivered exercise programmes on balance in people aged 65 years and over living in the community: A systematic review & meta-analysis of randomised controlled trials.

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Abstract

Objective: This systematic review and meta-analysis synthesised the evidence and evaluated the effect of eHealth-delivered exercise programmes compared to control on balance in community-dwelling people aged ≥65 years.

Design: Systematic review and meta-analysis

Eligibility: eligible studies included randomised controlled trial evaluating eHealth-delivered exercise programmes for community-dwelling people aged ≥65 years, published in English that included a balance outcome.

Data sources: Nine databases including MEDLINE, CINAHL, and Embase, were searched to until September 2020 to identify all relevant studies.

Outcome measures: Primary outcomes were static and dynamic balance. Secondary outcomes included fall risk and fear of falling. We calculated standardised mean differences (SMDs, Hedges' g) with 95% confidence intervals (CIs) from random effects meta-analyses.

Results: We identified nine eligible trials that included 498 participants. Methodological quality ranged from 3 to 7 (mean, 5.5). Risk of bias was moderate to high for static and dynamic balance. The pooled effect indicated that eHealth-delivered exercise programmes have a significant effect on static balance (eight trials; SMD = 0.40; 95% CI 0.14 to 0.67). There was no effect on dynamic balance (nine trials; SMD=0.22; 95% CI -0.09 to 0.54), fall risk (three trials; SMD=0.28; 95% CI -0.06 to 0.63) or fear of falling (three trials; SMD= -0.07; 95% CI -0.34 to 0.20).

Conclusion: eHealth-delivered exercise programmes significantly improved static balance in people aged ≥65 years. Further research is needed to fully understand the effect of eHealth delivered exercise programmes on dynamic balance and other fall-related outcomes.

PROSPERO Registration: CRD42018115098.

KEYWORDS

postural balance, accidental falls, internet, exergames, mobile games.

Article Summary

Strengths and limitations of the study

- We conducted this systematic review in accordance with PRISMA guidelines and followed a prespecified protocol registered on PROSPERO.
- We had specific criteria that allowed for the inclusion of trials with both generally healthy participants and those with selected clinical conditions.
- We also ensured the inclusion of as many relevant trials as possible by searching across nine databases, conducting a thorough hand search of relevant published literature, and consulting with experts in the field.
- Included trials had to comprise a measure of balance and we may have missed relevant studies that included measures of falls.
- We only included outcome data from the immediate post-intervention time point, which limits the interpretation of results to the short-term.

Introduction

Ageing is associated with a decline in the physiological systems responsible for postural stability and hence an increase in the risk of falls[1]. A fall is defined as "an unexpected event in which the participants come to rest on the ground, floor, or other lower level"[2]. Each year approximately one-third of community-dwelling people aged 65 years and over experience a fall[3 4]. Forty percent of injuries requiring hospital admission are due to falls, and in 2016-2017 more than 125,000 Australians aged 65 years or over were hospitalised due to a fall[5 6]. Falls place a significant burden on health systems and can result in serious long-term costs to the individual[7]. Falls can also result in loss of independence, depression, social isolation, and admission of the older person to a care facility[7]. As such, fall prevention is a public health priority.

There is clear evidence that exercise is crucial for preventing falls in community-dwelling older people[8]. However, the effect on falls varies by exercise type. A Cochrane systematic review that included 108 trials of exercise, established that exercise that challenges balance has the greatest effect on both the rate of falls (24% reduction) and risk of falls (13% reduction) in community-dwelling older people[8]. Despite the benefits of exercise for preventing falls, widespread implementation and adherence to effective programmes is poor, significantly reducing the population-wide impact[9]. Furthermore, the 2020 World Health Organization (WHO) guidelines on physical activity and sedentary behaviour recommend that older adults should undertake multicomponent physical activity that emphasises functional balance and strength training at least three-times per week to enhance functional capacity and prevent falls[10]. Therefore, exploring the effectiveness of novel exercise programmes with potential for wide reach that can improve balance is important.

Advances in technology have led to new ways to deliver exercise-based programmes. Such technology-based programmes, commonly referred to as electronic-Health (eHealth), that use the internet, websites, mobile applications (apps) or exergames, may provide effective alternatives to more traditional modes of delivering exercise-based programmes to improve balance and prevent falls, and increase access to such programmes. Previous studies show that eHealth interventions can successfully improve the health and physical activity of older people[11-16], and adherence by some older people is higher for technology-delivered interventions compared to traditional interventions, independent of study site, level of supervision and mode of delivery[17].

eHealth-delivered exercise programmes are a safe way to exercise, and many older people perceive them as fun and enjoyable[18-22]. This mode of delivery has also been successful for improving balance in younger adults, aged 18+ years, with a number of systematic reviews evaluating the effectiveness of specific, technology-based approaches to improving balance or reducing fall risk in adults[23-26].

Given the lack of systematic reviews and meta-analyses on the effectiveness of eHealth-delivered exercise programmes for improving balance in older people, further evaluation of the role of technology-driven platforms is needed. This systematic review and meta-analysis aimed to synthesise the evidence and evaluated the effect of eHealth-delivered exercise programmes on balance in people aged 65 years and older living in the community compared to a control.

Methods

<u>Protocol</u>

This review was registered on the PROSPERO database (CRD42018115098) and followed the Preferred Reporting Items for Systematic Review and Meta-analysis (PRISMA) guidelines[27]. The systematic review protocol has been published and provides a full outline of the methods[28]. A summary of the methods is reported in this paper.

Data Sources

A database search was conducted from inception to September 2020 of MEDLINE, CINAHL Complete, Embase, PsychINFO, Scopus, Web of Science, PubMed Central, Cochrane Database Central, and PEDro. The Protocol details the complete search strategy used[28].

Eligibility Criteria

Studies included in this systematic review met the following criteria: (1) published in English, (2) randomised controlled trial (RCT), (3) participants were community-dwelling people aged ≥65 years, (4) reported data for a validated measure of balance, (5) included eHealth delivery of an exercise programme compared with no intervention, usual care or wait-list control. Studies that did not meet these criteria were excluded.

We included all RCT designs such as crossover, cluster, patient-randomised clinical trials that examined the effect of eHealth-delivered exercise programmes versus a control group. Single and multi-factorial interventions were also included. Trials published only as abstracts or yet to be published were excluded due to possible data inaccuracy and incompleteness.

Patient and Public Involvement

Patient and public involvement is beyond the scope of this Systematic Review.

Outcome measures

The primary outcome measure was balance. Balance outcomes were further categorised as static or dynamic measures of balance in the analyses. In the absence of functional measures of balance, we included trials which reported direct measures of balance, such as those measured with a force platform. Fall risk, fear of falling and fall rate were included as secondary outcomes. We included trials that used either validated self-report questionnaires or performance-based measures for these outcomes.

Study Selection

After pilot-testing criteria for full-text articles, screening for eligible trials was conducted independently by two reviewers (XX, XX). An electronic screening form was used, and screening occurred in stages: firstly, titles were screened, followed by abstracts, and finally full-text articles were screened. Conflicts were resolved by a consensus from XX, XX, and XX.

Data Extraction

Data extraction was completed by two researchers independently from one another (XX, XX), and conflicts were resolved by a third reviewer (XX). Data were extracted using a piloted electronic data extraction form, and according to the PRISMA statement[27]. Where data were missing, study authors were contacted by email to provide further information. Where the authors did not reply within two weeks, a second email was sent as a reminder.

The following data were extracted from each trial: author, year of publication, country, sample characteristics (sample size, age, sex of participants and health status), study design: including number of study arms, recruitment sources, eligibility criteria, setting, delivery method and technology used, intervention description, comparator, intervention duration and frequency, assessment time-points. Also extracted were data on drop out, attrition, adverse events, and intervention features such as implementation fidelity, evidenced-based theory, tailoring, supervision, intervention acceptability. Primary and secondary outcome data were extracted for pre-intervention and post-intervention timepoints. Where data were available for more than one post-intervention timepoint, we included the data from the timepoint closest to intervention completion.

Methodological quality and risk of bias assessment

The PEDro scale (1-10) was used to assess the methodological quality of the included trials. PEDro scores were extracted from the PEDro database[29]. The PEDro scale assesses the internal validity of an RCT by evaluating 11 items: participant eligibility criteria, random allocation, concealed allocation, homogeneity of groups at baseline, blinding of subjects, blinding of therapist, blinding of assessor, completeness of follow up, intention-to-treat analysis, between-group statistical analysis, and variability and point measures[30]. A score of 10 is considered to be methodologically excellent, whereas 0 demonstrates poor methodological quality[30]. Methodological quality was not an inclusion criterion for this review.

In addition to the PEDro scale, we also used the Cochrane Risk of Bias to assess the risk of bias in each included trial. The Cochrane Risk of Bias was undertaken by two independent reviewers (XX, XX) with conflicts resolved by a third reviewer (XX). Risk of bias is assessed across a number of domains as a judgement of low risk, high risk, or unclear [31].

Assessment of quality of evidence

To evaluate overall quality of evidence we used the Grading of Recommendations, Assessment, Development and Evaluations (GRADE) system. The GRADE appraisal was conducted by pairs of independent reviewers (XX, XX). This is a subjective evaluation of the quality of the evidence as High, Moderate, Low, or Very Low based on the presence or extent of the following factors: risk of bias, imprecision, and inconsistency of the effect. The GRADE classification was downgraded from high quality by one level for each factor encountered: (1) Design limitations (>25% of studies with low methodological quality based on the Cochrane Risk of bias), (2) Inconsistency of results (large heterogeneity between the trials $I^2>50\%$), (3) Imprecision (<400 participants for each outcome. We did not consider indirectness as it encompasses a specific population (older people) with relevant outcome measures (balance) and direct comparisons. We were unable to consider publication bias as our review included nine studies[31].

Statistical Analysis

We performed meta-analyses with Comprehensive Meta-Analysis software (V.3, Biostat, Englewood, New Jersey, USA) using the random effects models for primary and secondary outcome measures. We calculated treatment effects for the continuous variables using standardised mean differences (Hedges' g) standardised by post-score standard deviation (or its estimate) with 95% CIs, for either between-group differences in point estimates at the follow-up time points or between-group differences in change scores based on available data. Standardised mean differences were calculated using the pre-mean and post-mean and standard deviation (SD). Where this was not available, we used the mean change score. Effect sizes were categorised as small (0.2), medium (0.5), or large (0.8 or greater)[32].

We visually inspected the forest plot for evidence of heterogeneity among trials with consideration of the I^2 and Chi-square tests. We determined clinical heterogeneity by consensus among the investigators on the basis of collective experience in the field.

