



Effect of home-based exercise programs with e-devices on falls among community-dwelling older adults: a meta-analysis

Yu-ting Cao^{1,2}, Jian-jie Wang², Yi-ting Yang^{1,2}, Shi-jie Zhu^{1,2}, Liang-dong Zheng^{1,2}, Wei-wei Lu³, Rui Zhu^{*,1,2}  & Tao Wu⁴

¹Shanghai YangZhi Rehabilitation Hospital (Shanghai Sunshine Rehabilitation Center), School of Medicine, Tongji University, Shanghai, 200092, China

²Key Laboratory of Spine & Spinal Cord Injury Repair & Regeneration of the Ministry of Education, Tongji Hospital, School of Medicine, Tongji University, 389 Xincun Road, Shanghai, 200065, China

³Zhongshan Hospital, Fudan University, Shanghai, 200030, China

⁴Shanghai University of Medicine & Health Sciences, Shanghai, 201318, China

*Author for correspondence: Tel.: +86 2166 111 205; zhurui08@hotmail.com

Aim: To explore the effectiveness of home-based exercise programs with e-devices (HEPEs) on falls among community-dwelling older adults. **Methods:** Twelve randomized controlled trials were included in the meta-analysis considering four fall-related outcomes. **Results:** HEPEs significantly reduced the rate of falls (risk ratio: 0.82; 95% CI: 0.72–0.95; $p = 0.006$) and improved lower extremity strength (mean difference: -0.94; 95% CI: -1.71 to -0.47; $p < 0.001$). There was a significant improvement favoring HEPEs on balance if the participants were aged >75 years (mean difference: -0.55; 95% CI: -1.05 to -0.05; $p = 0.03$), or the intervention duration was at least 16 weeks (mean difference: -0.81; 95% CI: -1.58 to -0.05; $p = 0.04$). **Conclusion:** HEPEs demonstrated an overall positive effect on falls among community-dwelling older adults.

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Falls among older people are a worldwide public health issue. Almost one in three community-dwelling people who are aged 65 years or older will fall at least once per year [1], and the risk of falling increases to one in two adults per year among those aged 80 years or older [2]. Furthermore, fall-related injuries are the leading causes of death and disability among older adults [3]. According to the data, 40% of all kinds of injury-related deaths and over 80% of all injury admissions to hospital are caused by falls [4].

To reduce the rate of falls, many fall prevention interventions have been established and evaluated. For instance, home modification is effective in persons at higher risk for falling, including those with vision impairment [5,6]; medication reduction or withdrawal is stressed for all older people [7]; and assessment and treatment of postural hypotension should also be included for older adults [8].

In fact, it is worth noting that intervention including physical exercises is proved to be the most effective [9,10]. In other words, exercise intervention is an efficient and cost-effective way to reduce the risk of falls [11]. Strong evidence shows that exercise-based intervention can reduce falls through improving gait ability [12], balance [12,13], strength [14,15], endurance [14,16], psychosocial health [15,17] and bone metabolism [16,18]. In order to achieve these benefits, different forms of exercises have been developed and proved, mainly including physical therapy [19,20], tai chi [21], yoga [22] and group and home-based exercise programs [23]. Another review reported that group and home-based exercise programs are not only conducive to reduce the rate of falls and risk of falling, but also more suitable for most of the older people in the community compared with the others [24]. Evidence demonstrates that home-based strength and balance training programs are able to reduce falls in community-dwelling people who are

at least 75 years old [25–27]. It has also been proved that implementing a personalized intervention for older adults is helpful to improve the gait speed and reduce the risk of falls [28,29]. Therefore a personalized home-based exercise program is a promising way to meet the needs of older people with different health conditions [30–32].

According to the review by Sherrington *et al.*, a larger dose and longer intervention time lead to a better effect for the old [33]; therefore adherence to the exercise program is significant. Researchers used to utilize paper-based booklets [34], multiple home visits [35–37] or telephone calls [38] to help the older people stick to the program. While these methods may be helpful, a better intervention can further improve adherence among older through providing supervision or making the exercise more engaging and accessible [39]. The use of e-devices, including mobile phones, tablets or personal computers, may be a promising approach [40]. For example, the majority of commercially available gaming technology, as known as exergaming, used in supervised interventions, led to a high adherence [41]. Silveira *et al.* evaluated the effect of a tablet-based exercise application compared with a brochure-based program over 12 weeks [42,43]. The result demonstrated a higher adherence for the application programs than the paper program. Similarly, the Test-and-Exercise program allows participants to establish their own exercise plans by using a mobile application, which also showed a positive effect in fall prevention in elderly people due to better adherence [34].

Recently, the COVID-19 pandemic has negatively affected individuals' lives. In order to decelerate the spread of COVID-19, social distancing and quarantine protocols have been established [44]. During quarantine, isolation affects the physical [45,46] and mental [47] health of the elderly. In this circumstance, medical workers should consider setting up a better way to provide answers and direction to the old based on home-based exercises [46]. With the development and generalization of e-devices, this can be a good solution because there is no need to travel a long distance to conduct a home visit for the professionals. Participants can engage in the home-based program at any time without extra labor cost or facing any risks of the pandemic [44,48].

To summarize from the current evidence, a home-based exercise program with e-devices (HEPE) can improve the participants' adherence, reduce the harm of epidemic exposure and save the medical workers' labor cost. However, to our knowledge, there is no meta-analysis evidence on the effects of HEPE in community-dwelling older adults. So, due to the growing importance of fall prevention and the pressure from COVID-19, the aim of this systematic review (SR) and meta-analysis was to assess the effects of HEPEs in community-dwelling older adults.

Materials & methods

This SR followed the Preferred Reporting Items for Systematic Review and Meta-analyses (PRISMA) [49]. In order to prevent duplication of reviews, a search for previous and ongoing SRs similar to this study was conducted.

Search strategy

Eight online databases were searched for published works which were published until May 2022, namely: PubMed, Cochrane, CINAHL, Scopus, Ovid MEDLINE, ScienceDirect, Web of Science and Embase. In addition, ongoing and unpublished trials were searched in the Cochrane Controlled Register of Trials. The complete search strategy is summarized in [Supplementary Table 1](#). Later, a manual search of relevant randomized controlled trials (RCTs) from reference lists was carried out, producing three additional relevant records. All the mentioned articles were written in English.

