REVIEW ARTICLE

MACHINES THAT GO "PING" MAY IMPROVE BALANCE BUT MAY NOT IMPROVE MOBILITY OR REDUCE RISK OF FALLS: A SYSTEMATIC REVIEW

Amy M. Dennett, BPhty(Hons) and Nicholas F. Taylor, PhD

From the Faculty of Health Sciences, La Trobe University and Allied Health Clinical Research Office, Eastern Health, Victoria, Australia

Objective: **To determine the effectiveness of computer-based electronic devices that provide feedback in improving mobility and balance and reducing falls.**
Data sources: **Randomized controlled trials were searched from the earliest available date to August 2013.**
Data extraction: **Standardized mean differences were used to complete meta-analyses, with statistical heterogeneity being described with the I-squared statistic. The GRADE approach was used to summarize the level of evidence for each completed meta-analysis. Risk of bias for individual trials was assessed with the (Physiotherapy Evidence Database) PEDro scale.**
Data synthesis: **Thirty trials were included. There was high-quality evidence that computerized devices can improve dynamic balance in people with a neurological condition compared with no therapy. There was low-to-moderate-quality evidence that computerized devices have no significant effect on mobility, falls efficacy and falls risk in community-dwelling older adults, and people with a neurological condition compared with physiotherapy.**
Conclusion: **There is high-quality evidence that computerized devices that provide feedback may be useful in improving balance in people with neurological conditions compared with no therapy, but there is a lack of evidence supporting more meaningful changes in mobility and falls risk.**

Key words: falls; balance; mobility; virtual-reality; meta-analysis.

INTRODUCTION

Falls are a major issue affecting older people, with one-third of people aged 65 years and over falling at least once each year (1). This has significant implications for the individual in terms of injury, reduced mobility and independence at home and in the community. The impact of falls also has a significant cost for health services, with the annual cost of falls-related injury in Australia expected to rise almost 3-fold to AUD 1.4 billion by 2051 (2).

Poor balance is an important risk factor for falls (3–5). Exercise programmes are often prescribed to improve balance, with the aim of reducing falls. Indeed, it has been shown that up to 42% of falls in older people living in the community can be prevented by well-designed exercise programmes that provide a moderate-to-high challenge to balance, that are undertaken for at least 2 hours per week (6, 7). These exercise programmes may be undertaken within a home or clinical setting (7, 8).

The use of technology through interactive gaming and virtual-reality is becoming increasingly popular with clinicians to create stimulating and challenging environments to improve balance and mobility within therapy sessions. The Nintendo Wii alone has been adapted for rehabilitation across health settings in many countries, with reports of 61% of urban stroke rehabilitation centres owning a console in Australia (9, 10). The advantage of such gaming and other virtual-reality systems is that they provide visual or other forms of feedback through a screen or a head-mounted device, which allows the user to interact with virtual environments to simulate balance and functional tasks at intensities that may be greater than traditional therapies (11–13). This may be important, given that visual and proprioceptive feedback are important components of balance control (14, 15). It is also thought that this technology may be more engaging and fun for patients as they can interact with programmes and may be less likely to focus on their health condition. In turn, this may assist with improved adherence to such therapy programmes.

Current evidence has demonstrated positive effects of virtual-reality rehabilitation in people with upper limb impairments post stroke (16, 17). Less is known about the effectiveness of computer-based technology in other populations due to lack of quality randomized controlled trials (8, 10, 18). To date, there has been no systematic reviews that we are aware of that have synthesized the available evidence on the effectiveness of computer-based interventions in terms of balance and mobility outcomes during rehabilitation.

The purpose of this systematic review was therefore to determine whether the use of computer-based technology that provides feedback is effective in improving balance, and whether any benefits carry over into improved mobility or reduced risk of falls.

METHODS

Research design

A systematic review was completed in accordance with PRISMA guidelines (19, 20) and was registered prospectively through PROSPERO (CRD42013005726) (21).

Trials to be included in the review were identified though electronic database searching from the earliest available time until August 2013 through the following databases: MEDLINE, EMBASE and CINAHL. The search strategy used was based around synonyms and MeSH subject headings of the key concepts of: first, electronic devices and computer technology; secondly, balance; and thirdly, rehabilitation, combined with Boolean operators OR within each concept and the operator AND between the concepts (Appendix I). These terms were combined with the relevant filters (22) to identify randomized controlled trials and controlled trials. Studies from the EMBASE database were further limited by date (1990 to present) given the nature of the technology being studied. The search was supplemented by citation tracking and checking the reference lists of included studies.

Inclusion criteria

Title and abstracts of identified trials were assessed by 2 reviewers independently using predetermined inclusion and exclusion criteria (Table I). Full text articles were obtained and examined by both reviewers where inclusion could not clearly be determined by title and abstract alone. To be included in the review, trials were to use computer technology that provided feedback as a therapy tool such that any change could be attributed to the technology. Any device that was assistive or instructive was not included, as the investigation of the use of electronic feedback to improve balance was the primary aim of the current review.

Risk of bias assessment

Risk of bias of the included trials was assessed independently by 2 reviewers using the (Physiotherapy Evidence Database) PEDro scale. The 11 items on the PEDro scale are rated "yes" or "no", with a maximum score of 10 achieved for internal validity as the first item is not rated. The PEDro scale is a valid measure of methodological quality of clinical trials that has undergone Rasch analysis and has moderate levels of inter-rater reliability (ICC 0.68, 95% CI 0.57, 0.76) (23, 24). Trials were deemed high quality if scores were 6 or above. Trials that scored 4 or less were deemed lesser quality (25).

Data analysis

Meta-analyses were completed using a random effects model for clinically homogeneous data using standardized mean differences for continuous data. Statistical heterogeneity was described with the I-squared statistic. Descriptive analysis was completed for data that could not be analysed with meta-analyses. Data included in the analysis were evaluated according to the population studied and comparing the intervention with no therapy or traditional physiotherapy interventions.

The GRADE (Grading of Recommendations Assessment, Development and Evaluation) approach (26) was used to summarize the level of evidence for each completed meta-analysis. This approach involves downgrading the evidence from high to moderate to low to very low. Downgrading of the evidence would occur based on the following criteria: (1) the PEDro score was <6 for the majority of trials in the meta-analysis, (2) there was greater than low levels of statistical heterogeneity between the trials ($I^2 > 25\%$), and (3) there were large confidence intervals. A 95% confidence interval of > 0.8 in the standardized mean difference of the meta-analysis was regarded as large, since this value could span the difference between an intervention having no effect and a large effect according to Cohen's criteria (27). If there were serious issues with the methodological quality, such as all trials in the meta-analysis were < 6 PEDro score without allocation concealment and blinded assessors, then a double downgrade would occur (e.g. from high to low quality). Reasons for the grade applied to each meta-analysis were explained using footnotes.

RESULTS

The search of electronic databases resulted in a yield of 3,208 articles, which was reduced to 58 after application of inclusion/exclusion criteria to title and abstracts. After further assessment of full-text articles, this was reduced to 28 trials. No further trials were identified from review of the reference lists of the already included studies. Two relevant trials were identified using citation tracking, resulting in a final library of 30 trials to be included for review (Fig. 1).