Results

Flow of studies included in this review

The initial search of the databases resulted in 1,080 publications. An additional hand search, including the reference lists of relevant review articles found a further 40 publications. After removing duplicate papers, 783 publications were screened by title and abstract. Forty-five publications reported on potentially eligible trials before full-text screening. After the full-text screen, nine trials, reported by ten manuscripts, were identified as eligible and included in this study. Schoene et al.[33] conducted a trial involving interactive cognitive-motor step training, however this paper did not report the balance outcomes measured during this trial. These balance outcomes were reported in Gschwind et al.[34] as the SMT intervention group. This review extracted outcome data for the SMT group only from the Gschwind et al.[34] paper, all other data pertaining to this trial (including for the control group) were extracted from Schoene et al.[33]. Figure 1 outlines the PRISMA study flow of trials included in this review.

We pooled all included trials in the primary meta-analysis evaluating the effect of interventions that use an eHealth technology to deliver an exercise programme to older people.

Risk of Bias and Quality

Table 1 reports the methodological quality of eligible trials. The total PEDro scores ranged from 3 to 7 (mean of 5.5). For the static balance outcome four trials out of eight (50%) were of high methodological quality (a score ≥6)[18 34-36]. For the dynamic balance outcome, four trials out of nine (44%) were of high methodological quality[18 34-36]. All participants were randomly allocated and provided the calculation of point estimates and variability (PEDro items 2 and 11). Three trials out of nine (33%) did not undertake an intention-to-treat analysis[18 37 38]. None of the trials included blinded participants or blinded therapists, however blinding of participants or therapists is not possible for exercise interventions. Table 2 reports the quality of the evidence. Figure 2 presents the risk of bias.

Cohort Characteristics

Trials included samples ranging from 12 to 153 participants (n= 498; median 37). The mean age of participants ranged from 65 to 89 years. Both males and females were included in eight trials, all had a higher percentage of female participants[18 34-37 39-41]. One study included only female participants[38]. Every trial recruited participants from the general community[18 34-41]. One trial recruited participants with a history of falls[38]. Table 1 presents a summary of cohort characteristics.

Characteristics of included trials

Publication dates ranged from 2013 to 2018, with six (67%) published during or after 2015. Trials were conducted in eight different countries: single trials were conducted in Hong Kong[40], Taiwan[42], the United States of America[39], and the United Kingdom[37]; two trials were conducted in Australia[18 34], and South Korea[35 38], and one trial was conducted across three countries: Germany, Spain and Australia[36]. Details of trial characteristics are summarised in Table 1.

eHealth-delivered exercise programmes

The duration of the included interventions ranged from two to 16 weeks, with a mean duration of nine weeks. Seven trials (78%) used a commercially available exergame system to deliver the exercises: three (33%) trials used the Nintendo Wii console[35 37 39], two (20%) used the Microsoft Xbox Kinect[36 40], two (20%) used the Dance Dance Revolution StepMania[18 34]. The remaining two trials (22%) used customised technologies: a web-based intervention called telepresence[38], and the Xavix Measured Step System[42].

Four trials (44%) used technology to provide a home-based intervention[18 34 36 38]. Five trials (56%) used technology to deliver a supervised intervention: participants attended a supervised group class[35 40], or a supervised one-on-one session[37 39 42].

In four trials (%) the control group received no information and were encouraged to continue with normal daily activities[18 37 39 42]. Control participants in four trials (44%) received educational advice related to nutrition and physical activity, in the form of a booklet or classes[34-36 38]. Participants in one trial continued with the regular, seated social games available at the senior's activities centre[40].

Effect of eHealth-delivered exercise programmes on balance

Eight trials (89%) measured static balance using single leg stance[35 40 41], tandem stance[36], postural sway[18 34 37] and the Fullerton Advanced Balance Scale[39]. The pooled effect of eHealth-delivered exercise programmes on static balance indicates a small, statistically significant effect compared to control (SMD) = 0.40, 95% CI 0.14 to 0.67; $I^2 = 41\%$, $p = 0.105$) (Figure 3). The pooled results provide low-quality evidence (GRADE).

All nine trials measured dynamic balance with methods ranging from the Timed Up and Go[34-36 39-41], the Berg Balance Scale[37 38], and the Alternative Step test[18]. There was no evidence of an effect of eHealth-delivered exercise programmes on dynamic balance compared to control (SMD = 0.22, 95% CI -0.09 to 0.54; I^2 = 60.4%, p = 0.010) (Figure 3). The pooled results provide very low-quality evidence (GRADE).

Effect of eHealth-delivered exercise programmes on secondary outcomes

Three trials (33%) measured fall risk using the Physiological Profile Assessment (PPA)[18 34 36]. There was no evidence of an effect of eHealth-delivered exercise programmes on fall risk compared to control (SMD=0.28, 95% CI -0.06 to 0.63; I^2 = 42.9%, p = 0.173). The pooled results provide moderate-quality evidence (GRADE).

Three trials (33%) reported measures of fear of falling using the shortened Iconographical Falls Efficacy Scale (icon-FES)[18 36], or the Fear of Falling Questionnaire[38]. There was no evidence of an effect of eHealth-delivered exercise programmes on fear of falling compared to control (SMD = -0.07, 95 % CI -0.34 to 0.20; I^2 = 0.0%, p = 0.950). The pooled results provide moderate-quality evidence (GRADE).

One study reported a baseline measure for fall rate, but did not provide any further follow up data[35]. We were therefore unable to report on fall rate.

Adverse events

Seven included trials (78%) measured adverse events[33-38 40]. However, these trials reported no major adverse events related to the intervention occurred.

Discussion

This systematic review and meta-analysis provides preliminary evidence that eHealth-delivered exercise programmes improve static balance, and are a feasible and safe method of delivering an exercise programme to people aged ≥65 years living in the community. We also demonstrated that an eHealth-delivered exercise programme may improve static balance in people aged ≥65 years living in the community. However, there was not sufficient evidence to indicate an eHealth-delivered exercise programme improves dynamic balance in people aged ≥65 years living in the community.

There are a number of factors that may have influenced these results. Firstly, the dose and intensity of prescribed exercise in many of the trials may have been insufficient to substantially improve dynamic balance. A Cochrane review examining the effects of exercise interventions on balance found effective programmes were those attended three times per week for three months and involved dynamic exercises in a standing position[43]. While in half of the trials (5/9) participants completed intervention exercises three times per week, only three trials had an exercise duration of 12 or more weeks (mean duration = 8 weeks). Furthermore, a systematic review on falls prevention found greater effects from interventions that challenged balance and included >3 hours per week[44]. Only one trial included comprehensive tailoring, suggesting that the challenge to balance may not have been sufficient to have a meaningful affect dynamic balance. In addition, only two trials engaged participants in at least 180 minutes of exercise per week for the duration of the intervention. Most trials (67%) only engaged participants for between 30-120 minutes of exercise per week.

Finally, the tools used to measure dynamic balance may not be the most appropriate for the healthy older people included in 8 out of the 9 trials. The most frequently used measure of dynamic balance was the Timed-up-and-go (TUG) (6/9). While the TUG is a validated tool and is recommended by the National Institute of Clinical Evidence for the assessment of gait and balance in the prevention of falls in older people[3], research has found the TUG may be more appropriate for frail older people who use walking aids rather than healthy older people[45].

The results show no effect of eHealth-delivered exercise programmes on measures of fall risk, fear of falling and falls. This is despite strong evidence that exercise interventions reduce falls in older community-dwellers[8]. There are two possible explanations for these findings. Firstly, to be eligible the included trials had to report on balance, resulting in only a small number (n=4) of trials also reporting a fall-related measures. Therefore, we may have missed trials that measured the other fall-related outcomes of interest. Secondly, it is likely that the trials identified with a fall-related outcome, that ranged in sample size from 30 to 153, were not powered to detect an impact on falls[2].

Implications for clinicians and policymakers

Given the often low levels of adherence to exercise-based fall prevention programmes amongst older people, new delivery methods that may improve access and encourage uptake of programmes designed to improve balance and reduce falls are needed. This review demonstrates that eHealth platforms are a feasible and safe mode of delivering exercises to improve balance. Although we identified a small intervention effect on balance, this result needs to be considered in the context of the ability to scale-up and implement such interventions to large populations where resources are available. Clinicians should consider the use of eHealth platforms for delivering exercise programmes to older people living in the community.

Unanswered questions

Our results identified evidence of the benefit of eHealth-delivered exercise programmes on static balance in older people living in the community. However, what remains unclear is the effect of eHealth-delivered exercise programmes on dynamic balance, fall risk, fear of falling and fall rate in this population. Future studies should focus on high quality trials that deliver the recommended intensity and duration of exercise in order to provide a sufficiently high challenge to balance and impact on fall-related outcomes in a safe manner. Furthermore, future research needs to explore the long-term impact, cost-effectiveness and sustainability of eHealth-delivered programmes on balance and fall-related outcomes in older people living in the community.

Ethical approval

Not applicable.

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Competing Interests Statement

All authors declare there are no competing interests, including no financial relationships with any organisations that might have an interest in the submitted work.

Author Contributions

XX, XX, XX, XX and XX were involved in the conception of the design of this systematic review, including the scope of the review; development of selection criteria; and development of the data analysis strategy. XX and XX were involved in the screening and data extraction.

XX and XX were involved with the GRADE. XX, XX and XX were involved in the data analysis. XX drafted the manuscript. XX, XX, XX, XX, and XX were involved in all revisions and edits made to the manuscript. XX, XX, XX, XX, XX, XX, and XX were involved in the final approval of the version to be published. We acknowledge the assistance of XX and XX for the screening of articles.

Transparency statement

The lead author affirms that the manuscript is an honest, accurate, and transparent account of the Systematic Review being reported; that no important aspects of the study have been omitted; and that any discrepancies from the Systematic Review as originally planned (and, if relevant, registered) have been explained.

Patient and Public Consent for Publication

Patient and public involvement is beyond the scope of this systematic review.

Data sharing statement

We agree to share any relevant data.