Eligibility criteria

The eligibility criteria were strictly established according to the PICOS (population, intervention, comparison, outcome and study design) framework ([Table 1](#)) [50]. The target population was older adults (aged at least 60 years) who could participate in home-based exercises after professional evaluation, living independently in communities [51]. Because of the differences in life expectancy, the definition of older adults varies from country to country. According to WHO, in most regions of the world the rates of fall-related fatalities are highest among adults over the age of 60 years [52]. Therefore we used community-dwelling adults aged 60 years or over as the target population. Interventions included HEPE alone or in combination with other multifactorial interventions. The content of the HEPE should be acceptable, feasible and safe for the elderly (including but not limited to the following: simple balance training, strength training with moderate resistance or modified comprehensive training). Meanwhile, taking the variable physical level of the elderly into consideration, the exercise programs should also be personalized or under remote supervision by professionals. Comparison included standard physiotherapy or traditional home-based exercise (including group-based exercise classes, telephone call-based exercises, home visit-based exercises or

Table 1. Eligibility criteria based on the population, intervention, comparison, outcome and study design framework.

Category	Inclusion criteria	Exclusion criteria
Population	Elder adults aged at least 60 years old who could participate in home-based exercises after evaluation, living independently in communities	Studies involving participants with a diagnosis of chronic disease (e.g., multiple sclerosis, cancer, Parkinson's or Alzheimer's disease)
Intervention	Mobile phone, tablet, personal computer and home-based exercise program, either alone or in combination with other multifactorial interventions	Exercises not performed at home (e.g., group-based exercise classes), or home-based exercises without any e-device (e.g., telephone call-based exercises, home visit-based exercises or booklet-based exercises)
Comparison	Standard physiotherapy or traditional home-based exercise, usual medical care or no intervention	Lack of control group
Outcome	To contain at least one of: risk or rate of falls, balance ability, lower extremity strength, cognition function, quality of life, severity of falls and fear of falling	Did not contain any required outcomes, absence of baseline or follow-up data
Study design	Randomized controlled trial	Non-randomized controlled trial

booklet-based exercises), usual medical care or no intervention. Eligible studies should contain at least one of the following outcomes: the risk or rate of falls, balance ability, lower extremity strength, cognition function, severity of falls and fear of falling. Study design should meet the standard of a RCT [53].

Selection process

In this SR, the selection process was guided by the PRISMA flow diagram [50]. All articles identified from the searches were exported to EndNote v.20, and duplicates were removed automatically. The remaining articles were screened manually using the titles and abstracts. The verification of eligibility of the selected articles was done using the study titles and abstracts. Next, full texts were downloaded. Studies with inappropriate populations, interventions, comparisons and outcomes were excluded. Finally, the included studies were assessed on their suitability for meta-analysis. The number of studies included and excluded at each step and the reasons for exclusion are listed in the PRISMA diagram (Figure 1).

Quality assessment

The quality assessment was carried out by two raters based on the Physiotherapy Evidence Database (PEDro) scale [54,55]. This is a rating scale to assess the methodological quality of clinical trials which consists of 11 items encompassing external validity. A total score is reached by adding the ratings of items 2 to 11 for a final score of 0–10. Its authors have suggested that a PEDro score of <4 should be considered 'poor', 4 or 5 should be considered 'fair', 6–8 should be considered 'good' and 9 or 10 can be considered 'excellent' [56]. A third rater then resolved any potential disagreement.

Data extraction

The following data from each study were extracted: basic information and publication details; participants' characteristics; intervention characteristics; comparison characteristics; and outcome measurements. When there was a missing or inconsistent outcome because of the heterogeneity of the study designs, a narrative synthesis approach was performed to examine the results, rather than a meta-analysis. Dichotomous data (fall rate during the follow-up period) and quantitative data (including the result of timed up and go [TUG], five-times sit-to-stand test [FTSST] and physiological profile assessment [PPA]) extracted were then entered into Review Manager (v. 5.3; the Cochrane Collaboration, Oxford, UK) for meta-analysis.

Data synthesis

All statistical analyses were performed with Review Manager v. 5.3. Heterogeneity was initially explored through visual inspection of the forest plots, then a test for statistical heterogeneity was carried out using the I^2 and χ^2 test. A p-value of < 0.05 was considered to be statistically significant. According to the percentage of I^2 , values greater than 50% are considered to represent substantial heterogeneity. When this occurred, we attempted to explain the cause of the variation. If the value was less than 30%, the overall estimate was produced by a fixed-effects model. Otherwise, a random-effects model was used, for which the CIs are broader than those of a fixed-effects model [57]. Stability and publication bias were tested by a one-study leave-out sensitivity analysis.

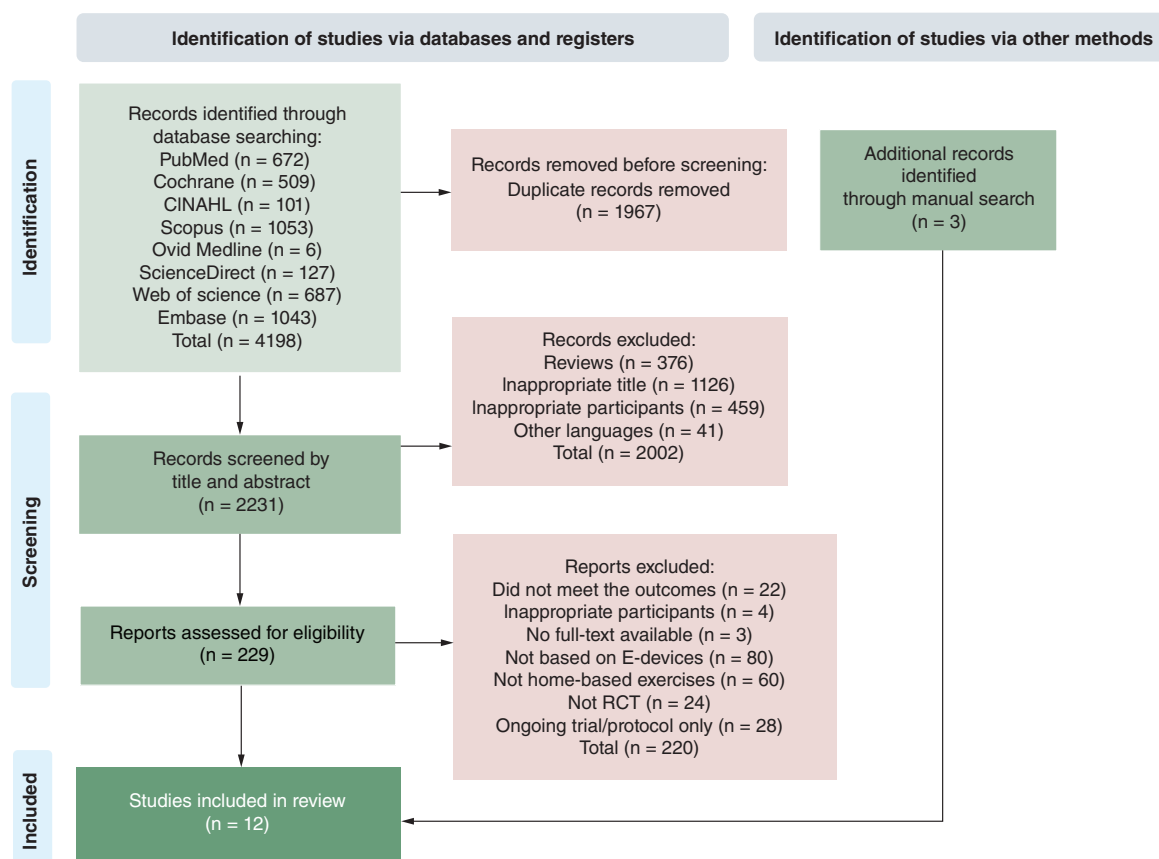


Figure 1. Preferred Reporting Items for Systematic Reviews and Meta-Analyses flowchart for selection of papers. RCT: Randomized controlled trial.