Risk of bias

All of the articles included in this review were randomized controlled trials. The median score of the included articles was 5 out of 10 (mean 5.2, range 3–8, mode = 6) on the PEDro scale (Table II). Only one study (28) scored 8 on the scale, which is the highest possible score, given the nature of the intervention being studied, where it would not be expected to be feasible to

Table I. *Inclusion/exclusion criteria*

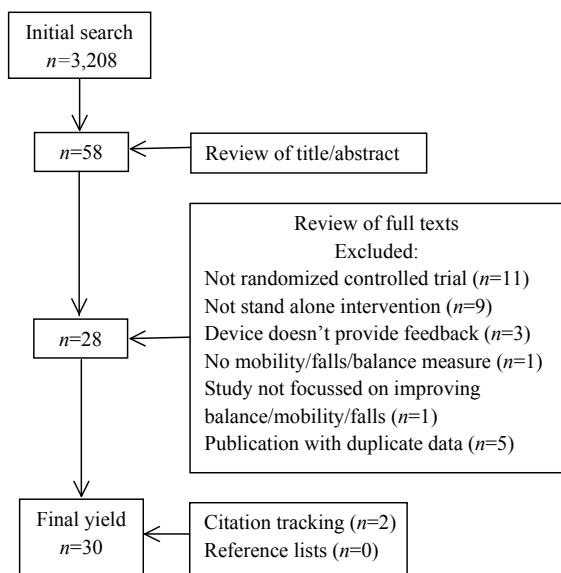| Inclusion criteria	Exclusion criteria
• Adults i.e. mean age ≥ 18 years old. • Randomized controlled trials. • Peer-reviewed journal article. • Written in English. • Use of computer technology or other electronic device that provides immediate and interactive visual, auditory or proprioceptive feedback as a therapy tool used for the purpose of improving balance or mobility. Includes virtual-reality and computer simulation. • Computer technology or electronic device should be used as the primary intervention. However, warm-up and cool-down exercises allowed if they do not take up more than 20% of intervention time and client may complete a supplementary home exercise program (HEP). • Use of at least one balance-, mobility- or falls-related outcome measure.	• Other research designs including: systematic reviews, case studies, opinion articles, editorials, book chapters, clinical guidelines, single group pre-post studies, controlled trials, abstracts, qualitative data. • Computer technology or electronic device that is used as an assessment tool, electronic medical records, tele/video-conferencing, electrical stimulation, computer devices or applications that only provide instructions (e.g. App that provides HEP) or device does not primarily provide direct feedback during balance activities or is assistive, e.g. robots, treadmills, vibration platforms. These devices may only be used if linked with an electronic device that does provide immediate feedback. • Technology intervention used as part of a co-intervention, e.g. combined with "conventional physiotherapy". • Only uses traditional physiotherapy modalities or equipment that is not computerized or provides electronic feedback, e.g. use of rocker-boards/wobble-board, foam mats, duradisks/bosu ball, balance beam, hydrotherapy, tai chi, etc. • Does not use balance, falls or mobility related outcomes.

Fig. 1. Selection process.

blind patients or clinicians. The criterion for random allocation of participants was the only criterion met by all of the included trials. Fifteen trials reported assessor blinding (28–41). Concealment of treatment allocation occurred in only 5 trials (28, 35, 37, 39, 40) and intention to treat analyses was completed in 7 trials (28, 30, 33, 41–44).

Summary of data

The results of a total of 1240 people were included in the review. The majority of participants were women (60%) with a mean age of 61 years (SD 19 years). The main health conditions represented by participants included: acquired brain injury (6 trials (30–34, 40), multiple sclerosis (3 trials (29, 35, 36)), acute and chronic peripheral vestibular dysfunction (3 trials (42, 45, 46)), Parkinson's disease (2 trials (41, 47)), and type 2 diabetes in 1 trial (48). Three trials investigated a healthy young adult population (49–51) and 11 trials investigated community-dwelling older adults (37–39, 43, 44, 52–57).

Table II. *Characteristics of included trials*

Study PEDro Score (/10)	Subjects, *n* Females, % Age, mean (SD)	Health condition	Intervention	Comparison	Dosage	Setting	Outcome measures	
Brumels et al., 2008 (49) 3	25 52% 19.6 (1.7)	Healthy young adults	Dance Dance Revolution Nintendo Wii Fit	Traditional balance programme	12–15 min 3×/week 4 weeks	Laboratory	Static balance	Single leg postural sway using force plate
							Dynamic balance	SEBT
Brichetto et al., 2013 (29) 6	36 61% 42 (11)	Multiple sclerosis	Nintendo Wii Fit	Traditional balance programme	60 min 3×/week 4 weeks	Outpatient clinic	Static Balance	Postural sway (BPEX platform)
							Dynamic balance	BBS
Daniel, 2012 (52) 3	23 40% 77 (5.3)	Community-dwelling older adults	Nintendo Wii Sports + weight vest	Seated exercise No therapy	45 min 3×/week 15 weeks	Laboratory	Activity limitation	Senior Fitness Test: 30 s STS 30 s arm curls no. of steps in 2 min chair sit & reach 8 ft up & go 15 ft WT CHAMPS LLFDS
							Balance confidence	ABC scale
Fitzgerald et al., 2010 (50) 4	28 55% 26.2 (2.7)	Healthy young adults	Exergaming using Dell Computers & Concept Wobbler	Traditional balance programme	15 min 3×/week 4 weeks	Laboratory	Dynamic balance	SEBT DPSI
Franco et al., 2011 (53) 5	32 78% 78.27 (6)	Community dwelling older adults	Nintendo Wii Fit	Traditional balance programme	10–15 min 2×/week 3weeks	Laboratory	Dynamic balance	BBS Tinetti Gait & Balance assessment
Fritz et al., 2013 (30) 7	30 Unknown 66.1 (9.7)	Chronic stroke	Nintendo Wii Fit & Sports PlayStation EyeToy2 & Kinetic	No therapy	50–60 min 4×/week 5 weeks	Laboratory	Dynamic balance	Fugl-Meyer Assessment BBS DGI
							Activity limitation	6 min WT 3 m WT TUGT