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Table 1 Summary of the characteristics of the included trials

Study Author; (year); Country	Study design; Sample size; PEDro Score	Sample	eHealth exercise intervention					Comparator	Adverse events
		Mean age; % female; health status	Intervention content	Outcome measures: Primary & Secondary	Tailored progression of exercises	Dosage: Duration; Session length; frequency	Setting		
Bieryla & Dold, (2013); USA	RCT; N=12; 3	81.5 ± 5.5; 83%; healthy	Exercises: yoga (half-moon, chair, warrior), aerobic (torso twist), balance games (soccer heading, ski jump)	Primary: FAB, BBS.		3 wk; 30 min; 3 x wk	Centre; supervised		
Chow & Mann, (2015); Hong Kong	RCT; N=20; 3	70.4; 65%; healthy	Exercises: Tiger Woods PGA Tour 13 golf game	Primary: SLS, TUG.		2 wk; 30-45 min; daily	Centre; supervised	Table games	
Gschwind et al., (2015a); Australia, Germany, Spain	RCT; N=153; 6	74.7 ± 6.3; 61%; healthy	Exercise: balance & muscle strength; educational booklet on general health & fall prevention.	Primary: tandem stance, TUG. Secondary: icon-FES, PPA		16 wk; Balance: 40 min; 3 x wk. Strength: 15-20 min; 3 x wk	Home; unsupervised	Educational booklet: general health & fall prevention	24 falls (IG: 8, CG: 15)
Gschwind et al., (2015b)/ Schoene et al., (2015); Australia	RCT; N= 90; 7	82±7; 66%; healthy	Exercises: trail-stepping - visual attention, set-shifting; stepping to connect numbers & letters, Tetris-stepping - visuo-spatial skills, problem-solving; stepping.	Primary: Standing Balance, TUG. Secondary: PPA:	↑ intensity; ↑ challenge	16 wk; 20 min; 3 x wk	Home; unsupervised	Educational booklet: general health & fall prevention	
Hong et al., (2018); South Korea	RCT; N=30; 5	78.10; 100%; fall risk	Exercises: resistance, two-legged standing, tandem standing, one-legged standing, semi-tandem standing, tandem walking, turning in a circle, toe stands + nutrition & exercise education.	Primary: BBS. Secondary: FES-K	↑ intensity	12 wk; 20-40 min; 3 x wk	Home; supervised	Nutrition & exercise education	
Lai et al., (2013); Taiwan	Cross-over; N=30; 4	70.6±3.5; 57%; healthy	Exercises: IVGB stepping exercise	Primary: SLS, BBS.		6 wk; 30 min; 3 x wk	Centre; supervised	Cross-over trial	
Lee et al., (2017); South Korea	RCT; N=44; 6	76.15±4.55; 77%; healthy	Exercises: jogging for gait, swordplay for agility & balance, ski jump for balance, hula-hoop for balance & lower extremity strength, tennis for balance & agility, & step	Primary: SLS, BBS.		6 wk; 60 min; 2 x wk	Centre: supervised	3x fall education sessions	

			dance for gait for lower extremity strength						
Schoene et al., (2013); Australia	RCT; N=37; 7	77.5±4.5; healthy	Exercises: a series of stepping challenges + cognitive load	Primary: SB, AST. Secondary: icon-FES, PPA	↑ intensity	8 wk; 15-20 min; 2-3 x wk	Home; unsupervised		
Whyatt et al., (2015); United Kingdom	RCT; N-82; 5	77.18±6.59; 70%; healthy	Exercises: games targeting components of balance (Apple Catch, Bubble Pop, Avoid the Shark, Smart Shrimp)	Primary: SLS, TUG. Secondary: ABC Scale	↑ challenge	5 wk; 30 min; 2 x wk	Centre: supervised	Activity diaries	

Abbreviations:
Wk: week(s); AD: Alzheimer's disease; PEDro: Physiotherapy Evidence Database (used to rate the methodological quality of studies – "poor" PEDro score of 1 to 3, "moderate" PEDro score of 4 to 5, and "high" PEDro score of 6 to 10); IVGB: interactive video game based; +: plus; ↑: increase; Min: minutes; x: times; Centre: exercise delivered within a gymnasium, clinic or other facility that is not the participants place of residence; Primary: primary outcome measure, Secondary: secondary outcome measure; Static balance: SLS - Single leg Stand; SB - Standing Balance; FAB - Fullerton Advanced Balance Scale; Dynamic balance: BBS - Berg Balance Scale; TUG - Timed Up and Go; FR - functional reach; AST - Alternative Step Test; Fear of Falling: Icon-FES - Iconographical Falls Efficacy Scale; FES-K - Falls Efficacy Scale Korea; FES-I - Falls Efficacy Scale – International; Fall risk: PPA - Physiological Profile Assessment; IG: intervention group; CG: control group

Table 2: Summary of the quality of evidence and strength of recommendation

	Quality Assessment			
Meta-analysis	**Study limitations[1]**	**Inconsistency[2]**	**Imprecision[3]**	**Overall GRADE**
Static balance	↓		↓	Low
Dynamic balance	↓	↓	↓	Very low
Fall risk			↓	Moderate
Fear of falling			↓	Moderate

[1] Risk of bias: We downgraded the evidence if >25% of included trials had a high risk of bias.
[2] Heterogeneity >50%
[3] We downgraded if there were <400 participants
↓ Downgraded

Figure 1

Figure 1 outlines the PRISMA study flow of trials included in this review.

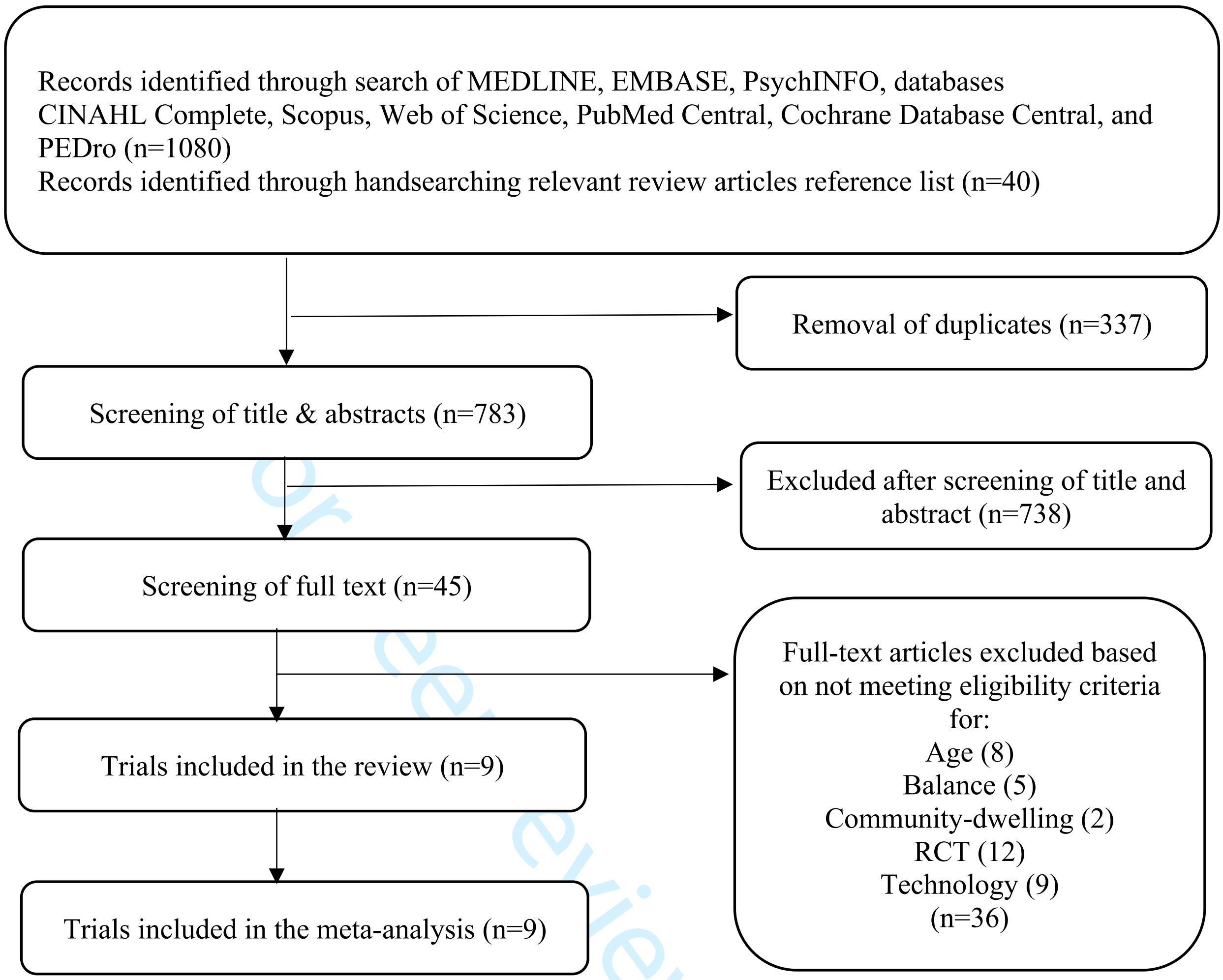
Figure 2

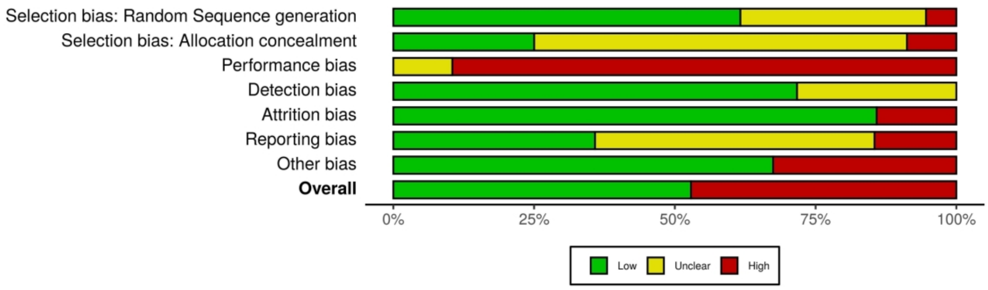
Figure 2 presents the risk of bias

Figure 3

Figure 3 Effect size (95% confidence interval) of eHealth interventions on the balance outcome by pooling data from 7 studies comparing e-health versus control using random-effects meta-analysis (dynamic balance: n =498; static balance: n=468)