Results

Studies' characteristics

A total of 4198 records were gathered from various databases, and three additional articles were found by hand-searching. After automatically removing the duplicates, 2231 records were kept. Then a screening according to the title and abstract was carried out by three independent authors, from which 2002 records were excluded. Finally, 229 records with corresponding full texts were further screened judging by the eligibility criteria; 12 studies (participants $n = 1648$) met all of the inclusion criteria and were included in the meta-analysis. The main reasons for exclusion are listed in the PRISMA diagram (Figure 1). The characteristics of the included studies are summarized in Table 2. The average age of the participants ranged from 70.22 to 85.2 years and all of them were community-dwelling older adults. The HEPEs were all personalized according to each participant's fitness level by the professionals. The interventions required 2–7 days per week (or 60–120 min per week) and lasted from 6 weeks to 24 months. According to most of the exercise programs, 30 min per day is an average intervention intensity.

The e-devices used in the studies included mobile phones [44], tablets [63–65], personal computers [59,62], a combination of all [31,66,67] or a customized system [58,60,61].

Quality assessment

The overall quality of the included studies could be considered as good (PEDro score: 6.83; range: 5–9; Table 3). None of the studies showed poor methodological quality. Only one study got 5 points, which should be considered as 'fair'; besides that, ten studies had good quality and one study had excellent quality.

Effect of HEPE on proportion of fallers

Among the 12 included studies, six reported the proportion of fallers, while the remaining six did not mention any information about the proportion of fallers or rate of falls in the end point measurements. Therefore, a total of 1242

Table 2. Main characteristics of the included studies.

Study (year)	Participants	Interventions				Comparison	Main outcomes	Ref.
		Duration	Frequency	Modality	E-devices used			
Rosie <i>et al.</i> (2007)	E-device group (n = 33, mean age [years] = 85.2); control group (n = 33, mean age [years] = 85.1)	6 weeks	7 days/week	Home-based sit-to-stand exercises	GrandStand System (a pressure cushion with a biofeedback monitor attached connecting to a tablet)	Knee extension exercises	Gait speed; chair stand (repetitions); BBS; modified falls efficacy scale; late-life function and disability instrument	[58]
Haines <i>et al.</i> (2009)	E-device group (n = 19, mean age [years] = 80.9); control group (n = 34, mean age [years] = 80.5)	6 months	7 days/week	'Kitchen Table Exercise Program' combining lower limb strength and balance exercises	DVD player	No intervention	Health-related quality of life; FAI; BOOMER; 15-s chair stand test; fear of falling; activity-specific balance confidence scale	[59]
Schoene <i>et al.</i> (2013)	E-device group (n = 15, mean age [years] = 77.5); control group (n = 17, mean age [years] = 78.4)	8 weeks	2–3 days/week	Step game based on the open-source DDR game Stepmania	A computer unit and step pad	No intervention	Choice stepping reaction time; PPA; TUG; FTSST; alternate step test	[60]
Gschwind <i>et al.</i> (2015)	E-device group (n = 78, mean age [years] = 74.7); control group (n = 75, mean age [years] = 74.7)	16 weeks	≥3 days/week	Comprehensive home-based exercise program including strength training and balance training exercises	The iStoppFalls program (including a PC, a Google TV set-top box, a senior mobility monitor and a Nexus 7 Android tablet)	Received an evidence-based educational booklet about general health and fall prevention	Melbourne edge test; peripheral sensation; balance; lower extremity muscle strength; hand reaction time; EQ-5D	[31]
Gschwind <i>et al.</i> (2015)	E-device group 1 (n = 24, mean age [years] = 80.1); e-device group 2 (n = 39, mean age [years] = 82.5); control group (n = 61, mean age [years] = 80.2)	16 weeks	E-device group 1: 120 min for balance and 60 minutes for strength/week; e-device group 2: 60 min/week	E-device group 1: KIN exergames (including balance and strength exergames); e-device group 2: SMT system (targeting specific cognitive functions associated with fall risk and stepping)	KIN and SMT systems (contained an input device, a computer, universal serial bus modems and participants' TVs)	Received an evidence-based educational booklet about health and fall prevention advice	Melbourne Edge Test; a lower limb-matching task; quadriceps strength; finger-press reaction time; postural sway	[61]
Boongird <i>et al.</i> (2017)	E-device group (n = 219, mean age [years] = 74.08); control group (n = 220, mean age [years] = 73.94)	12 months	120 min/week	Modified Otago exercise program including lower extremities strengthening, stretching and balance training	Video disk recorder	Only received fall prevention education	Number of reported falls; BBS; FTSST; TUG; Thai FES-I; Thai EQ-5D	[62]
Hong <i>et al.</i> (2018)	E-device group (n = 10, mean age [years] = 78.1); control group (n = 13, mean age [years] = 81.5)	12 weeks	3 days/week	Supervised, progressive exercise including warm-up, main exercise and cool-down activity	Web real-time communication technology based on a tablet PC	No intervention	The senior fitness test; BBS; falls efficacy; fear of falling	[63]
Shake <i>et al.</i> (2018)	E-device group (n = 60, mean age [years] = 73.59); control group (n = 45, mean age [years] = 73.22)	10 weeks	2 days/week	Special exercises program including cardiovascular/ balance, strength and flexibility exercises	Experimenter-provided tablets or Digiland 16GB Tablets with an app installed	Only received health education	Short performance physical battery; EXAMINER cognitive battery; health knowledge performance	[64]

BBS: Berg balance scale; BOOMER: Balance Outcome Measure for Elder Rehabilitation; DDR: Dance Dance Revolution; FAI: Frenchay Activities Index; FES-I: Fall Efficacy Scale – International; FTSST: Five-times sit-to-stand test; KIN: Microsoft Kinect®; PC: Personal computer; PPA: Physiological profile assessment; SMT: Step-mat training; TAI: Trait anxiety inventory; TUG: Timed up and go; WHL: WHO quality of life instrument (older adults module).

Table 2. Main characteristics of the included studies (cont.).