Table II. *Contd.*

Study PEDro Score (/10)	Subjects, *n* Females, % Age, mean (SD)	Health condition	Intervention	Comparison	Dosage	Setting	Outcome measures	
Gil-Gomez et al., 2011 (31) 6	17 35% 47.3 (17.8)	Chronic stroke TBI Cerebral neoplasm	eBaViR (modified WBB)	Traditional balance programme	60 min 3–5×/week 4–6 weeks	Outpatient clinic	Dynamic balance	BBS BBA Anterior Reach Test Stepping Test
							Activity limitation	Timed Stair Test 1 min WT 10 m WT TUGT 30 s STS
Hinman, 2002 (54) 4	88 63% 72	Community dwelling older adults	Biodex Balance System	Home exercise programme No therapy	20 min 3×/week 4 weeks	Laboratory	Dynamic Balance	BBS
							Activity Limitation	Timed 50 ft WT
							Falls Efficacy	Modified FES
Jung et al., 2012 (32) 6	21 38% 62.1 (6.9)	Chronic stroke	Virtual-reality Treadmill Training (Mybud, Accupix, Gyeonggi-do)	Usual treadmill training	30 min 5×/week 3 weeks	Laboratory	Activity limitation	TUGT
							Balance confidence	ABC Scale
Laver et al., 2012 (28) 8	44 80% 84.9 (4.5)	Hospitalized older adults (mix of fractures, falls, medical and surgical)	Nintendo Wii Fit	Conventional physiotherapy	25 min 5×/week duration of IP admission (usually 6 sessions ±2)	Acute hospital	Dynamic Balance	Modified BBS
							Balance Confidence	ABC Scale
							Activity Limitation	TUGT FIM SPPB Timed IADL
Marioni et al., 2013 (42) 5	30 40% 45 (7)	Acute vestibular	VRS system (computerized posturography)	No therapy	30 min 1×/week 5 weeks	Laboratory	Static Balance	Modified CTSIB LOS (computerized)
Melong & Keats, 2013 (51) 4	20 60% 19.7 (1.2)	Healthy young adults	Nintendo Wii Fit	Traditional balance programme	20min 3×/week 4 weeks	Laboratory	Static Balance	Stabilometer
Mirelman et al., 2009 (33) 7	18 17% 61.4 (9.1)	Chronic Stroke	Rutgers Ankle Rehabilitation system	Rutgers ankle rehabilitation system without virtual-reality	60 min 3×/week 4 weeks	Laboratory	Dynamic Balance	BBS
							Activity limitation	Patient Activity Monitor Lower Extremity Fugl-Meyer Scale 6 min WT 7 m WT
Mirelman et al., 2010 (34) 6	18 17% 61.4 (9.1)	Chronic Stroke	Rutgers Ankle Rehabilitation system	Rutgers ankle rehabilitation system without virtual-reality	60 min 3×/week 4 weeks	Laboratory	Activity limitation	Gait speed and kinematics (VICON)
Nilsagard et al., 2013 (35) 7	84 76% 49.7 (11.3)	Multiple sclerosis	Nintendo Wii Fit	No Therapy	30 min 2×/week 6–7 weeks	Laboratory	Dynamic balance Activity limitation	FSST Dynamic Gait Index TUGT TUGT + cognitive task 25 ft WT
							Balance confidence	Timed Chair Stand ABC Scale

Table II. *Contd.*

Study PEDro Score (/10)	Subjects, *n* Females, % Age, mean (SD)	Health condition	Intervention	Comparison	Dosage	Setting	Outcome measures	
Pluchino et al., 2012 (55) 4	40 63% 72.5 (8.4)	Community dwelling older adults	Nintendo Wii Fit	Tai chi Traditional balance programme	60 min 2×/week 8 weeks	Laboratory	Static balance	One-Leg Stance Force plate COP
							Dynamic balance	Dynamic posturography Functional reach test
							Activity limitation	TUGT Tinetti POMA
							Balance confidence	ABC Scale
							Falls efficacy	FES
							Falls risk	FROP-COM
Prosperini et al., 2013 (36) 6	36 69% 36.2 (8.7)	Multiple sclerosis	Nintendo Wii Fit	No therapy	30 min daily 12 weeks	Home	Static balance	Force plate COP (ProKin)
							Dynamic balance	FSST
							Activity limitation	25 ft WT
							Falls frequency	Number of falls (reported)
Qutubuddin et al., 2007 (47) 3	15 0% 72.8 (6.8)	Parkinson's Disease	Smart BalanceMaster	Conventional physiotherapy	30 min 2×/week 4 weeks	Outpatient clinic	Static balance	SOT Adaption test LOS (BalanceMaster)
							Dynamic balance	BBS
Rendon et al., 2012 (43) 6	40 39% 84.4 (5.2)	Community dwelling older adults	Nintendo Wii Fit	No therapy	35–45 min 3×/week 6 weeks	Outpatient clinic	Activity limitation	8 ft Up & Go
							Balance confidence	ABC scale
Rossi-Izquierdo et al., 2011 (45) 4	24 67% 51.7	Chronic Vestibular	Smart BalanceMaster	Optokinetic stimulation	15–20 min daily 5 days	Outpatient clinic	Static balance	SOT LOS (BalanceMaster)
Schoene et al., 2013 (37) 7	37 unknown 78 (5)	Community dwelling older adults	Dance Dance Revolution Stepmania	No therapy	15–20 min 2–3×/week 8 weeks	Home	Dynamic balance	Choice Stepping Reaction Time Alternate Step Test INHIB stepping task
							Activity limitation	TUGT TUGT Cognitive 5× Sit to Stand
							Falls efficacy	FES
							Falls risk	PPA
Singh et al., 2012 (38) 6	38 100% 62.6 (4.8)	Community dwelling older adults	Nintendo Wii Fit	Traditional balance programme	40 min 2×/week 6 weeks	Laboratory	Balance confidence	ABC scale
							Falls risk	FallsScreen PPA
Singh et al., 2013 (56) 5	38 100% 62.6 (4.8)	Community dwelling older adults	Nintendo Wii Fit	Traditional balance programme	30 min 2×/week 6 weeks	Laboratory	Static balance	Postural sway (ProBalance)
							Dynamic balance	Ten Step Test
							Activity limitation	TUGT
Sparrer et al., 2013 (46) 3	71 62% 43.5 (3.5)	Acute vestibular	Nintendo Wii Fit	No therapy	45 min daily 5 days	Laboratory	Static balance	SOT (EquiTest) One-leg stance (Wii)

Table II. *Contd.*

Study PEDro Score (/10)	Subjects, *n* Females, % Age, mean (SD)	Health condition	Intervention	Comparison	Dosage	Setting	Outcome measures	
Sun Woo et al., 2012 (48) 5	55 71% 74.1 (5)	Type 2 Diabetes	PlayStation Eye Toy	Education only	50 min 2×/week 10 weeks	Laboratory	Static balance	Postural sway (PDM Forceplate)
Szturm et al., 2011 (39) 7	30 63% 80.8 (7.5)	Community dwelling older adults	Exergaming using FSA Pressure Mat	Traditional balance programme	45 min 2×/week 8 weeks	Outpatient clinic	Static balance Dynamic balance	Modified CTSIB BBS
							Activity limitation Balance confidence	GaitRite TUGT ABC scale
Toulotte et al., 2012 (44) 4	36 61% 75.1 (10.3)	Community dwelling older adults	NintendoWii Fit	No therapy Conventional physiotherapy Wii + Conventional PT	60 min 1×/week 20 weeks	Laboratory	Static balance Activity limitation	COG (Wii) Unipedal test Tinnetti questionnaire
Wolf et al., 1996 (57) 4	200 81% 76.2 (8)	Community dwelling older adults	Computerized Balance Training using Chattecx	Education only tai chi	45 min 1×/week 15 weeks	Laboratory	Falls risk Falls efficacy Activity limitation	Time to falls occurrence Number of falls Fear of falls 12 min WT IADL Scale
Yang et al., 2008 (40) 6	24 42% 61 (9.8)	Chronic Stroke	Virtual-reality Treadmill Training (Fastrack, Pohlemus)	Standard treadmill training	20 min 3×/week 3 weeks	Laboratory	Activity limitation Balance confidence	10 m WT Community walk test (400 m) WAQ ABC Scale
Yen et al., 2011 (41) 7	42 21% 78 (5)	Parkinson's Disease	Computerized Balance Board (+Virtools)	No therapy Traditional balance programme	30 min 2×/week 6 weeks	Laboratory	Static balance	SOT SOT + cognitive task reaction time (SMART Balance System)

SEBT: Star Excursion Balance Test; BBS: Berg Balance Scale; STS: Sit to Stand; WT: walk test; CHAMPS: Community Healthy Activities Model Program for Seniors Physical Activity Questionnaire; LLFDS: Late Life Function & Disability Scale; ABC scale: Activities Balance Confidence Scale; DPSI: Dynamic Postural Stability Index; DGI: Dynamic Gait Index; TUGT: Timed Up & Go Test; BBA: Brunel Balance Assessment; FES: Falls Efficacy Scale; SPPB: Short Physical Performance Battery; IADL: instrumental activities of daily living; CTSIB: Clinical Test of Sensory Integration of Balance; LOS: Limits of Stability; FSST: Four Square Step Test; COP: centre of pressure; POMA: Performance Orientated Mobility Assessment; FROP-COM: Falls Risk for Older People in the Community; SOT: Sensory Organisation Test; PPA: Physical Profile Assessment Score; COG: centre of gravity; WAQ: walking ability questionnaire.