Figure 1: PRISMA flow of trials through the review

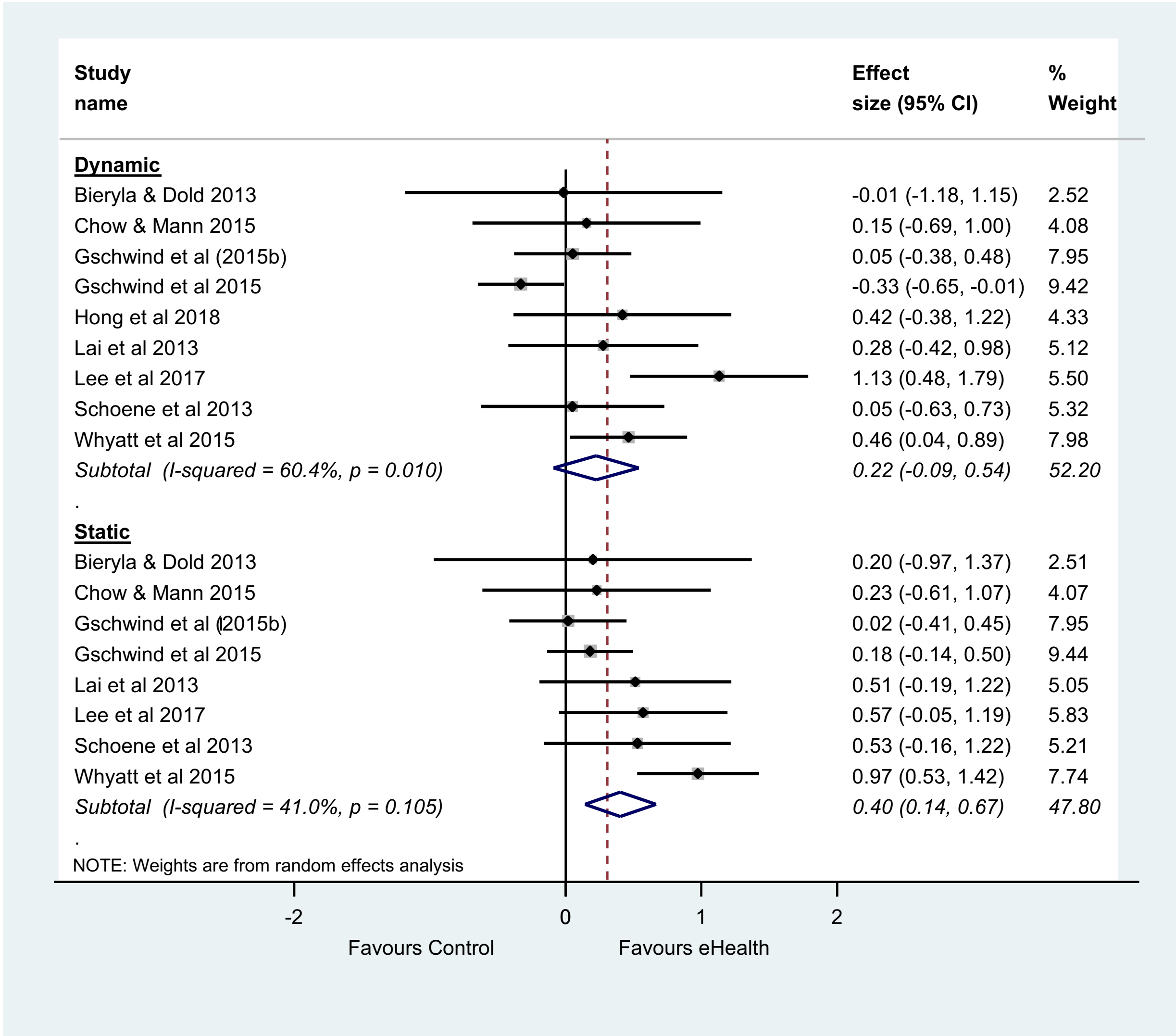




Risk of bias

203x61mm (300 x 300 DPI)

Figure 3 Effect size (95% confidence interval) of eHealth interventions on the balance outcome by pooling data from 7 studies comparing e-health versus control using random-effects meta-analysis (dynamic balance: n =498; static balance: n=468)



PRISMA 2009 Checklist

Section/topic	#	Checklist item	Reported on page #
TITLE			
Title	1	Identify the report as a systematic review, meta-analysis, or both.	1
ABSTRACT			
Structured summary	2	Provide a structured summary including, as applicable: background; objectives; data sources; study eligibility criteria, participants, and interventions; study appraisal and synthesis methods; results; limitations; conclusions and implications of key findings; systematic review registration number.	2
INTRODUCTION			
Rationale	3	Describe the rationale for the review in the context of what is already known.	3-4
Objectives	4	Provide an explicit statement of questions being addressed with reference to participants, interventions, comparisons, outcomes, and study design (PICOS).	4
METHODS			
Protocol and registration	5	Indicate if a review protocol exists, if and where it can be accessed (e.g., Web address), and, if available, provide registration information including registration number.	5
Eligibility criteria	6	Specify study characteristics (e.g., PICOS, length of follow-up) and report characteristics (e.g., years considered, language, publication status) used as criteria for eligibility, giving rationale.	5
Information sources	7	Describe all information sources (e.g., databases with dates of coverage, contact with study authors to identify additional studies) in the search and date last searched.	5, Figure 1
Search	8	Present full electronic search strategy for at least one database, including any limits used, such that it could be repeated.	Supplementary file 1
Study selection	9	State the process for selecting studies (i.e., screening, eligibility, included in systematic review, and, if applicable, included in the meta-analysis).	5-8
Data collection process	10	Describe method of data extraction from reports (e.g., piloted forms, independently, in duplicate) and any processes for obtaining and confirming data from investigators.	6-7
Data items	11	List and define all variables for which data were sought (e.g., PICOS, funding sources) and any assumptions and simplifications made.	6-7
Risk of bias in individual studies	12	Describe methods used for assessing risk of bias of individual studies (including specification of whether this was done at the study or outcome level), and how this information is to be used in any data synthesis.	7-8, 10
Summary measures	13	State the principal summary measures (e.g., risk ratio, difference in means).	8-9
Synthesis of results	14	Describe the methods of handling data and combining results of studies, if done, including measures of consistency (e.g., I^2) for each meta-analysis.	8-9

PRISMA 2009 Checklist

Section/topic	#	Checklist item	Reported on page #
Risk of bias across studies	15	Specify any assessment of risk of bias that may affect the cumulative evidence (e.g., publication bias, selective reporting within studies).	7-8, 13, Figure 2
Additional analyses	16	Describe methods of additional analyses (e.g., sensitivity or subgroup analyses, meta-regression), if done, indicating which were pre-specified.	N/A
RESULTS			
Study selection	17	Give numbers of studies screened, assessed for eligibility, and included in the review, with reasons for exclusions at each stage, ideally with a flow diagram.	9, Figure 1
Study characteristics	18	For each study, present characteristics for which data were extracted (e.g., study size, PICOS, follow-up period) and provide the citations.	10-11, Table 1
Risk of bias within studies	19	Present data on risk of bias of each study and, if available, any outcome level assessment (see item 12).	7, Figure 2
Results of individual studies	20	For all outcomes considered (benefits or harms), present, for each study: (a) simple summary data for each intervention group (b) effect estimates and confidence intervals, ideally with a forest plot.	12-13, 15, Figure 3, Supplementary files 2, 3.
Synthesis of results	21	Present results of each meta-analysis done, including confidence intervals and measures of consistency.	13-15,
Risk of bias across studies	22	Present results of any assessment of risk of bias across studies (see Item 15).	7-8, 13, Figure 1
Additional analysis	23	Give results of additional analyses, if done (e.g., sensitivity or subgroup analyses, meta-regression [see Item 16]).	N/A
DISCUSSION			
Summary of evidence	24	Summarize the main findings including the strength of evidence for each main outcome; consider their relevance to key groups (e.g., healthcare providers, users, and policy makers).	13-16
Limitations	25	Discuss limitations at study and outcome level (e.g., risk of bias), and at review-level (e.g., incomplete retrieval of identified research, reporting bias).	15
Conclusions	26	Provide a general interpretation of the results in the context of other evidence, and implications for future research.	15-16
FUNDING			

PRISMA 2009 Checklist

Funding	27	Describe sources of funding for the systematic review and other support (e.g., supply of data); role of funders for the systematic review.	Title page

From: Moher D, Liberati A, Tetzlaff J, Altman DG, The PRISMA Group (2009). Preferred Reporting Items for Systematic Reviews and Meta-Analyses: The PRISMA Statement. PLoS Med 6(7): e1000097. doi:10.1371/journal.pmed1000097

For more information, visit: **www.prisma-statement.org**.

BMJ Open

The effect of eHealth-delivered exercise programmes on balance in people aged 65 years and over living in the community: A systematic review & meta-analysis of randomised controlled trials.

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The effect of eHealth-delivered exercise programmes on balance in people aged 65 years and over living in the community: A systematic review & meta-analysis of randomised controlled trials.

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Abstract

Introduction: Exercise that challenges balance is proven to prevent falls in community-dwelling older people, yet widespread implementation and uptake of effective programmes is low. This systematic review and meta-analysis synthesised the evidence and evaluated the effect of eHealth-delivered exercise programmes compared to control on balance in community-dwelling people aged ≥65 years.

Methods: Nine databases including MEDLINE, CINAHL, and Embase, were searched from inception to January 2022 to identify randomised controlled trials evaluating eHealth-delivered exercise programmes for community-dwelling people aged ≥65 years, published in English that included a balance outcome. Primary outcomes were static and dynamic balance. Secondary outcomes included fall risk and fear of falling. We calculated standardised mean differences (SMDs, Hedges' g) with 95% confidence intervals (CIs) from random effects meta-analyses.

Results: We identified 14 eligible studies that included 1,180 participants. Methodological quality ranged from 3 to 8 (mean, 5). The pooled effect indicated that eHealth-delivered exercise programmes have a medium significant effect on static balance (11 studies; SMD = 0.62, 95% CI 0.27 to 0.72) with very low-quality evidence. There was small statistically significant effect on dynamic balance (14 studies; SMD = 0.42, 95% CI 0.11 to 0.73) with very low-quality evidence, and fall risk (five studies; SMD = 0.32, 95% CI 0.00 to 0.64) with moderate-quality evidence. No significant effect of eHealth programmes on fear of falling was found (four studies; SMD = 0.10, 95 % CI -0.05 to 0.24; high-quality evidence).

Conclusion: This review provides preliminary evidence that eHealth-delivered exercise programmes improved balance and reduced fall risk in people aged ≥65 years. There is still uncertainty regarding the effect of eHealth delivered exercise programmes on fear of falling.

PROSPERO Registration: CRD42018115098.

KEYWORDS

postural balance, accidental falls, internet, exergames, mobile games.

Article Summary

Strengths and limitations of the study

- We conducted this systematic review in accordance with PRISMA guidelines and followed a prespecified protocol registered on PROSPERO.
- We had specific criteria that allowed for the inclusion of studies with both generally healthy participants and those with selected clinical conditions.
- We also ensured the inclusion of as many relevant studies as possible by searching across nine databases, conducting a thorough hand search of relevant published literature, and consulting with experts in the field.
- Included studies had to comprise a measure of balance and we may have missed relevant studies that included measures of falls.
- We only included outcome data from the immediate post-intervention time point, which limits the interpretation of results to the short-term.

Introduction

Ageing is associated with a decline in the physiological systems responsible for postural stability and hence an increase in the risk of falls.[1] A fall is defined as "an unexpected event in which the participants come to rest on the ground, floor, or other lower level".[2] Each year approximately one-third of community-dwelling people aged 65 years and over experience a fall.[3 4] Forty percent of injuries requiring hospital admission are due to falls, and in 2016-2017 more than 125,000 Australians aged 65 years or over were hospitalised due to a fall.[5 6] Falls place a significant burden on health systems and can result in serious long-term costs to the individual.[7] Falls can also result in loss of independence, depression, social isolation, and admission of the older person to a care facility.[7] As such, fall prevention is a public health priority.