Study (year)	Participants	Interventions				Comparison	Main outcomes	Ref.
		Duration	Frequency	Modality	E-devices used			
Delbaere <i>et al.</i> (2021)	E-device group (n = 254, mean age [years] = 77.1); control group (n = 249, mean age [years] = 77.7)	24 months	120 min/week	Static balance and dynamic balance training exercises and the Standing Tall education program	Tablet PC	Only received the Standing Tall education program	Number of fallers and falls rate; static balance measures; maximal balance range test; TUG; sit-to-stand test; walking speed; stepping performance; cognitive performance and executive function; psychological assessment; health-related quality of life; physical activity levels	[65]
Li <i>et al.</i> (2021)	E-device group (n = 15, mean age [years] = 76.13); control group (n = 15, mean age [years] = 76.2)	24 weeks	2 days/week	Zoom-based online classes including progressive core training, interactive cognitive–physical exercises	PC, iPad or smartphone	Stretching exercises	Incidence of falls; number of fallers; four-stage balance test; 30-s chair stands; TUG	[66]
Yerlikaya <i>et al.</i> (2021)	E-device group (n = 18, mean age [years] = 70.22); control group 1 (n = 16, mean age [years] = 71.81); control group 2 (n = 16, mean age [years] = 75.62)	8 weeks	3 days/week	Online exercise classes via video access platforms such as WhatsApp and Google Meet	PC, tablet or smartphone	Control group 1: the same exercises but without supervision; control group 2: no intervention	BBS; TUG; Sway Balance mobile application; TAI; WHL	[67]
Yi <i>et al.</i> (2021)	E-device group (n = 35, mean age [years] = 76.11); control group (n = 35, mean age [years] = 77.31)	8 weeks	2 days/week	Comprehensive exercise program including warm-up, main exercise and cool-down exercises	Smartphone	No intervention	Geriatric depression scale; FTSST; handgrip strength; 10-m walk test; gait analysis; TUG; postural sway test	[44]

BBS: Berg balance scale; BOOMER: Balance Outcome Measure for Elder Rehabilitation; DDR: Dance Dance Revolution; FAI: Frenchay Activities Index; FES-I: Fall Efficacy Scale – International; FTSST: Five-times sit-to-stand test; KIN: Microsoft Kinect®; PC: Personal computer; PPA: Physiological profile assessment; SMT: Step-mat training; TAI: Trait anxiety inventory; TUG: Timed up and go; WHL: WHO quality of life instrument (older adults module).

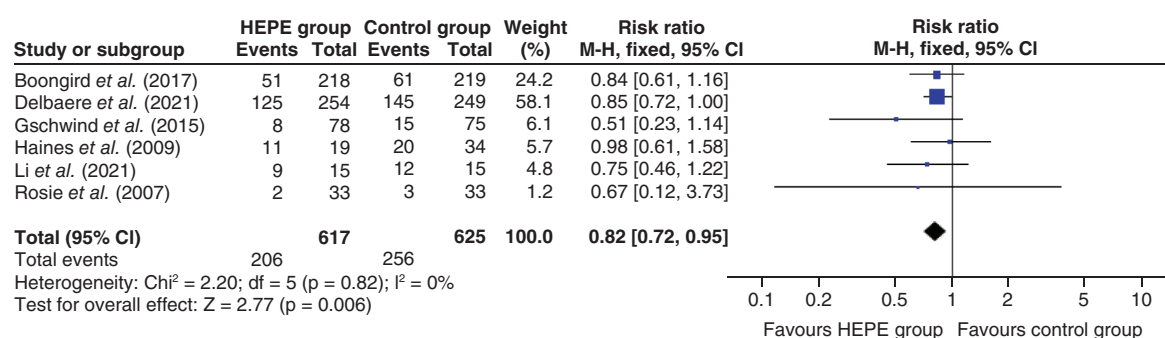


Figure 2. Forest plot of the effect of home-based exercise programs with e-devices on proportion of fallers. HEPE: Home-based exercise program with e-device; M–H: Mantel–Haenszel statistical method.

participants were included in the meta-analysis (Figure 2). The proportion of fallers is defined as the ratio of fallers to the total number of participants. The data were generally collected during the interventions or the follow-up period through a self-report method. A lower risk ratio indicates a reduced rate of falls. The pooled effect of HEPEs in reducing the proportion of fallers is statistically significant (risk ratio [RR]: 0.82; 95% CI: 0.72–0.95; $Z = 2.11$; $p = 0.006$), favoring HEPE groups to control groups, as determined by the fixed-effects method. Meanwhile, the heterogeneity tests indicated that nonheterogeneity was found across the six studies ($I^2 = 0\%$; $\chi^2 = 2.20$; $p = 0.82$).

Table 3. Methodological quality of the included studies.

Study (year)	Items											Total score [†]	Ref.
	1	2	3	4	5	6	7	8	9	10	11		
Rosieet <i>et al.</i> (2007)	+	+	-	+	+	-	-	+	+	+	+	7	[58]
Haineset <i>et al.</i> (2009)	+	+	+	+	+	-	+	+	+	+	+	9	[59]
Schoene <i>et al.</i> (2013)	+	+	+	+	-	-	+	+	-	+	+	7	[60]
Gschwind <i>et al.</i> (2015)	+	+	+	+	+	-	-	+	+	+	+	8	[31]
Gschwind <i>et al.</i> (2015)	+	+	-	+	-	-	+	+	+	+	+	7	[61]
Boongird <i>et al.</i> (2017)	+	+	+	-	-	-	+	+	+	+	-	6	[62]
Hong <i>et al.</i> (2018)	+	+	-	-	-	-	+	+	+	+	+	6	[63]
Shake <i>et al.</i> (2018)	+	+	-	-	+	-	+	+	-	+	+	6	[64]
Delbaere <i>et al.</i> (2021)	+	+	+	+	-	-	+	+	+	+	+	8	[65]
Li <i>et al.</i> (2021)	+	+	+	-	-	-	+	+	+	+	+	7	[66]
Yerlikaya <i>et al.</i> (2021)	+	+	+	-	-	-	-	+	+	+	+	6	[67]
Yi <i>et al.</i> (2021)	+	+	-	-	-	-	-	+	+	+	+	5	[44]

[†]Total score is achieved by adding the ratings of items 2–11 for a combined total score between 0 and 10.

The column numbers correspond to the following criteria on the PEDro scale: 1 – eligibility criteria were specified; 2 – subjects were randomly allocated to groups; 3 – allocation was concealed; 4 – the groups were similar at baseline regarding the most important prognostic indicators; 5 – there was blinding of all subjects; 6 – there was blinding of all therapists who administered the therapy; 7 – there was blinding of all assessors who measured at least one key outcome; 8 – measures of at least one key outcome were obtained from more than 85% of the subjects initially allocated to groups; 9 – all subjects for whom outcome measures were available received the treatment or control condition as allocated or, where this was not the case, data for at least one key outcome were analyzed by ‘intention to treat’; 10 – the results of between-group statistical comparisons were reported for at least one key outcome; 11 – the study provided both point measures and measures of variability for at least one key outcome. + indicates the criterion was satisfied; – indicates that the criterion was not satisfied.