Interventions

All trials included in the review used computer-based technology to improve balance or mobility using electronic feedback. The most popular device was the Nintendo Wii, which was used in 15 trials (28–30, 35, 36, 38, 43, 44, 46, 49, 51–53, 55, 56). Other commercial video-game based devices were used in 4 trials (30, 37, 48, 49). Nine trials used customized electronic balance devices, where games could be individually tailored by the therapists (31, 39, 41, 42, 45, 47, 50, 54, 57). Two trials used virtual-reality based treadmill training (32, 40) and 2 trials used virtual-reality based robot training (33, 34). Most interventions were conducted in an outpatient clinic or laboratory setting, with two trials using a home-based setting (36, 37) and

one completed in an acute hospital (28). The duration of each intervention varied from 10–60 min. Typically, sessions were completed 2–3 times per week for, on average, 6 weeks (range 1–20 weeks). The computerized intervention was compared with conventional physiotherapy interventions (termed physiotherapy for the purpose of this review) in 17 trials (28, 29, 31, 38, 39, 41, 44, 45, 47, 49–56). Physiotherapy interventions included traditional balance, seated exercise and home exercise programmes, which included functional mobility, static and dynamic balance, strength and flexibility exercises. Two studies included ocular mobility and optokinetic stimulation as part of the physiotherapy intervention (45, 46). Two trials compared the intervention with tai chi (55, 57). Two trials compared treadmill training with and

without virtual-reality (32, 40) and 2 trials compared a robotic ankle device with and without virtual-reality (33, 34). Thirteen trials had a control group with no exercise intervention (30, 35–37, 41–44, 46, 48, 52, 54, 57) (Table II). However, 2 of these trials received education (48, 57).

Adverse events and adherence

Three trials reported that there were no adverse events attributed to the use of the computerized intervention (35, 42, 46). One trial (36) of the 30, reported adverse events attributed to the use of the intervention. In this trial, 3 participants developed low-back pain and 2 participants developed knee pain from the use of the computer-based intervention. The other 26 trials failed to report whether any adverse events occurred.

Four trials reported increased levels of enjoyment and motivation when using the computerized intervention (31, 49–51). However, 3 trials reported no significant difference in compliance with the computerized intervention compared with physiotherapy (28, 47, 51).

Effect of computer-based intervention vs physiotherapy in people without a primary health condition

For older community-dwelling people, meta-analysis of 4 trials with 132 participants provided low-quality evidence that there was no difference in dynamic balance (Fig. 2a) compared with physiotherapy. Meta-analysis of 5 trials with 153 participants provided low-quality evidence that there was no difference in falls efficacy or balance confidence (Fig. 2b). Furthermore, 3 trials with 79 participants demonstrated low-quality evidence that there was no difference in falls risk (Fig. 2c).

Trials on community-dwelling older adults that could not be included in the meta-analysis due to clinical heterogeneity also found no difference in static or dynamic balance, balance confidence or falls efficacy, or mobility compared with physiotherapy.
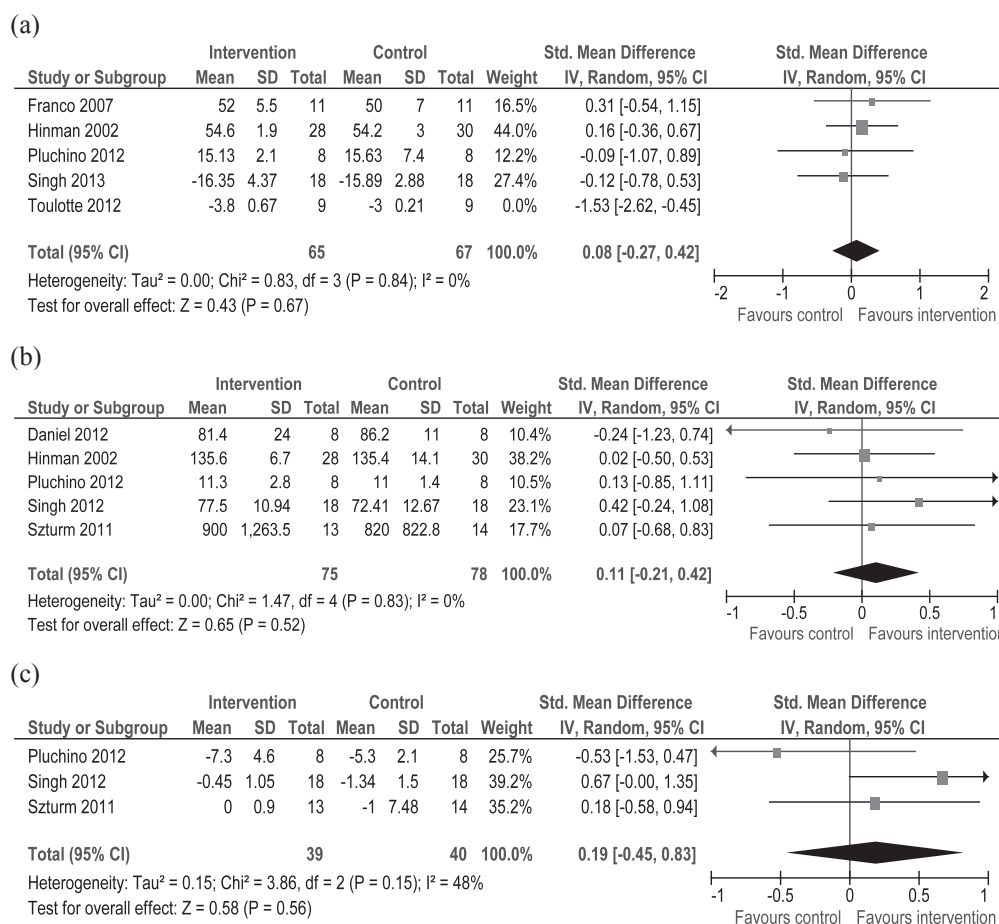
(a)

Study or Subgroup	Intervention Mean	SD	Total	Control Mean	SD	Total	Weight	Std. Mean Difference IV, Random, 95% CI
Franco 2007	52	5.5	11	50	7	11	16.5%	0.31 [-0.54, 1.15]
Hinman 2002	54.6	1.9	28	54.2	3	30	44.0%	0.16 [-0.36, 0.67]
Pluchino 2012	15.13	2.1	8	15.63	7.4	8	12.2%	-0.09 [-1.07, 0.89]
Singh 2013	-16.35	4.37	18	-15.89	2.88	18	27.4%	-0.12 [-0.78, 0.53]
Toulotte 2012	-3.8	0.67	9	-3	0.21	9	0.0%	-1.53 [-2.62, -0.45]
Total (95% CI)			65			67	100.0%	0.08 [-0.27, 0.42]