There is clear evidence that exercise is crucial for preventing falls in community-dwelling older people.[8] However, the effect on falls varies by exercise type. A Cochrane systematic review that included 108 studies of exercise, established that exercise that challenges balance has the greatest effect on both the rate of falls (24% reduction) and risk of falls (13% reduction) in community-dwelling older people.[8] Despite the benefits of exercise for preventing falls, widespread implementation and adherence to effective programmes is poor, significantly reducing the population-wide impact.[9] Furthermore, the 2020 World Health Organization (WHO) guidelines on physical activity and sedentary behaviour recommend that older adults should undertake multicomponent physical activity that emphasises functional balance and strength training at least three-times per week to enhance functional capacity and prevent falls.[10] Therefore, exploring the effectiveness of novel exercise programmes with potential for wide reach that can improve balance is important.

Advances in technology have led to new ways to deliver exercise-based programmes. Such technology-based programmes, commonly referred to as electronic-Health (eHealth), that use the internet, websites, mobile applications (apps) or exergames, may provide effective alternatives to more traditional modes of delivering exercise-based programmes to improve balance and prevent falls, and increase access to such programmes. Previous studies show that eHealth interventions can successfully improve the health and physical activity of older people,[11-16] and adherence by some older people is higher for technology-delivered interventions compared to traditional interventions, independent of study site, level of supervision and mode of delivery.[17]

eHealth-delivered exercise programmes are a safe way to exercise, and many older people perceive them as fun and enjoyable.[18-22] This mode of delivery has also been successful for improving balance in younger adults, aged 18+ years, with a number of systematic reviews evaluating the effectiveness of specific, technology-based approaches to improving balance or reducing fall risk in adults.[23-26]

Given the lack of systematic reviews and meta-analyses on the effectiveness of eHealth-delivered exercise programmes for improving balance in older people, further evaluation of the role of technology-driven platforms is needed. This systematic review and meta-analysis aimed to synthesise the evidence and evaluated the effect of eHealth-delivered exercise programmes on balance in people aged 65 years and older living in the community compared to a control.

Methods

Protocol

This review was registered on the PROSPERO database (CRD42018115098) and followed the Preferred Reporting Items for Systematic Review and Meta-analysis (PRISMA) guidelines.[27] The systematic review protocol has been published and provides a full outline of the methods.[28] A summary of the methods is reported in this paper.

Data Sources

A database search was conducted from inception to January 2022 of MEDLINE, CINAHL Complete, Embase, PsychINFO, Scopus, Web of Science, PubMed Central, Cochrane Database Central, and PEDro. The Protocol[28] details the complete search strategy used. Supplementary Figure 1 provides the MEDLINE search strategy.

Eligibility Criteria

Studies included in this systematic review met the following criteria: (1) published in English, (2) randomised controlled trials (RCT), (3) participants were community-dwelling people aged ≥65 years, (4) reported data for a validated measure of balance, (5) included eHealth delivery of an exercise programme compared with no intervention, usual care or wait-list control. Studies that did not meet these criteria were excluded.

We included all RCT designs such as crossover, cluster, patient-randomised clinical trials that examined the effect of eHealth-delivered exercise programmes versus a control group. Single and multi-factorial interventions were also included. Studies published only as abstracts or yet to be published were excluded due to possible data inaccuracy and incompleteness.

Outcome measures

The primary outcome measure was balance, defined as staying upright and steady when stationary, such as when standing, or sitting, or during movement.[29] Technically, balance is defined as “the ability to maintain the projection of the body’s centre of mass (CoM) within manageable limits of the base of support, as in sitting or standing, or in transit to a new base of support, as in walking”.[30] The balance outcomes were further categorised as static or dynamic measures of balance in the analyses. Static balance refers to maintaining balance when the body has a constant or static base of support.[29] Whereas dynamic balance refers to maintaining balance during movement from one base of support to another, such as when walking.[29] In the absence of functional measures of balance, we included studies which reported direct measures of balance, such as those measured with a force platform. Fall risk, fear of falling and fall rate were included as secondary outcomes. We included studies that used either validated self-report questionnaires or performance-based measures for these outcomes.

Study Selection

After pilot-testing criteria for full-text articles, screening for eligible studies was conducted independently by two reviewers (MA, KLA/RS). An electronic screening form was used, and screening occurred in stages: firstly, titles were screened, followed by abstracts, and finally full-text articles were screened. Conflicts were resolved by a consensus from AT, KD, and CV.

Data Extraction

Data extraction was completed by two researchers independently from one another (MA, QT), and conflicts were resolved by a third reviewer (SJA). Data were extracted using a piloted electronic data extraction form, and according to the PRISMA statement.[27] Where data were missing, study authors were contacted by email to provide further information. Where the authors did not reply within two weeks, a second email was sent as a reminder.

The following data were extracted from each study: author, year of publication, country, sample characteristics (sample size, age, sex of participants and health status), study design: including number of study arms, recruitment sources, eligibility criteria, setting, delivery method and technology used, intervention description, comparator, intervention duration and frequency, assessment time-points. Also extracted were data on drop out, attrition, adverse events, and intervention features such as implementation fidelity, evidenced-based theory, tailoring, supervision, intervention acceptability. Primary and secondary outcome data were extracted for pre-intervention and post-intervention timepoints. Where data were available for more than one post-intervention timepoint, we included the data from the timepoint closest to intervention completion.

<u>Methodological quality and risk of bias assessment</u>

The PEDro scale (1-10) was used to assess the methodological quality of the included studies. PEDro scores were extracted from the PEDro database.[31] The PEDro scale assesses the internal validity of an RCT by evaluating 11 items: participant eligibility criteria, random allocation, concealed allocation, homogeneity of groups at baseline, blinding of subjects, blinding of therapist, blinding of assessor, completeness of follow up, intention-to-treat analysis, between-group statistical analysis, and variability and point measures.[32] A score of 10 is considered to be methodologically excellent, whereas 0 demonstrates poor methodological quality.[32] Methodological quality was not an inclusion criterion for this review.

In addition to the PEDro scale, we also used the Cochrane Risk of Bias to assess the risk of bias in each included study. The Cochrane Risk of Bias was undertaken by two independent reviewers (MA, SJA) with conflicts resolved by a third reviewer (CV). Risk of bias is assessed across a number of domains as a judgement of low risk, high risk, or unclear.[33]

<u>Assessment of quality of evidence</u>

To evaluate overall quality of evidence we used the Grading of Recommendations, Assessment, Development and Evaluations (GRADE) system. The GRADE appraisal was conducted by pairs of independent reviewers (MA, JSO) and guided by the Cochrane Handbook for Systematic Reviews. [33] This is a subjective evaluation of the quality of the evidence as High, Moderate, Low, or Very Low based on the presence or extent of the following factors: risk of bias, imprecision, and inconsistency of the effect. The GRADE classification was downgraded from high quality by one level for each factor encountered: (1) Design limitations (>25% of studies with low methodological quality based on the Cochrane Risk of bias), (2) Inconsistency of results (large heterogeneity between the studies $I^2>50\%$), (3) Imprecision (<400 participants for each outcome).[33] We did not consider indirectness as it encompasses a specific population (older people) with relevant outcome measures (balance) and direct comparisons. We were unable to consider publication bias for secondary outcome measures due to the limited number of studies that collected measures for the fall-related outcome measures.[33]

Statistical Analysis

We performed meta-analyses with Comprehensive Meta-Analysis software (V.3, Biostat, Englewood, New Jersey, USA) using the random effects models for primary and secondary outcome measures. The random effects model was chosen given the heterogeneity of the population and the interventions being evaluated. We calculated treatment effects for the continuous variables using standardised mean differences (Hedges' g) standardised by post-score standard deviation (or its estimate) with 95% CIs, for either between-group differences in point estimates at the follow-up time points or between-group differences in change scores based on available data. Standardised mean differences were calculated using the pre-mean and post-mean and standard deviation (SD). Where this was not available, we used the mean change score. Effect sizes were categorised as small (0.2), medium (0.5), or large (0.8 or greater).[34]

We visually inspected the forest plot for evidence of heterogeneity among studies with consideration of the I^2 and Chi-square tests. We determined clinical heterogeneity by consensus among the investigators on the basis of collective experience in the field.

Results

Flow of studies included in this review

The initial search of the databases resulted in 1,080 publications. An additional hand search, including the reference lists of relevant review articles found a further 40 publications. After removing duplicate papers, 783 publications were screened by title and abstract. Forty-five publications reported on potentially eligible studies before full-text screening. After the full-text screen, 14 studies, reported by 15 manuscripts, were identified as eligible and included in this study. Schoene et al.[35] conducted a study involving interactive cognitive-motor step training, however this paper did not report the balance outcomes measured during this study. These balance outcomes were reported in Gschwind et al.[36] as the step-mat-training (SMT) intervention group. This review extracted outcome data for the SMT group only from the Gschwind et al.[36] paper, all other data pertaining to this study (including for the control group) were extracted from Schoene et al.[35] Figure 1 outlines the PRISMA study flow of studies included in this review.

We pooled all included studies in the primary meta-analysis evaluating the effect of interventions that use an eHealth technology to deliver an exercise programme to older people.

Risk of Bias and Quality

Table 1 reports the methodological quality of eligible studies. The total PEDro scores ranged from 3 to 8 (mean of 5). For the static balance outcome five studies out of 11 (45%) were of high methodological quality (a score ≥6).[18 36-39] For the dynamic balance outcome, five studies out of 14 (36%) were of high methodological quality.[18 36-39] All participants were randomly allocated and provided the calculation of point estimates and variability (PEDro items 2 and 11). Four studies out of 14 (29%) did not undertake an intention-to-treat analysis[18 40-42] and 3 studies provided insufficient information to determine this.[43-45] None of the studies included blinded participants or blinded therapists, however blinding of participants or therapists is not possible for exercise interventions. Table 2 reports the quality of the evidence. Figure 2 presents the risk of bias.

Cohort Characteristics

Studies included samples ranging from 9 to 503 participants (n= 1,180). The mean age of participants ranged from 65 to 89 years. Both males and females were included in 11 studies, all had a higher percentage of female participants.[18 36-38 40 42 46 47] Two studies included only female participants[41 45], one study include only male participants.[48] Every study recruited participants from the general community.[18 36-48] Two studies recruited participants with a history of falls.[41 45] Table 1 presents a summary of cohort characteristics.