PEDro: Physiotherapy Evidence Database.

Effect of HEPE on balance

Seven studies utilized the TUG test to estimate the balance of the participants, which were pooled in meta-analysis by a random-effects model.

TUG is a simple and widely used test of overall functional mobility, assessing the individual’s ability to transfer, walk and change direction [68]. According to the results from TUG, a shorter time taken to complete the whole test indicates better balance and functional performance [69]; therefore we took TUG as the index of balance in the meta-analysis with 865 participants included (Figure 3A). The HEPE group showed an improvement trend in balance, but without statistical significance (MD: -0.71; 95% CI: -1.47 to 0.05; $Z = 1.83$; $p = 0.07$).

Three studies (Rosie *et al.* [58], Boongird *et al.* [62] and Hong *et al.* [63]) used the Berg balance scale (BBS) to measure balance in the elderly. The scale consists of 14 items, scored from 0 to 4, which are added to make a total score between 0 and 56 [70]. Evidence has shown that total scores below 45 are associated with a higher risk of falls; an individual with a history of falls and a total score below 51 is highly predictive of falls; a score of less than 40 is associated with a fall risk of almost 100% [71]. Rosie *et al.* reported that the HEPE group had a significant within-group improvement in BBS score (mean improvement 1.67 ± 2.64 points; $p = 0.001$) compared with the control group [58]. Hong *et al.* further proved a significant interaction effect between group and time regarding the scores of BBS ($p = 0.03$) [63]. According to Boongird *et al.*, the result from BBS did not show a significant improvement for the HEPE group, but maintained a fair level compared with the control group ($p = 0.258$) [62]. Haines *et al.* utilized the Balance Outcome Measure for Elder Rehabilitation to test the balance, but no statistical significance was found in their study [59]. Shake *et al.* [64] used the Short Physical Performance Battery in the study, which is a well-established tool to assess lower extremity muscular strength, agility and dynamic balance [72]; the composite scores of the entire battery showed only a main effect of time ($F_{1,83} = 13.86$; $p < 0.001$) [64].

Of note, two studies (Schoene *et al.* [60] and Li *et al.* [66]) conducted a dual-task TUG test as well; this is a modified TUG test combined with cognitive-related dual tasks. Previous research has shown that dual-task TUG may have an added value for fall prediction over TUG [73,74]. Schoene *et al.* found that the HEPE group improved significantly in the dual-task TUG test ($F_{31,1} = 4.226$; $p = 0.049$) [60]. A similar result was also shown in another study (mean difference [MD]: -2.35; $p < 0.001$) [66].

Meanwhile, there was high heterogeneity across the seven studies included in the meta-analysis ($I^2 = 80\%$; $\chi^2 = 30.50$; $p < 0.001$). The heterogeneity could be caused by different ages of the participants or the intervention duration. Thus a subgroup analysis was conducted to explain the heterogeneity.

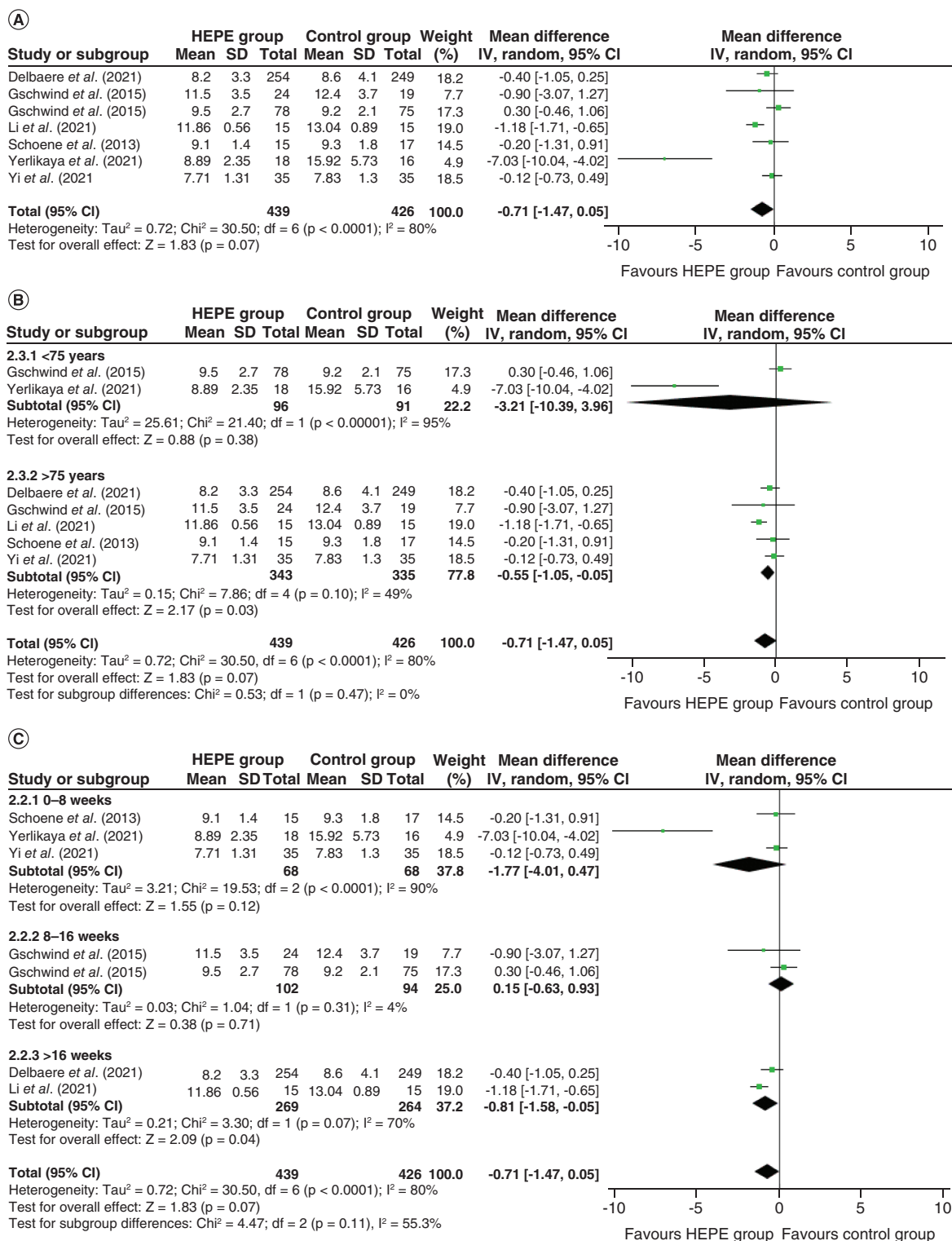


Figure 3. Forest plot of the effect of home-based exercise programs with e-devices on balance. (A) The pooled effect of HEPEs on balance. (B) The result of subgroup analysis on different ages of the participants. (C) The result of subgroup analysis on different intervention durations.