Heterogeneity: Tau² = 0.00; Chi² = 0.83, df = 3 (P = 0.84); I² = 0%
Test for overall effect: Z = 0.43 (P = 0.67)

(b)

Study or Subgroup	Intervention Mean	SD	Total	Control Mean	SD	Total	Weight	Std. Mean Difference IV, Random, 95% CI
Daniel 2012	81.4	24	8	86.2	11	8	10.4%	-0.24 [-1.23, 0.74]
Hinman 2002	135.6	6.7	28	135.4	14.1	30	38.2%	0.02 [-0.50, 0.53]
Pluchino 2012	11.3	2.8	8	11	1.4	8	10.5%	0.13 [-0.85, 1.11]
Singh 2012	77.5	10.94	18	72.41	12.67	18	23.1%	0.42 [-0.24, 1.08]
Szturm 2011	900	1,263.5	13	820	822.8	14	17.7%	0.07 [-0.68, 0.83]
Total (95% CI)			75			78	100.0%	0.11 [-0.21, 0.42]

Heterogeneity: Tau² = 0.00; Chi² = 1.47, df = 4 (P = 0.83); I² = 0%
Test for overall effect: Z = 0.65 (P = 0.52)

(c)

Study or Subgroup	Intervention Mean	SD	Total	Control Mean	SD	Total	Weight	Std. Mean Difference IV, Random, 95% CI
Pluchino 2012	-7.3	4.6	8	-5.3	2.1	8	25.7%	-0.53 [-1.53, 0.47]
Singh 2012	-0.45	1.05	18	-1.34	1.5	18	39.2%	0.67 [-0.00, 1.35]
Szturm 2011	0	0.9	13	-1	7.48	14	35.2%	0.18 [-0.58, 0.94]
Total (95% CI)			39			40	100.0%	0.19 [-0.45, 0.83]

Heterogeneity: Tau² = 0.15; Chi² = 3.86, df = 2 (P = 0.15); I² = 48%
Test for overall effect: Z = 0.58 (P = 0.56)

Fig. 2. Effect of computer-based intervention vs physiotherapy for people without a primary health condition. (a) Standard mean difference (SMD) (95% confidence interval (95% CI) of effect of computer-based intervention vs physiotherapy on dynamic balance for community-dwelling elders. GRADE=Low. GRADE working group grades of evidence (see Reason for downgrade). Reason for downgrade: all trials rated lesser quality (PEDro <6) without blinded outcome measures and allocation concealment. (b) SMD (95% CI) of effect of computer-based intervention vs physiotherapy on falls efficacy and balance confidence for community-dwelling elders. GRADE=Low. GRADE working group grades of evidence (see Reason for downgrade). Reason for downgrade: 3 trials (51, 53, 54) rated lesser quality (PEDro <6) without blinded outcome measures and allocation concealment. (c) SMD (95% CI) of effect of computer-based intervention vs physiotherapy on falls risk for community-dwelling elders. GRADE=Low. GRADE working group grades of evidence (see Reason for downgrade) Reason for downgrade: statistical heterogeneity (I²=48%), very large confidence intervals.

The 3 trials investigating use of computer-based balance training in young healthy adults could not be included in meta-analysis as there was insufficient data. Two of these studies did not show any significant differences in postural stability compared with traditional therapies (50, 51). One trial (49) did demonstrate significant improvement in reduction of postural sway compared with physiotherapy.

Effect of computer-based intervention vs physiotherapy in people with a primary health condition

Meta-analysis of 2 trials on 41 participants with a neurological condition demonstrated low-quality evidence that there was no difference for balance confidence (Fig. 3a) compared with physiotherapy. Meta-analysis of 4 trials with 76 participants demonstrated moderate-quality evidence that there was no difference for mobility (Fig. 3b) compared with physiotherapy.

Individual trials on participants with a neurological population that could not be combined in meta-analysis due to heterogeneity found no difference in static or dynamic balance.

One high-quality study investigating computer-based balance training on a sample of people with a variety of medical conditions on an acute hospital ward (28) also did not find any differences in mobility, dynamic balance or balance confidence after 6 sessions of therapy for the duration of their inpatient admission compared with physiotherapy.

Effect of computer-based intervention vs no therapy in people without a primary health condition

Meta-analysis of 4 trials with 130 community-dwelling older adults demonstrated low-quality evidence that there were no

differences for dynamic balance (Fig. 4a) compared with no therapy. Meta-analysis of 4 trials with 139 participants also demonstrated low-quality evidence that there were no differences for falls efficacy and balance confidence (Fig. 4b) compared with no therapy. Meta-analysis of 4 trials with 183 participants also demonstrated low-quality evidence that there was no difference for mobility (Fig. 4c) compared with no therapy.

Individual trials that could not be included in the meta-analysis due to clinical heterogeneity found no difference in static or dynamic balance, or falls risk compared with no therapy.

No included trials compared the computer-based intervention with no therapy in young healthy adults.

Effect of computer-based intervention vs no therapy in people with a primary health condition

Meta-analysis of 4 trials with 213 participants with a neurological condition demonstrated high-quality evidence for improved dynamic balance immediately post intervention (Fig. 5a) compared with no therapy. Meta-analysis of 3 trials with 146 participants demonstrated high-quality evidence that there was no significant difference in mobility (Fig. 5b) compared with no therapy.

Individual trials that could not be included in meta-analysis due to heterogeneity demonstrated no difference in static balance or balance confidence in participants with acquired brain injury and multiple sclerosis (35, 36, 40) One trial on a vestibular population showed moderate effect in favour of the computer-based intervention for single-leg stance immediately post intervention, which was not sustained at 10 weeks (46).
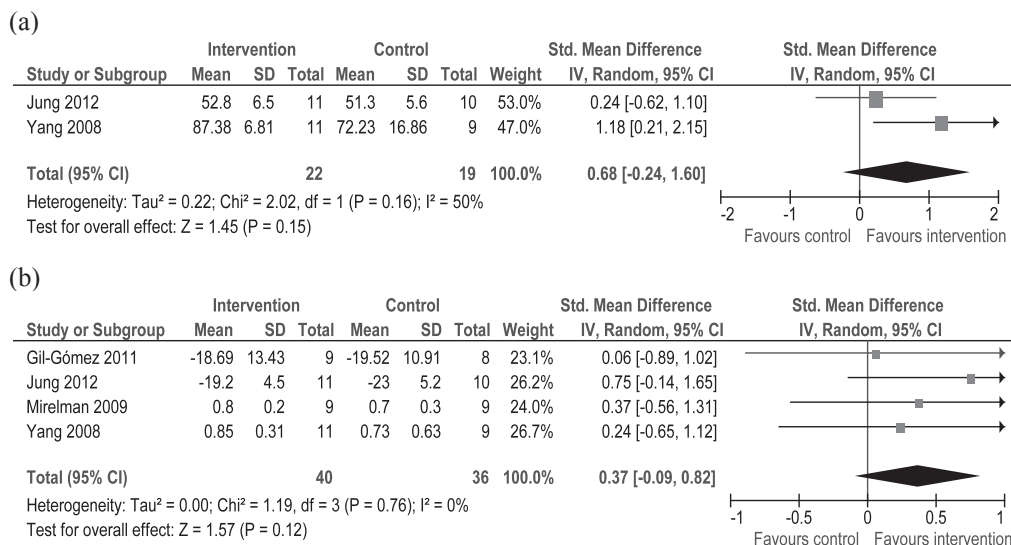