Characteristics of included studies

Publication dates ranged from 2013 to 2021, with 11 (76%) published during or after 2015. Studies were conducted in eight different countries: single studies were conducted in Hong Kong,[46] Taiwan,[49] the United States of America,[42] the United Kingdom,[40] Japan,[44] Malaysia,[48] and Thailand;[43] three studies were conducted in Australia,[18 36 39] and South Korea;[37 41 45] and one study was conducted across three countries: Germany, Spain and Australia.[38] Details of study characteristics are summarised in Table 1.

eHealth-delivered exercise programmes

The duration of the included interventions ranged from two to 52 weeks, with a mean duration of 12 weeks. Eleven studies (79%) used a commercially available exergame system to deliver the exercises: five (36%) used the Microsoft Xbox Kinect,[38 43 44 46 48] four (29%) studies used the Nintendo Wii console,[37 40 42 45] two (14%) used the Dance Dance Revolution StepMania.[18 36] Three studies (21%) used customised technologies: an app-based intervention called *StandingTall*,[39] a web-based intervention called telepresence,[41] and the Xavix Measured Step System.[49]

Five studies (36%) used technology to provide a home-based intervention.[18 36 38 39 41] Nine studies (64%) used technology to deliver a supervised intervention: participants attended a supervised group class,[37 44 46] or a supervised one-on-one session.[40 42 43 45 48 49]

In seven studies (50%), the control group received no information and were encouraged to continue with normal daily activities.[18 40 42 49] Control participants in five studies (36%) received educational advice related to fall prevention, general health, nutrition and physical activity, in the form of a booklet or classes.[36-39 41] Participants in one study continued with the regular, seated social games available at the senior's activities centre.[46]

Effect of eHealth-delivered exercise programmes on balance

Eleven studies (79%) measured static balance using static balance,[39] single leg stance,[37 46-48] tandem stance,[38] postural sway,[18 36 40] functional reach,[45] and the Fullerton Advanced Balance

Scale.[42] The pooled effect of eHealth-delivered exercise programmes on static balance indicates a medium, statistically significant effect compared to control (SMD = 0.62, 95% CI 0.27 to 0.72; I^2 = 82%, p = 0.001) (Figure 3). The pooled results provide very low-quality evidence (GRADE).

All 14 studies measured dynamic balance with methods ranging from the Timed Up and Go,[36-39 42 43 45-48] the Berg Balance Scale,[40 41 44] and the Alternative Step test.[18] The pooled effect of eHealth-delivered exercise programmes on dynamic balance indicates there was a small, statistically significant effect compared to control (SMD = 0.42, 95% CI 0.11 to 0.73; I^2 = 79%, p = 0.009) (Figure 4). The pooled results provide very low-quality evidence (GRADE). Supplementary Figure 2 provides the Funnel plot for static and dynamic balance.

Effect of eHealth-delivered exercise programmes on secondary outcomes

Five studies (36%) measured fall risk using the Physiological Profile Assessment (PPA).[18 36 38 39 43] The pooled effect of eHealth-delivered exercise programs on fall risk indicates a small effect compared to control (SMD = 0.32, 95% CI 0.00 to 0.64; I^2 = 69.6%, p = 0.048). The pooled results provide moderate-quality evidence (GRADE).

Four studies (29%) reported measures of fear of falling using the shortened Iconographical Falls Efficacy Scale (icon-FES),[18 38 39] or the Fear of Falling Questionnaire.[41] The pooled effect indicates no significant effect of eHealth-delivered exercise programmes on fear of falling compared to control (SMD = 0.10, 95 % CI -0.05 to 0.24; I^2 = 0.0%, p = 0.201). The pooled results provide high-quality evidence (GRADE).

Two studies collected data for fall rate.[37 39] However, Lee et al.[37] only reported a baseline measure for fall rate without providing further follow up data. We were therefore unable to report on fall rate.

Adverse events

Eight included studies (57%) measured adverse events.[35-41 46] Of those reported, no major adverse events were related to the intervention.

Discussion

This systematic review and meta-analysis provides preliminary evidence that eHealth-delivered exercise programmes improve balance (static and dynamic) and provide an alternative method of delivering an exercise programme to people aged ≥65 years living in the community. This reviews also demonstrates that an eHealth-delivered exercise programme may improve fall risk in people aged ≥65 years living in the community. However, we are uncertain whether an eHealth-delivered exercise programme improves fear of falling or fall rate in people aged ≥65 years living in the community.

There are a number of factors that may have influenced these results. Firstly, the dose and intensity of prescribed exercise in many of the studies may have been insufficient to substantially improve dynamic balance. A Cochrane review examining the effects of exercise interventions on balance found effective programmes were those attended three times per week for three months and involved dynamic exercises in a standing position.[29] While in 79% of studies (11/14) participants completed intervention exercises three times per week, only five studies had an exercise duration of 12 or more weeks. Furthermore, a systematic review on falls prevention found greater effects from interventions that challenged balance and included

>3 hours per week.[50] Six studies (43%) included tailoring (increases in intensity and challenge). In addition, only four studies engaged participants in at least 180 minutes of exercise per week for the duration of the intervention. Most studies (71%) only engaged participants for between 30-120 minutes of exercise per week. This suggests that the challenge to balance may not have been of a sufficiently high dose. Therefore, considering our results indicate a small but statistically significant effect on dynamic balance is promising. Further research is needed to explore the effect higher dosage (i.e., tailoring exercises to achieve increased intensity and challenge over the duration of the intervention) has on dynamic balance.

Finally, the tools used to measure dynamic balance may not be the most appropriate for the healthy older people. The most frequently used measure of dynamic balance was the Timed-up-and-go (TUG) (10/14). While the TUG is a validated tool and is recommended by the National Institute of Clinical Evidence for the assessment of gait and balance in the prevention of falls in older people,[3] research has found the TUG may be more appropriate for frail older people who use walking aids rather than healthy older people.[51]

The results for the secondary measures related to falls are mixed. While there was a small but significant effect on fall risk compared to the control, there is still uncertainty around the effect eHealth-delivered exercise programmes have on fear of falling. This is despite strong evidence that exercise interventions reduce falls in older community-dwellers.[8] There are two possible explanations for these findings. Firstly, to be eligible the included studies had to report on balance, resulting in only a small number (n=5 fall risk; n=4 fear of falling) of studies also reporting a fall-related measure. This suggests we may have missed studies that measured the other fall-related outcomes of interest. Secondly, it is likely that the studies that reported a fall-related outcome, were not powered to detect an impact on falls (sample sizes ranged from 30 to 503 participants).[2]

Implications for clinicians and policymakers

Given the often low levels of adherence to exercise-based fall prevention programmes amongst older people, new delivery methods that improve access and encourage uptake of programmes designed to improve balance and reduce falls are needed. This review demonstrates that eHealth platforms are an effective mode of delivering exercises to improve balance. Although we identified an intervention effect on balance (static and dynamic), not only does this need to be considered in the context of the quality of the evidence but also in the ability to scale-up and implement such interventions to large populations where resources are available. Clinicians should consider the use of eHealth platforms for delivering exercise programmes to older people living in the community.

Unanswered questions

Our results identified evidence of the benefit of eHealth-delivered exercise programmes on balance (static and dynamic) in older people living in the community. However, what remains unclear is the effect of eHealth-delivered exercise programmes on fall risk, fear of falling and fall rate in this population. Future studies should focus on high quality studies that deliver the recommended intensity and duration of exercise to provide a sufficiently high challenge to balance and impact on fall-related outcomes in a safe manner. Furthermore, future research needs to explore the long-term impact, cost-effectiveness, and sustainability of eHealth-delivered programmes on balance and fall-related outcomes in older people living in the community.

Ethical approval

Not applicable.

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Competing Interests Statement

All authors declare there are no competing interests, including no financial relationships with any organisations that might have an interest in the submitted work.

Author Contributions

MA, CV, AT, SJA and KD were involved in the conception of the design of this systematic review, including the scope of the review; development of selection criteria; and development of the data analysis strategy. MA and QT were involved in the screening and data extraction. MA and JSO were involved with the GRADE. MA, JSO and AT were involved in the data analysis. MA drafted the manuscript. MA, CV, AT, SJA, and KD were involved in all revisions and edits made to the manuscript. MA, CV, AT, SJA, KD, QT, and JSO were involved in the final approval of the version to be published. We acknowledge the assistance of KLA and RS for the screening of articles.

Transparency statement

The lead author affirms that the manuscript is an honest, accurate, and transparent account of the Systematic Review being reported; that no important aspects of the study have been omitted; and that any discrepancies from the Systematic Review as originally planned (and, if relevant, registered) have been explained.

Patient and Public Consent for Publication

Patient and public involvement is beyond the scope of this systematic review.

Data sharing statement

We agree to share any relevant data.

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Table 1 Summary of the characteristics of the included studies

Study Author; (year); Country	Study design; Sample size; PEDro Score	Sample Mean age; % female; health status	eHealth exercise intervention: Intervention content	Outcome measures: Primary & Secondary	Tailored progression of exercises	Dosage: Duration; Session length; frequency	Setting	Comparator	Adverse events	Intervention acceptability & how it was assessed
Bieryla & Dold, (2013); USA	RCT; N=12; 3	81.5 ± 5.5; 83%; healthy	Exercises: yoga (half-moon, chair, warrior), aerobic (torso twist), balance games (soccer heading, ski jump).	Primary: FAB, BBS.		3 wk; 30 min; 3 x wk	Centre; supervised			Not assessed
Chow & Mann, (2015); Hong Kong	RCT; N=20; 3	70.4; 65%; healthy	Exercises: Tiger Woods PGA Tour 13 golf game.	Primary: SLS, TUG.		2 wk; 30-45 min; daily	Centre; supervised	Table games		Not assessed
Delbaere et al. (2021); Australia	RCT; N=503; 8	77.1±5.5; 67%; healthy	Exercises: balance & lower limb muscle strength; health education	Primary: Standing balance, TUG Secondary: PPA, icon-FES	↑ intensity; ↑ challenge ↑ duration	52 wk (balance measures), 104 wk (fall measures); 120 min per wk	Home; unsupervised	Health education program delivered via iPad	5 falls	SUS to assess usability
Gschwind et al., (2015a); Australia, Germany, Spain	RCT; N=153; 6	74.7 ± 6.3; 61%; healthy	Exercise: balance & muscle strength; educational booklet on general health & fall prevention.	Primary: tandem stance, TUG. Secondary: icon-FES, PPA		16 wk; Balance: 40 min; 3 x wk. Strength: 15-20 min; 3 x wk	Home; unsupervised	Educational booklet: general health & fall prevention	24 falls (IG: 8, CG: 15)	SUS to assess usability & enjoyment; DART to assess user acceptance.
Gschwind et al., (2015b)/ Schoene et al., (2015); Australia	RCT; N= 90; 7	82±7; 66%; healthy	Exercises: trail-stepping - visual attention, set-shifting; stepping to connect numbers & letters, Tetris-stepping - visuo-spatial skills, problem-solving; stepping.	Primary: Standing Balance, TUG. Secondary: PPA:	↑ intensity; ↑ challenge	16 wk; 20 min; 3 x wk	Home; unsupervised	Educational booklet: general health & fall prevention		Not assessed
Hong et al., (2018); South Korea	RCT; N=30; 5	78.10; 100%; fall risk	Exercises: resistance, two-legged standing, tandem standing, one-legged standing, semi-tandem standing, tandem walking, turning in a circle, toe stands + nutrition & exercise education.	Primary: BBS. Secondary: FES-K	↑ intensity	12 wk; 20-40 min; 3 x wk	Home; supervised	Nutrition & exercise education		Not assessed