HEPE: Home-based exercise program with e-device; IV: Inverse variance statistical method; SD: Standard deviation.

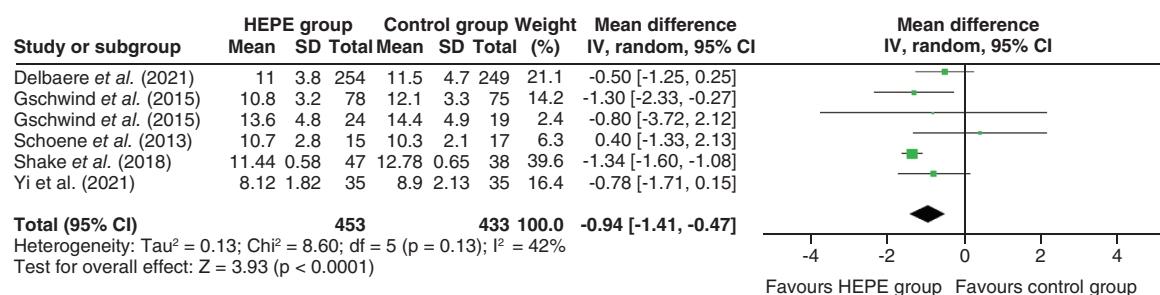


Figure 4. Forest plot of the effect of home-based exercise programs with e-devices on lower extremity strength.
 HEPE: Home-based exercise program with e-device; IV: Inverse variance statistical method; SD: Standard deviation.

Effect of HEPE on balance: grouping by different ages

Firstly, a subgroup analysis was carried out to investigate the influence of different ages of the participants. According to the mean ages of the participants from the included studies, we divided them into two groups: the over-75 years group (n = 2) and the under-75 years group (n = 5). There was no significant subgroup difference in MD ($\chi^2 = 0.53$; p = 0.47) across the two groups. The results indicated that the age of the participants was not the cause of the heterogeneity. Of note, a huge heterogeneity was found in the under-75 years group, and no statistically significant difference was found (MD: -3.21; 95% CI: -10.39 to 3.96; Z = 0.88; p = 0.38). Meanwhile, there was a statistically significant difference (MD: -0.55; 95% CI: -1.05 to -0.05; Z = 2.17; p = 0.03) in the over-75 years group with a fair heterogeneity (I² = 49%; $\chi^2 = 7.86$; p = 0.10) (Figure 3B).

Effect of HEPE on balance: grouping by intervention duration

Given that the intervention duration varied greatly among studies, another subgroup analysis was then conducted. Similarly, the studies were divided into three groups based on the intervention duration: 0–8 weeks (n = 3), 8–16 weeks (n = 2) and >16 weeks (n = 2). Again, there was no significant subgroup difference in MD ($\chi^2 = 4.47$; p = 0.11) across the three groups. However, the p-value was less than the one in the age-based subgroup analysis. Relatively speaking, the result could partly explain the heterogeneity. Of note, the >16 weeks group showed a significantly improved balance (MD: -0.81; 95% CI: -1.58 to -0.05; Z = 2.09; p = 0.04), while the 0–8 (MD: -1.77; 95% CI: -4.01 to 0.47; Z = 1.55; p = 0.12) and 8–16 weeks groups (MD: 0.15; 95% CI: -0.63 to 0.93; Z = 0.38; p = 0.71) did not (Figure 3C).

Effect of HEPE on lower extremity strength

Six studies reported the changes of lower extremity strength by FTSST. Previous studies have proved the excellent reliability and validity of FTSST to assess sitting and standing performance and lower limb strength [75] in both healthy adults and those with pathologies [76,77]. The improvement of HEPE on lower extremity strength is significant (MD: -0.94; 95% CI: -1.71 to -0.47; Z = 3.93; p < 0.001) as determined by a random-effects model. The MDs ranged from -1.34 [64] to 0.40 [60]. A heterogeneity test suggested a fair heterogeneity across the studies (I² = 42%; $\chi^2 = 8.60$; p = 0.13) (Figure 4).

Effect of HEPE on fall risk & fall efficacy

Physiological fall risk was estimated using the PPA in four studies. PPA involves a series of simple tests of vision, peripheral sensation, muscle force, reaction time and postural sway, and is a useful tool in quantifying fall risks [78,79]. According to the meta-analysis results, there was no statistical significance (MD: -0.22; 95% CI: -0.46 to 0.01; Z = 1.90; p = 0.06) across the included studies with 731 participants involved, but the overall trend favored the HEPE groups. Meanwhile, a fair heterogeneity existed across the studies (I² = 48%; $\chi^2 = 5.73$; p = 0.13) (Figure 5).

The fall risk could also be measured by fall efficacy, which is related to the level of fear of falling. According to previous studies, various kinds of fall efficacy scales have been developed and proved to be accurate in predicting physiological fall risks [80]. Rosie *et al.* reported the fall efficacy by the modified falls self-efficacy scale, from which no statistical difference was found either in-group (p = 0.393) or between-group (p = 0.818) [58]. Haines *et al.* measured the fall efficacy by the activities-specific balance confidence scale [59]. Similarly, a negative result was found, according to a linear regression analysis (regression coefficient = -0.30; 95% CI: -1.49 to 0.89; p = 0.61) [59].

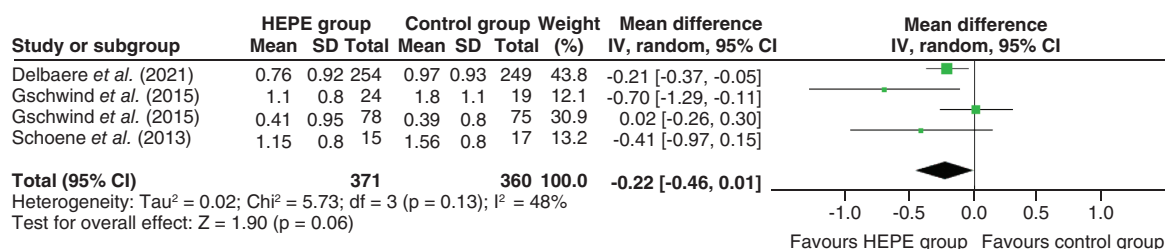


Figure 5. Forest plot of the effect of home-based exercise programs with e-devices on fall risk.
 HEPE: Home-based exercise program with e-device; IV: Inverse variance statistical method; SD: Standard deviation.