Fig. 3. Effect of computer-based intervention vs physiotherapy for people with a health condition. (a) SMD (95% confidence interval (95% CI)) of effect of computer-based intervention vs physiotherapy on balance confidence for people with a neurological condition. GRADE=Low. GRADE working group grades of evidence (see Reason for downgrade). Reason for downgrade: statistical heterogeneity (I²=50%), very large confidence intervals. (b) SMD (95% CI) of effect of computer-based intervention vs physiotherapy on mobility for people with a neurological condition. GRADE=Moderate. GRADE working group grades of evidence (see Reason for downgrade). Reason for downgrade: very large confidence intervals.
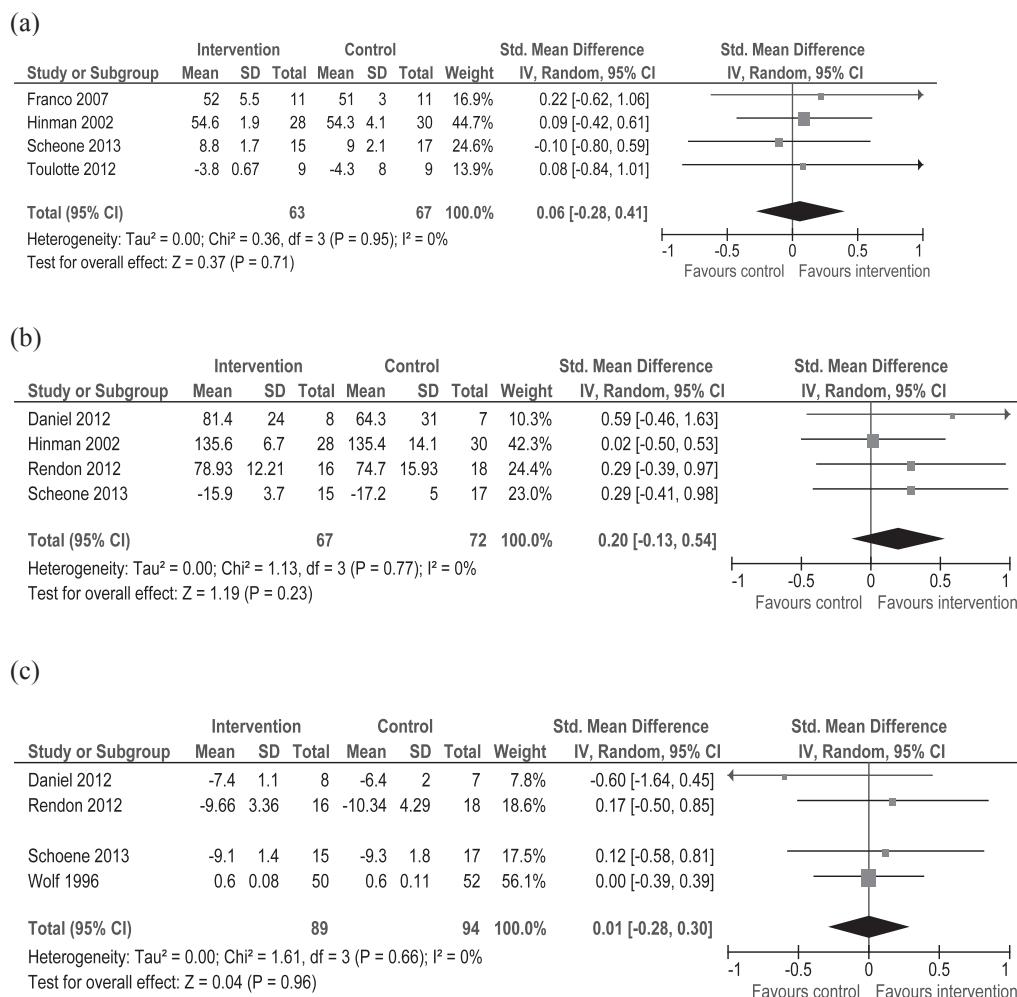
(a)

Study or Subgroup	Intervention Mean	SD	Total	Control Mean	SD	Total	Weight	Std. Mean Difference IV, Random, 95% CI
Franco 2007	52	5.5	11	51	3	11	16.9%	0.22 [-0.62, 1.06]
Hinman 2002	54.6	1.9	28	54.3	4.1	30	44.7%	0.09 [-0.42, 0.61]
Scheone 2013	8.8	1.7	15	9	2.1	17	24.6%	-0.10 [-0.80, 0.59]
Toulotte 2012	-3.8	0.67	9	-4.3	8	9	13.9%	0.08 [-0.84, 1.01]
Total (95% CI)			63			67	100.0%	0.06 [-0.28, 0.41]

Heterogeneity: Tau² = 0.00; Chi² = 0.36, df = 3 (P = 0.95); I² = 0%
Test for overall effect: Z = 0.37 (P = 0.71)

(b)

Study or Subgroup	Intervention Mean	SD	Total	Control Mean	SD	Total	Weight	Std. Mean Difference IV, Random, 95% CI
Daniel 2012	81.4	24	8	64.3	31	7	10.3%	0.59 [-0.46, 1.63]
Hinman 2002	135.6	6.7	28	135.4	14.1	30	42.3%	0.02 [-0.50, 0.53]
Rendon 2012	78.93	12.21	16	74.7	15.93	18	24.4%	0.29 [-0.39, 0.97]
Scheone 2013	-15.9	3.7	15	-17.2	5	17	23.0%	0.29 [-0.41, 0.98]
Total (95% CI)			67			72	100.0%	0.20 [-0.13, 0.54]

Heterogeneity: Tau² = 0.00; Chi² = 1.13, df = 3 (P = 0.77); I² = 0%
Test for overall effect: Z = 1.19 (P = 0.23)

(c)

Study or Subgroup	Intervention Mean	SD	Total	Control Mean	SD	Total	Weight	Std. Mean Difference IV, Random, 95% CI
Daniel 2012	-7.4	1.1	8	-6.4	2	7	7.8%	-0.60 [-1.64, 0.45]
Rendon 2012	-9.66	3.36	16	-10.34	4.29	18	18.6%	0.17 [-0.50, 0.85]
Schoene 2013	-9.1	1.4	15	-9.3	1.8	17	17.5%	0.12 [-0.58, 0.81]
Wolf 1996	0.6	0.08	50	0.6	0.11	52	56.1%	0.00 [-0.39, 0.39]
Total (95% CI)			89			94	100.0%	0.01 [-0.28, 0.30]

Heterogeneity: Tau² = 0.00; Chi² = 1.61, df = 3 (P = 0.66); I² = 0%
Test for overall effect: Z = 0.04 (P = 0.96)

Fig. 4. Effect of computer-based intervention vs no therapy for people without a primary health condition. (a) SMD (95% confidence interval (95% CI)) of effect of computer-based intervention vs no therapy on dynamic balance for community-dwelling elders. GRADE=Low. GRADE working group grades of evidence (see Reason for downgrade). Reason for downgrade: 3 studies (43, 52, 53) rated lesser quality (PEDro <6), without blinded outcome measures or allocation concealment. (b) SMD (95% CI) of effect of computer-based intervention vs no therapy on falls efficacy and balance confidence for community-dwelling elders. GRADE=Low. GRADE working group grades of evidence (see Reason for downgrade). Reason for downgrade: 2 studies (51, 53) rated lesser quality (PEDro <6), without blinded outcome measures or allocation concealment. (c) SMD (95% CI) of effect of computer-based intervention vs no therapy on mobility for community-dwelling elders. GRADE=Low. GRADE working group grades of evidence (see Reason for downgrade). Reason for downgrade: 2 trials (52, 56) rated lesser quality (PEDro <6), without blinded outcome measures or allocation concealment.