Jung et al., (2015); Republic of Korea	RCT; N=24; 4	74.3±2.1; 100%; fall risk	Exercises (NWS group): including the wakeboard, Frisbee dog, jet ski, and canoe games.	Primary: Functional reach, TUG, BBS.		8 wk; 30 min; 2 x wk.	Centre: supervised			Not assessed
Lai et al., (2013); Taiwan	Cross-over; N=30; 4	70.6±3.5; 57%; healthy	Exercises: IVGB stepping exercise.	Primary: SLS, BBS.		6 wk; 30 min; 3 x wk	Centre; supervised	Cross-over trial		Not assessed
Lee et al., (2017); South Korea	RCT; N=44; 6	76.15±4.55; 77%; healthy	Exercises: jogging for gait, swordplay for agility & balance, ski jump for balance, hula-hoop for balance & lower extremity strength, tennis for balance & agility, & step dance for gait for lower extremity strength.	Primary: SLS, BBS.		6 wk; 60 min; 2 x wk	Centre: supervised	3x fall education sessions		Not assessed
Phirom et al. (2020); Thailand	RCT; N=40	70.21±4.18; healthy	Exercises: interactive game-based training which involved stepping on different targets and in different directions and balance training.	Primary: TUG Secondary: PPA		12 wk; 60 min; 3 x wk	Centre; supervised			Not assessed
Sadeghi et al. (2021); Malaysia	RCT; N=64; 5	71.8±6.09; 0%; healthy	Exercises (BT group): single-leg stance with eyes open and closed, standing on heels or toes, tandem and semi-tandem foot stance, tandem walking, walking backward and forward, and weight shifting.	Primary: SLS, TUG	↑ intensity; ↑ challenge	8 wk; 40 min; 3 x wk	Centre; supervised	Educational material covering cognitive enhancement and fall prevention strategies.		Not assessed
Sato et al. (2015); Japan	RCT; N=54; 4	69.25±5.41; 80%; healthy	Complete 4 games - apple game, balloon popping game, tightrope game, one-leg standing game.	Primary: BBS		9 wk (24 sessions); 40-60min; 2-3 x wk	Centre; supervised			Not assessed
Schoene et al., (2013); Australia	RCT; N=37; 7	77.5±4.5; healthy	Exercises: a series of stepping challenges + cognitive load.	Primary: SB, AST. Secondary: icon-FES, PPA	↑ intensity	8 wk; 15-20 min; 2-3 x wk	Home; unsupervised			Participants were asked whether they enjoyed playing the exergame (YES/NO response)
Whyatt et al., (2015); United Kingdom	RCT; N-82; 5	77.18±6.59; 70%; healthy	Exercises: games targeting components of balance (Apple Catch, Bubble Pop, Avoid the Shark, Smart Shrimp).	Primary: SLS, TUG. Secondary: ABC Scale	↑ challenge	5 wk; 30 min; 2 x wk	Centre: supervised	Activity diaries		Not assessed

Abbreviations:
Wk: week(s); PEDro: Physiotherapy Evidence Database (used to rate the methodological quality of studies – “poor” PEDro score of 1 to 3, “moderate” PEDro score of 4 to 5, and “high” PEDro score of 6 to 10); IVGB: interactive video game based; +: plus; ↑: increase; Min: minutes; x: times; Centre: exercise delivered within a gymnasium, clinic or other facility that is not the participants place of residence; Primary: primary outcome measure, Secondary: secondary outcome measure; Static balance: SLS - Single leg Stand; SB - Standing Balance; FAB - Fullerton Advanced Balance Scale; Dynamic balance: BBS - Berg Balance Scale; TUG - Timed Up and Go; FR - functional reach; AST - Alternative Step Test; Fear of Falling: Icon-FES - Iconographical Falls Efficacy Scale; FES-K -

Falls Efficacy Scale Korea; FES-I - Falls Efficacy Scale – International; Fall risk: PPA - Physiological Profile Assessment; IG: intervention group; CG: control group; NWS group: Nintendo Wii Sports group; NSW BT group: balance training group; SUS: System Usability Scale; DART: Dynamic Acceptable Model for the Re-evaluation of Technologies.

Table 2: Summary of the quality of evidence and strength of recommendation

Meta-analysis	Quality Assessment				
	Study limitations[1]	**Inconsistency[2]**	**Imprecision[3]**	**Publication bias**	**Overall GRADE**
Static balance	↓	↓		↓	Very low
Dynamic balance	↓	↓		↓	Very low
Fall risk		↓			Moderate
Fear of falling					High

[1] Risk of bias: We downgraded the evidence if >25% of included studies had a high risk of bias.
[2] Heterogeneity >50%
[3] We downgraded if there were <400 participants
↓ Downgraded

Figure: PRISMA flow of studies through the review

Figure 2 Risk of Bias attached as a separate file

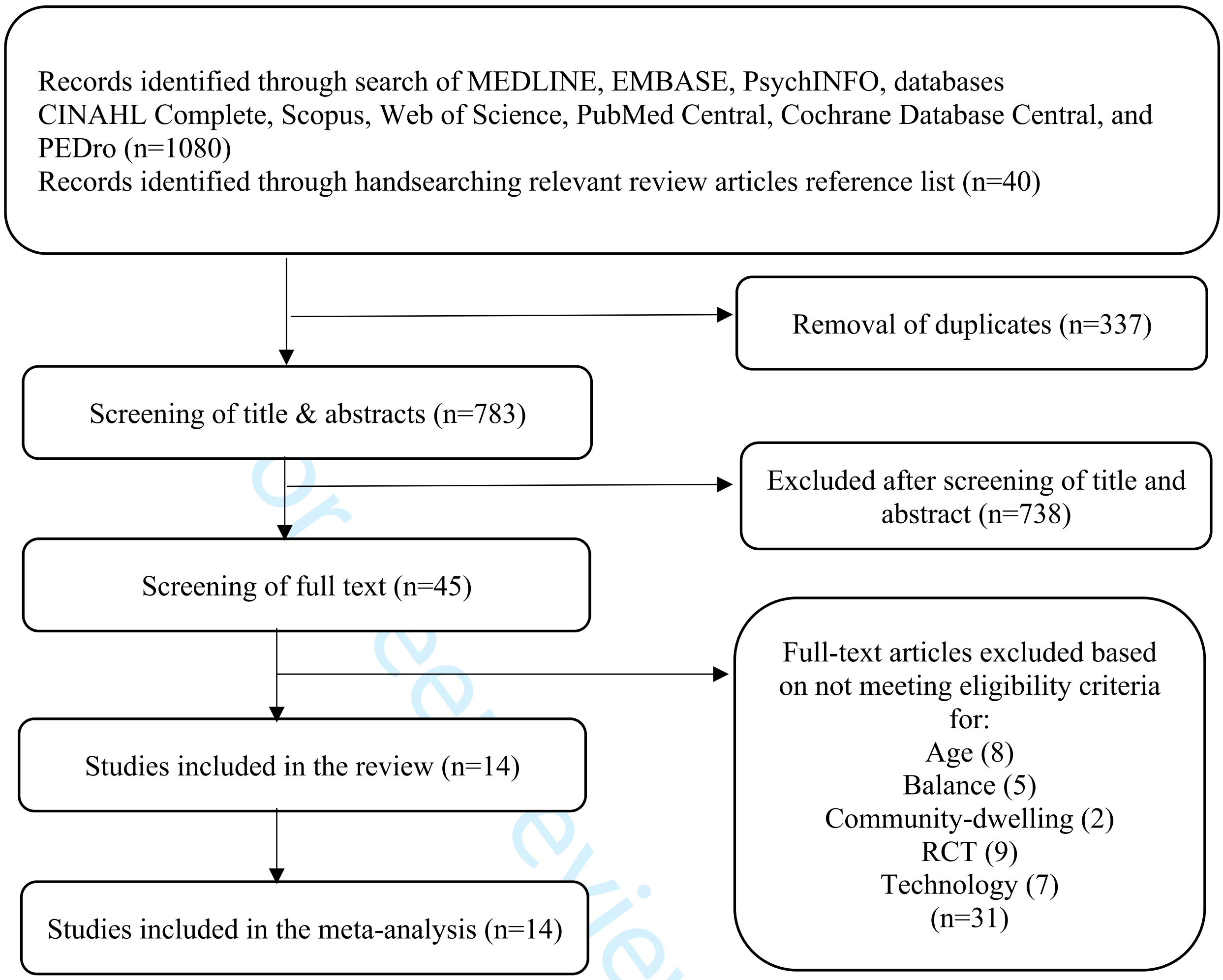
Figure 3 Forest plot – Static balance attached as a separate file

Figure 4 Forest plot – Dynamic balance attached as a separate file

Supplementary Figure 1 – Search strategy for MEDLINE

Supplementary Figure 2 - Funnel plot of standard error by Hedges' g for trial included in the meta-analysis for balance, fear of falling and fall risk

Figure 1: PRISMA flow of studies through the review



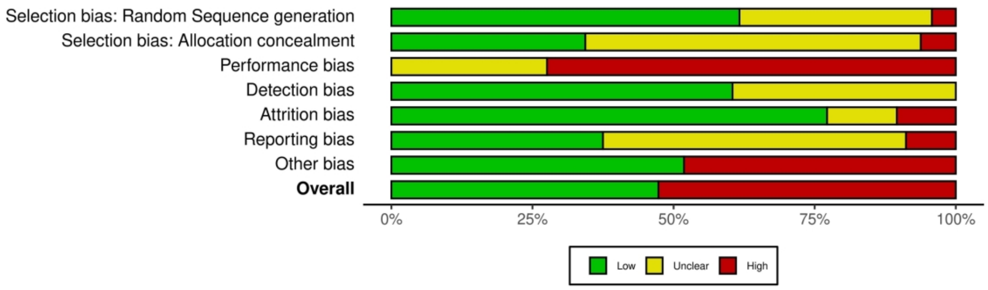


Figure 2 Risk of Bias

203x61mm (300 x 300 DPI)

Figure 3: Effect size (95% confidence interval) of e-Health interventions on **static balance** outcome by pooling data from 11 studies comparing e-Health versus control using random-effects meta-analysis (n = 1,056)