Boongird *et al.* applied the Thai fall efficacy scale to measure the fall efficacy in their trial and found that fall efficacy improved significantly in the HEPE group at the 6-month follow-up ($p = 0.003$) [62]. According to Hong *et al.*, there were no changes in falls efficacy in either activities of daily living ($p = 0.55$) or social activities ($p = 0.51$) by means of the Korean falls efficacy scale [63]. However, the additional measurement of fear of falling, assessed through a fear of falling questionnaire, was carried out in their study and revealed a significant interaction effect between group and time ($p = 0.009$). The HEPE group showed a better fall efficacy than the control group ($p = 0.008$).

Discussion

This SR was carried out in the context of: the importance of fall prevention among community-dwelling older adults; the labor cost of medical workers; a shortfall in adherence of home-based exercise programs; and the special needs caused by the COVID-19 pandemic. The SR and meta-analysis was aimed at the home-based exercise program with e-devices which showed a better adherence compared with traditional home-based exercise programs [40]. We investigated the effectiveness of personalized HEPEs on the proportion of fallers, balance, lower extremity strength and fall risks.

Effectiveness of HEPE

The fall risk in the HEPE group was significantly decreased, by 18% (RR: 0.82; 95% CI: 0.72–0.95) compared with the controls according to the changes in the proportion of fallers. Notably, a previous review indicated that balance and functional exercises reduced the rate of falls by 24% (RR: 0.76; 95% CI: 0.70–0.81), while multiple types of exercise (most commonly balance and functional exercises plus resistance exercises) reduced the rate by 34% (RR: 0.66; 95% CI: 0.50–0.88) [51]. This result suggests that HEPEs may be more effective in reducing the fall rate if multiple types of exercise are applied.

Our findings suggested that the overall effect of HEPEs was not significant in improving balance as measured by TUG. A previous review indicated that elderly adults showed an age-related decline in balance and gait with increased gait variability and an associated increased risk of falls [81]. Considering that age is one of the factors that may affect the balance and intervention effect, a subgroup analysis was then carried out; we found that balance was significantly improved when the average age of involved participants was over 75. Of note, the traditional home-based interventions seemed to have limited impact on balance improvement in older adults (aged over 75). For example, a RCT enrolled 64 subjects whose average age was 75.9 years; after 15 weeks of home-based exercise, no significant improvement was found in balance as measured by TUG ($p = 0.90$) [82]. Therefore this is an exciting finding, because HEPE could be a more suitable intervention for older adults compared with the traditional home-based programs. On the one hand, the HEPEs took advantage of the better adherence brought by e-devices. As previous studies have shown, 67% of participants using the digital program continued to exercise regularly compared with 35% for the paper booklet ($p = 0.036$) [83]. Similarly, a RCT comparing adherence to laboratory-based trials using a supervised e-device versus traditional home-based trials yielded similar results [39]. Therefore a digital program was able to facilitate long-term maintenance of regular exercise so as to bring about a better curative effect on balance. On the other hand, as all the HEPEs involved were individually tailored, the exercise programs fitted the functional level of the elderly well. Evidence has shown that tailored exercise programs cause significant improvements in balance compared with fixed ones [84]. For example, in the study of Rosie *et al.*, the results showed a significant within-group improvement in balance in the HEPE group ($p = 0.001$), while no change was revealed in the control group performing knee extension ($p = 0.258$) [58]. This aligned with another SR which found that individualized home-based exercise programs promoted autonomy and were therefore seen as

superior to generic fall-prevention programs among participants at an average age of 80.1 years [85]. The mentioned two reasons might explain why the HEPEs could significantly improve balance in people over 75 years of age.

The result of another subgroup analysis based on different intervention durations suggested that >16 weeks was an appropriate intervention duration, as a significant improvement in balance was found compared with the subgroup training for less than 16 weeks. A SR aimed at dose–response relationships in balance training in older adults illustrated that balance training lasting for less than 11 weeks resulted in lower effects on balance performance [86]. Another previous review which examined the efficacy of exercise to reduce falls recommended at least 2 h of training per week for a training period of more than 6 months to reduce falls [87]. In our SR, the average amount of exercise was 121.25 min per week, which was in accordance with the analysis by Sherrington *et al.* [87]. These findings might indicate that an intervention period for HEPE of more than 16 weeks could be more effective in improving overall balance performance.

Muscle strength (especially in the lower extremities) is one of the factors that are closely related to falls in older adults [88]. The result found that lower extremity strength was significantly improved in HEPE groups as measured by FTSST. The positive finding might be because most of the HEPEs consisted of strength or functional training. Almost all of the studies delivered individually tailored muscle strength training, including stepping or stretching exercises that would increase in difficulty over time, as recommended by Gschwind *et al.* and Shake *et al.* [31,60,61,64,65]. A more comprehensive program including vestibular rehabilitation, core and limb strengthening exercises, joint motion range exercises and balance exercises was used in the study of Yi *et al.* [44]. Therefore, in order to achieve better results in improving lower limb strength, multimodal exercise programs were recommended in HEPEs.

Conversely, the effect of HEPEs on fall risk as measured by PPA was not significant. The between-trial heterogeneity ($I^2 = 48\%$) could be explained by a single study from Gschwind *et al.* [31]. The heterogeneity reduced to 28% ($\chi^2 = 2.79$; $p = 0.25$) when this trial was removed from the meta-analysis, and the overall effect of HEPEs on fall risks was then significant (MD: -0.32; 95% CI: -0.58 to -0.07; $Z = 2.46$; $p = 0.01$). According to Gschwind *et al.*, a low adherence rate may explain the limited improvement of PPA. There was a significant three-way interaction for fall risk assessed by the PPA in a subgroup analysis between the high-adherence (>90 min of exercise per week), low-adherence (<90 min of exercise per week) and control groups ($p = 0.044$) [31]. In addition, two-way analysis comparing the high-adherence group with the control group revealed a significantly larger effect in favor of the high-adherence group for fall risk ($p = 0.031$) [31]. This result was in accordance with our finding that only a certain amount of exercise (at least 120 min per week for over 16 weeks) can achieve significant improvement in physical behavior. Our finding was better supported by the following studies which validated the dose–response relationship between fall risk and fall effectiveness. Haines *et al.* found a negative result of fall efficacy as measured by the activity-specific balance confidence scale after only 8 weeks of intervention (regression coefficient: -0.30; 95% CI: -1.49 to 0.89; $p = 0.61$) [59]. Contrary to this, another RCT suggested that a 24-week home-based tele-rehabilitation program could significantly reduce the risk of falls (RR: 0.60; 95% CI: 0.44–0.83; $p < 0.001$) [89].