Another trial with a vestibular population demonstrated large effect in favour of the computer-based intervention for standing balance on foam with eyes open and closed immediately post and at 6 weeks post intervention (42).

One low-quality study investigating the computer-based intervention on a sample of older people with type 2 diabetes demonstrated a large effect in favour of the intervention for reducing postural sway after 10 weeks of training (48).

DISCUSSION

The results of this systematic review of 30 randomized controlled trials provides high-quality evidence that computerized balance interventions that provide feedback improve dynamic balance in people with a neurological condition, and low-quality evidence that these devices improve static balance in people with vestibular conditions compared with no therapy. However, there was low-quality evidence that computerized balance interventions resulted in no difference in falls risk, falls and balance confidence or mobility in people who have a neurological condition compared with no therapy. In community-dwelling older adults and healthy young adults, there was low-quality evidence that computerized balance interventions resulted in no difference in balance, mobility or reduce falls risk compared with no intervention. Furthermore, compared with physiotherapy interventions used to improve balance, such as balance exercise programmes and tai chi, there was low-to-moderate-quality evidence that computerized balance
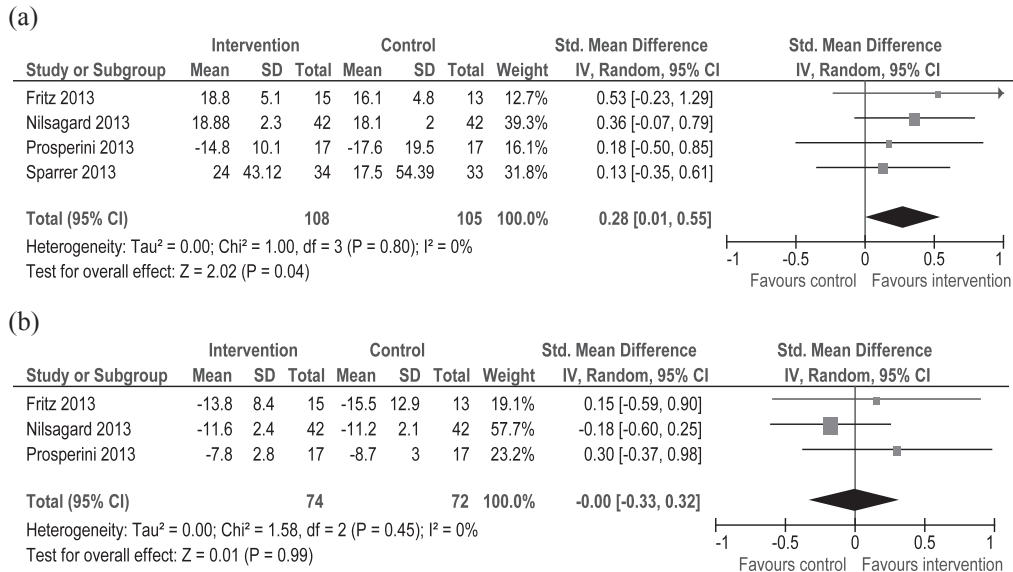
(a)

Study or Subgroup	Intervention			Control			Weight	Std. Mean Difference IV, Random, 95% CI	Std. Mean Difference IV, Random, 95% CI
	Mean	SD	Total	Mean	SD	Total			
Fritz 2013	18.8	5.1	15	16.1	4.8	13	12.7%	0.53 [-0.23, 1.29]	
Nilsagard 2013	18.88	2.3	42	18.1	2	42	39.3%	0.36 [-0.07, 0.79]	
Prosperini 2013	-14.8	10.1	17	-17.6	19.5	17	16.1%	0.18 [-0.50, 0.85]	
Sparrer 2013	24	43.12	34	17.5	54.39	33	31.8%	0.13 [-0.35, 0.61]	
Total (95% CI)			**108**			**105**	**100.0%**	**0.28 [0.01, 0.55]**	

Heterogeneity: Tau² = 0.00; Chi² = 1.00, df = 3 (P = 0.80); I² = 0%
Test for overall effect: Z = 2.02 (P = 0.04)

Favours control   Favours intervention

(b)

Study or Subgroup	Intervention			Control			Weight	Std. Mean Difference IV, Random, 95% CI	Std. Mean Difference IV, Random, 95% CI
	Mean	SD	Total	Mean	SD	Total			
Fritz 2013	-13.8	8.4	15	-15.5	12.9	13	19.1%	0.15 [-0.59, 0.90]	
Nilsagard 2013	-11.6	2.4	42	-11.2	2.1	42	57.7%	-0.18 [-0.60, 0.25]	
Prosperini 2013	-7.8	2.8	17	-8.7	3	17	23.2%	0.30 [-0.37, 0.98]	
Total (95% CI)			**74**			**72**	**100.0%**	**-0.00 [-0.33, 0.32]**	

Heterogeneity: Tau² = 0.00; Chi² = 1.58, df = 2 (P = 0.45); I² = 0%
Test for overall effect: Z = 0.01 (P = 0.99)

Favours control   Favours intervention

Fig. 5. Effect of computer-based intervention vs no therapy for people with a neurological condition. (a) SMD (95% CI) of effect of computer-based intervention vs no therapy on dynamic balance for people with a neurological condition. GRADE=High. GRADE working group grades of evidence. (b) SMD (95% CI) of effect of computer-based intervention vs no therapy on mobility for people with a neurological condition. GRADE=High. GRADE working group grades of evidence.

interventions resulted in no difference in improving balance, falls or mobility in people regardless of age or whether a health condition was present.

Overall, these results question the usefulness of the use of computerized feedback interventions in training balance for people at risk of falling. One explanation for the lack of effect may be because of the uni-dimensional nature of the intervention. Exercise prescription, particularly in the complex area of falls and balance rehabilitation, needs to be multi-faceted and specific to the needs of individuals. Balance is a multi-system function that relies on the interaction of tactile, proprioceptive, visual and vestibular feedback in order to maintain the body's centre of mass within the limits of our base of support during functional tasks (14, 15). It also relies on other factors, such as strength, pain, cognition and falls efficacy, to allow safe mobility (58, 59). Many of the devices included in this review predominantly focus on a single component of standing balance; the centre of pressure (18).