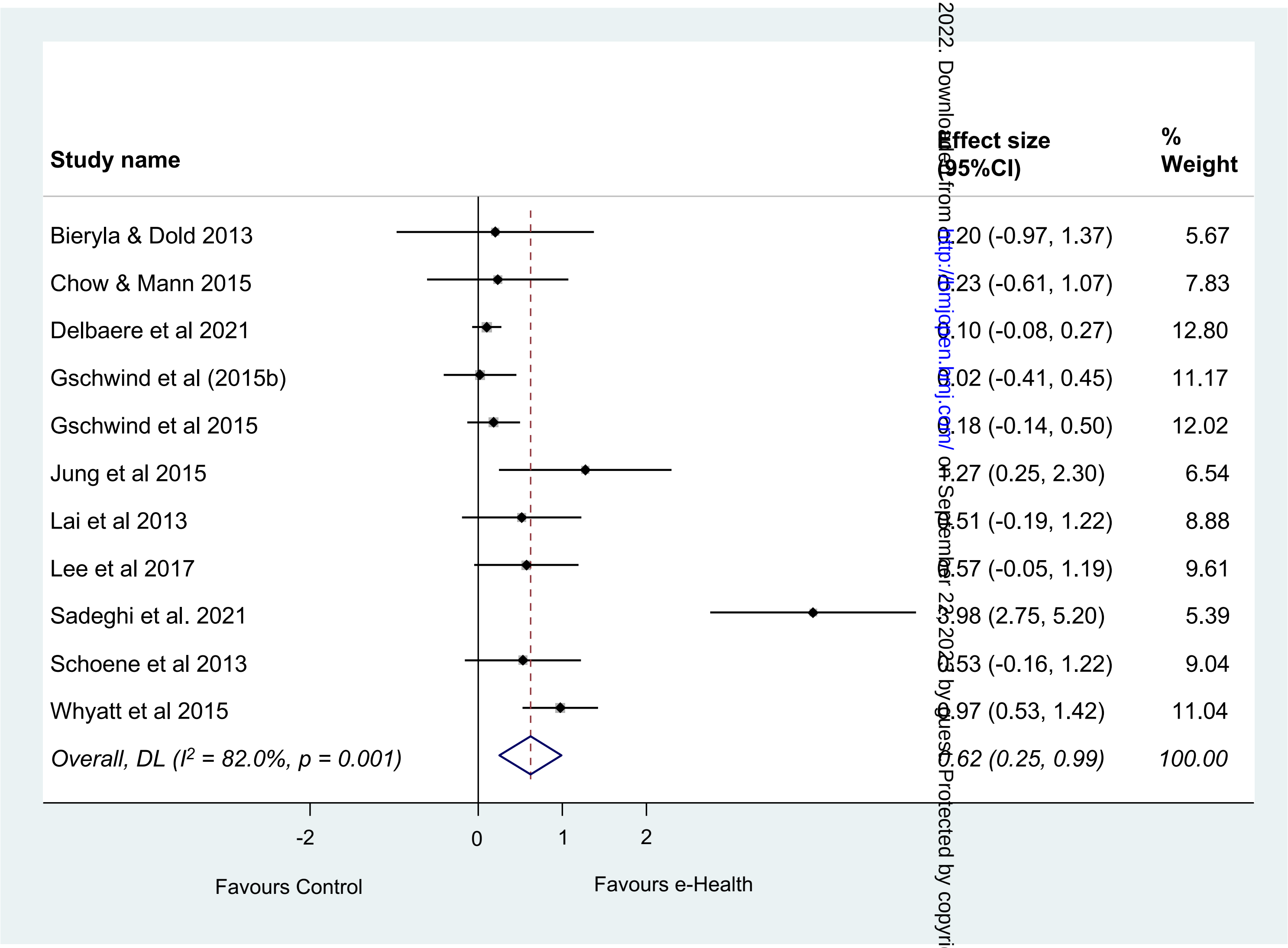
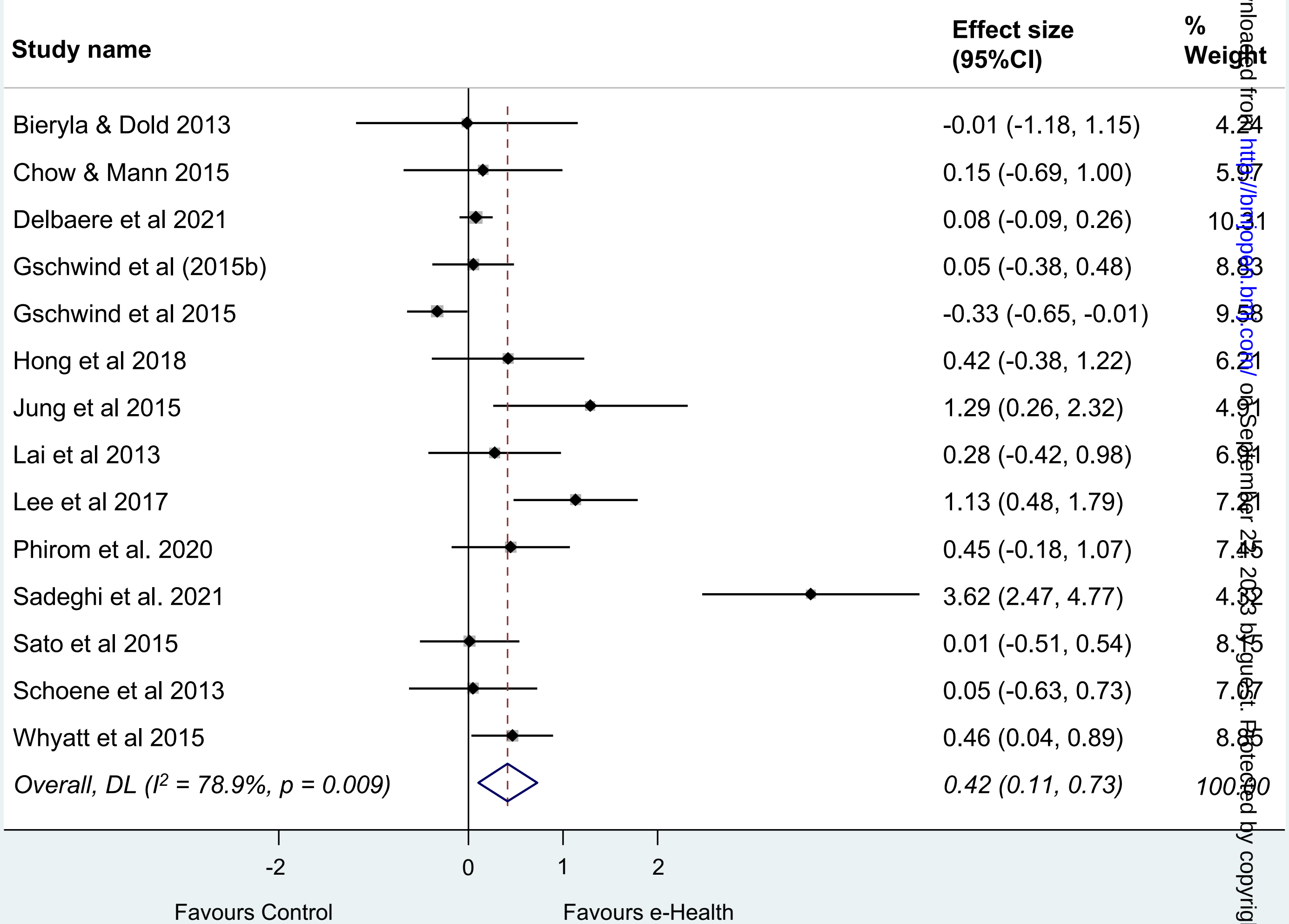


Figure 4 Effect size (95% confidence interval) of e-Health interventions on **dynamic balance** outcome by pooling data from 14 studies comparing e-Health versus control using random-effects meta-analysis (n = 1,180)

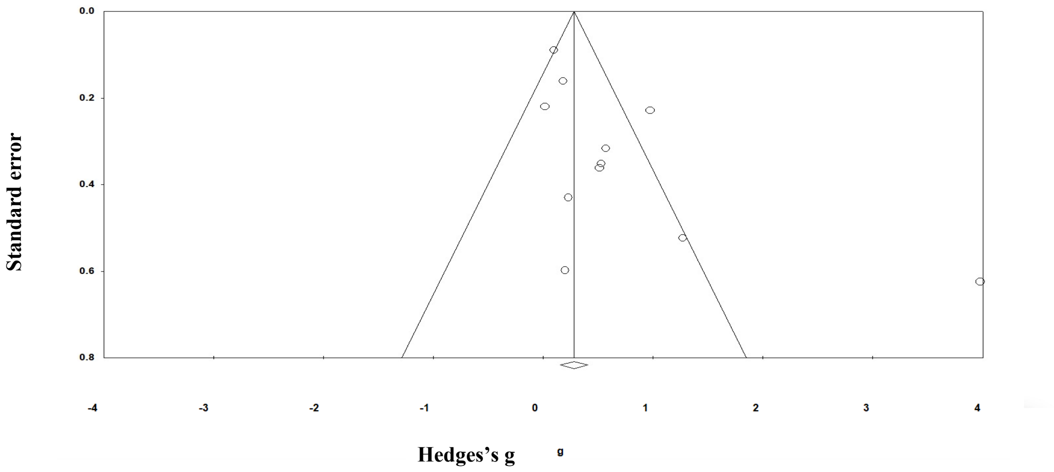


Supplementary Figure 1: A draft literature search for MEDLINE (the key words search string)

MEDLINE Search Strategy	
Population	*(senior* OR elderly OR aged OR old OR age OR "older adult" OR older OR 65 years)*
Intervention	*(technology OR telemedicine OR telehealth OR "communication technology" OR ICT OR "electronic health" OR eHealth OR internet OR online OR tablet OR ipad OR web OR "world wide web" OR email OR website OR "web-based" OR "website delivered" OR PDA OR "mobile health" OR mHealth OR "mobile phone" OR "short messaging service" OR "multimedia messaging service" OR SMS OR "multimedia messaging service" OR MMS OR "text message" OR app OR smartphone OR "cell phone" OR "cellular phone" or "picture message" OR tracker OR wearable* OR "digital health" OR "Information technology" OR fitbit OR garmin OR jawbone OR fuelband OR pedometer OR "step counter" OR sensors OR exergame* OR nintento OR wiifit OR wii-fit OR wii fit)*
Setting	(community dwelling OR community-dwelling OR community dweller* OR community-dweller*)
Outcome	*(accidental falls OR falls OR faller OR fall* OR tripping OR balance OR mobility)*

Supplementary Figure 2 Funnel plot of standard error by Hedges' g for trial included in the meta-analysis for balance, fear of falling and fall risk. Each circle represents one trial.

a) Static balance



b) Dynamic balance