Meanwhile, it was important to know whether exercise-induced overall physical improvement was stable over time. Evidence indicated that the fall prevention program with exercise intervention improved functional performance at 3 months in community-dwelling older adults with risk of falls, but did not reduce falls at 1-year follow-up [90]. Arkkukangas *et al.* conducted a trial of 12 weeks of fall prevention exercise for community-dwelling older adults, in which a significant within-group improvement was found in physical performance ($p = 0.04$), fall efficacy ($p = 0.02$) and physical activity level ($p = 0.02$) according to a short-term follow-up [91]. However, the positive result was not reproduced in their 2-year follow-up study [92]. Likewise, Naseri *et al.* found a similar time–efficacy relationship at 6-month follow-up [93]. With reference to the mentioned studies, we suggest conducting HEPEs on a permanent basis to counteract time-related declines in overall physical performance. In addition to applying different kinds of e-devices, the following improvements were adopted by the included studies to enable better long-term adherence: the exercise programs were modified and supplemented to suit the older adults in seven studies [31,44,58,61,63,64,66]; two studies provided a video of the exercises [62,67]; and three studies provided remote guidance for any possible problems [59,60,65].

Of note, the positive changes in dual-task TUG were also enlightening. As dual-task TUG is a cognitive-related test [74], this might mean that HEPEs could improve cognitive function in older adults. In addition to the studies of Schoene *et al.* and Li *et al.* [60,66], Shake *et al.* also paid attention to cognitive changes; these results suggested a significant main effect of group exercise ($p < 0.05$) and an interaction effect ($p = 0.02$) [64]. However, a review suggested that physical activity or exercise alone was able to improve the attentional control so as to help improve

cognition in older at-risk individuals [94]. Likewise, a meta-analysis among older adults also showed that exercise training had a significant benefit for cognitive function ($p < 0.001$) [95]. Therefore the improvements associated with dual-task TUG or cognitive tasks were mostly attributed to the exercise itself. Whether the intervention of e-devices could improve cognitive function needed further experimental proof. So any evidence of potential benefits from HEPEs should be interpreted cautiously, given the limited evidence of changes to cognitive function.

Strengths & limitations

This review, to our knowledge, is the first SR and meta-analysis examining the effectiveness of HEPEs on fall prevention among community-dwelling older adults. Especially in the background of COVID-19, this cost-friendly and contactless intervention is worthy of being studied and popularized. Meanwhile, intervention using e-devices has solved the problem of poor adherence of home-based exercises to a great extent. A previous review proved that telehealth combined with e-devices was able to reduce fall risk and fall efficacy significantly [40], and evidence also showed that individualized home-based exercise programs can lead to significant improvements in physical activity, balance, mobility and muscle strength for older people [85]. In the review we focused on home-based exercise programs delivered by e-devices; we not only proved the effectiveness of HEPEs for fall prevention, but also reached a quantitative conclusion on the optimum exercise volume when using a HEPE. The specific volume of exercise can help healthcare providers or physiotherapist to make an informed decision for community-dwelling older adults in relation to falls. Furthermore, in addition to qualitative and quantitative perspectives, we compared HEPEs with traditional home-based exercise programs and face-to-face exercise programs in terms of fall rates. Last but not least, our findings were based on 12 studies that can be considered, on average, of good quality (PEDro score = 6.83).

This review is not without limitations. First of all, the small number of available studies and the lack of a consistent set of tests make our conclusions preliminary in essence. In fact, the sample sizes of the included studies were uneven, ranging from 30 to 503. As such, the results had smaller effect sizes and may not be representative of larger populations. Secondly, the review excluded older adults with a diagnosis of chronic diseases such as multiple sclerosis, cancer, Parkinson's disease or Alzheimer's disease, because these patients may have a different performance in terms of balance [96], strength [97], mobility [98] or cognitive ability [99], which increases the risk of falls and restricts the effectiveness of HEPEs. Therefore future studies should consider investigating the effects of HEPEs on older adults with different chronic diseases. Thirdly, most of the included studies were conducted in Asia and Australia; the result might be different in other regions, as many factors have been proved to influence fall risk, including ethnicity and health status [100]. Finally, almost all the studies were from developed countries, so the results might not be replicable in nondeveloped countries or remote areas.

Implications for practice & research

In terms of implications for practice, the intervention pattern of a HEPE should be personalized and contain multiple types of exercise (including balance, strength training and functional training) to achieve a better curative effect. Next, the duration of intervention should be more than 16 weeks. Besides that, a permanent exercise plan is recommended in order to counteract time-related declines in overall physical performance. The frequency of HEPE-based exercise should be at least 120 min per week. Last but not least, step-by-step instructions and important advice regarding the method of application of the e-devices are necessary to increase the acceptance of new technologies among the elderly [101].

In terms of implications for research, as we did not find significant positive results from HEPEs on cognitive performance, future studies could pay attention to the special effects of HEPEs on cognition. Furthermore, multiple test methods should be applied in any future study in order to reduce the deviation of results caused by single tests and reinforce the credibility of the results.

Conclusion

This review proved the effectiveness of HEPEs on falls among community-dwelling older adults during the COVID-19 period. The results showed that HEPEs significantly improved lower extremity strength and reduced the rate of falls among healthy older adults. Compared with those aged below 75 years, HEPEs had a positive effect on those aged over 75 years. We also found that the volume of exercise should ideally be at least 120 min per week for over 16 weeks. Despite their preliminary nature, these findings suggest that HEPEs can be promoted in the elderly as

an effective fall prevention intervention due to the exponential aging of the population and the present situation caused by the COVID-19 pandemic.

Future perspective

Future studies could pay attention to investigating the effectiveness of HEPEs on other fall-related factors. Examples include, but are not limited to, cognitive performance, vision or psychological status. In the context of COVID-19 and global aging, remote health interventions can be an innovative and effective pattern to deliver healthcare to the community-dwelling older adult.

Summary points

Background

- Falls among older people are a worldwide public health issue.
- Home-based exercise programs with e-devices (HEPEs) can improve participants' adherence, reduce the influence of COVID-19 and save the medical workers' labor cost.
- This is the first meta-analysis providing evidence on the effects of HEPEs in community-dwelling older adults.

Methods

- An extensive literature search was performed using the Preferred Reporting Items for Systematic Reviews and Meta-Analyses approach.
- Four fall-related outcomes were evaluated in the meta-analysis: rate of falls (proportion of fallers), balance (timed up and go), lower extremity strength (five-times sit-to-stand test) and fall efficacy (physiological profile assessment). Subgroup and sensitivity analyses were conducted during the meta-analysis.

Results

- A total of 12 studies were finally included, and their overall quality was good (average score from the Physiotherapy Evidence Database = 6.83).
- HEPEs could significantly reduce the rate of falls and improve lower extremity strength.
- HEPEs could improve balance if the participants were aged over 75 years or the intervention duration was at least 16 weeks.

Conclusion

- HEPEs demonstrated an overall positive effect on falls among community-dwelling older adults.
- Based on the results, we recommend that older adults do exercise that lasts at least 120 min per week for over 16 weeks.

Supplementary data

To view the supplementary data that accompany this paper please visit the journal website at: www.futuremedicine.com/doi/suppl/10.2217/cer-2022-0130

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Ethical conduct of research

Ethical approval was noted for all of the published papers included in this review.

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