The results of this review may also be explained by the principle of specificity of practice; that is, the idea that you gain what you train (60, 61). Static and dynamic balance were the only outcomes that demonstrated improvement in our meta-analyses. Regardless of the type of device, their main objective is to improve balance. They do not necessarily provide a functional environment to improve other aspects of balance.

One interpretation of the results of this review is that it may not be the type of electronic device that is important, but more so the content of rehabilitation programmes that is most valuable in improving mobility and preventing falls. It appears that in this evolving world of technology, there may be too much focus on the marketing of these products

for rehabilitation, with clinicians getting caught up in their popularity and not considering the evidence base for applying their use for therapy sessions. It is possible that getting back to basics and using well-designed exercise programmes and physiotherapy interventions may be more clinically effective at improving balance, mobility and reducing falls than relying on uni-dimensional computer-based interventions.

Previous research has demonstrated that, in order for exercise to be effective at reducing falls risk, it must be sufficiently challenging to balance and of high intensity (7). At least 50 hours of balance training is required to reduce falls, which equates to a twice weekly programme over 25 weeks (62). Of the trials included in this review, only 1 of 30 trials achieved this recommendation (36). The importance of exercise intensity using virtual-reality has been reported elsewhere (16). It is also possible that the interventions included in this review did not provide sufficient challenge to balance or mobility, particularly as many of the devices are designed predominantly for entertainment purposes and not for the purpose of rehabilitation (10). Furthermore, physiotherapy interventions are often multi-faceted and include falls education and environment modification, which are also important aspects for reducing falls risk (6, 63).

Our primary analysis did not consider the importance of novelty and enjoyment of using these computerized balance devices. Often balance training can become repetitive and mundane, but using these electronic devices provides a new and potentially exciting modality for therapy. It has been reported that in older, healthy populations found using computerized training was easy and enjoyable (54, 64). Three other studies on a young, university population also found higher levels

of enjoyment in those who used the gaming device and subsequently found improved levels of adherence (49–51). This has important implications for adherence of balance exercise programmes in order to achieve the exercise dosage required for positive balance outcomes and maintaining these changes in clinical practice. A recent systematic review of the use of home-based virtual-reality and gaming systems demonstrated strong retention and adherence to these programmes (65). Despite this, the 3 trials in our review reporting adherence data reported no significant difference with the computerized intervention compared with physiotherapy (28, 47, 51).

The cost of purchasing these devices should also be considered when prescribing exercise for rehabilitation purposes. There is potential that their use may allow improved independence with therapy programmes and reduce need for therapist supervision, particularly in low-risk clients living in the community, as commercial gaming devices become more affordable and readily available. However, given the current lack of evidence to support the clinical advantages in using of computer-based devices for improving health outcomes compared with physiotherapy, a health economic analysis may be required.

Our findings are similar to that of previous reviews that focussed on a single intervention or single population (10, 16, 18). Our review added to the previous literature by including all computerized interventions that use feedback to potentially improve balance and did not limit the target population. Given the increasing frequency of use and development of this new technology, we were able to include 16 trials that have been published since 2011. This allowed us to conduct meta-analyses for our outcomes.

Our review followed PRISMA Guidelines (19, 20), which is the preferred reporting method for systematic reviews and meta-analysis. The GRADE approach (26) was also applied to the meta-analyses to help determine the level of confidence in the results for clinicians and policymakers. All of the studies included in the review were randomized controlled trials, which reduces risk of selection bias in increases confidence in our results.

Limitations

Limitations of this review include our search strategy, which did not include languages other than English and did not include all available databases. However, our search strategy was thorough as only 2 trials were identified with citation tracking. Another limitation is the quality of the available evidence. Much of the evidence in the meta-analyses was downgraded to low or moderate, due in part to the low-to-moderate quality of the individual trials in this review, as judged on the PEDro scale, and small sample sizes of the included trials contributing to relatively large confidence intervals around the estimated standardized mean differences. It should also be considered whether heterogeneity within subgroups of the meta-analysis as well as a variety of outcome measures that were used af-

fected the results of the meta-analyses. For example, patients with a variety of neurological diagnoses were combined in the meta-analyses. However, the findings of individual trials in our review were consistent with the results of the meta-analyses.

Conclusion

There is high-quality evidence from 4 trials that computer-based interventions that provide feedback improve dynamic balance in people with a neurological condition compared with no therapy. There is low-quality evidence from 3 trials that computer interventions improve postural sway in people with a vestibular condition and in people with type 2 diabetes. However, there is high- to low-quality evidence that demonstrates no significant benefits for mobility, falls and balance efficacy and falls risk when using computerized interventions that provide feedback in young or community-dwelling older people, or people with other health conditions. There is low-to-moderate-quality evidence that demonstrates no significant benefits for the use of computerized interventions over traditional physiotherapy. Given the complex and multifactorial nature of balance and falls, these results suggest that physiotherapy interventions should not be overlooked when considering the use of this emerging technology.

The authors declare no conflicts of interest.

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APPENDIX I. Example of search strategy: MEDLINE $n=210$

Search ID#	Search terms
S44	S35 AND S43
S43	S36 OR S37 OR S38 OR S39 OR S42
S42	(MH "Placebos")
S41	"(clinical adj trial$).tw"
S40	(MH "Multicenter Study")
S39	(MH "Clinical Trial") OR (MH "Clinical Trial, Phase I") OR (MH "Clinical Trial, Phase II") OR (MH "Clinical Trial, Phase III") OR (MH "Clinical Trial, Phase IV") OR (MH "Controlled Clinical Trial")
S38	(MH "Double-Blind Method") OR (MH "Single-Blind Method")
S37	(MH "Random Allocation") OR "random allocation"
S36	(MH "Randomized Controlled Trials as Topic") OR "Randomized Controlled Trials"
S35	S31 AND S34
S34	S30 OR S33
S33	(MH "Postural Balance") OR "postur* train* OR propriocept* train*"
S32	S30 AND S31
S31	S7 OR S8 OR S9 OR S10 OR S11 OR S12 OR S13 OR S14 OR S15 OR S16 OR S17 OR S19 OR S20 OR S21 OR S22 OR S29
S30	S1 OR S2 OR S3 OR S4 OR S5 OR S6 OR S23 OR S24 OR S25 OR S26 OR S27 OR S28
S29	"wii"
S28	"proprioceptive rehabilit*"
S27	"vestibular exerci*"
S26	"vestibular rehabilitat*"
S25	(MH "Therapeutic Exercise") OR "exercise therap*"
S24	(MH "Physical Therapy") OR "physical therap*"
S23	"physiotherap*"
S22	"equitest"
S21	"balance master"
S20	"e-rehabilitation"
S19	"telerehabilitat*"
S18	S7 OR S8 OR S9 OR S10 OR S11 OR S12 OR S13 OR S14 OR S15 OR S16 OR S17
S17	(MH "Computer Simulation") OR "computer simulation"
S16	(MH "Virtual Reality") OR "virtual realit"
S15	(MH "Information Technology") OR "information technology"
S14	"computer*"
S13	"video consol*"
S12	(MH "Video Games") OR "video gam*"
S11	"balance machin*"
S10	"balance platform*"
S9	"e-health"
S8	"e-technology"
S7	"electronic devic*" OR (MH "Games")
S6	"balance activit*"
S5	"balance program*"
S4	"balance rehabilitat*"
S3	"balance exerci*"
S2	"balance rehabilitat*"
S1	"balance train*"