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Visual-related training to improve balance and walking ability in older adults: a systematic review

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Abstract

Evidence has emerged about the use of visual-related training as an intervention to improve mobility that could implicate fall prevention in the older population. The objective of this systematic review was to investigate whether visual-related interventions are effective in improving balance and walking ability in healthy older adults. An electronic database search was conducted using Pubmed, Embase, CINAHL Plus, Web of Science, PsycINFO, and SportDiscus. Seventeen studies out of a total of 3,297 studies were identified in this review that met the inclusion criteria of (1) adopting a longitudinal design with at least one control comparison group, (2) targeting healthy older adults (age 60 or above), (3) primary focus targeting visual element, and (4) the primary outcome(s) are measures indicating walking and/or balance ability. Our results indicated that visual-related training generally led to improvements in balance and walking ability in healthy older adults. It seems necessary that visual-related training should at least involve mobility-related movement component(s), or form a part of a multi-component training to achieve a beneficial effect on balance and walking. The effectiveness and feasibility of these visual-related training in clinical practice for rehabilitation has been discussed and needs to be investigated in future studies.

(197/200)

***Keywords*:** visual training, balance, walking, older adults

1. Introduction

More than one out of four older adults falls at least once each year (Bergen et al., 2016), and this chance of falling doubles once they have fallen before (O'Loughlin et al., 1993). It is estimated that falls cost the healthcare system in the United States a total of more than $50 billion in 2015 (Florence et al., 2018). In a systematic review, Rubenstein and Josephson (2006) reported that gait and balance impairments are the second most common cause for falls in older adults. Literature has suggested that between 20% and 33% of the population reports difficulties with ambulation or balance (Lin and Bhattacharyya, 2012); problems that are mostly experienced and reported to physicians (Barin and Dodson, 2011).

Gait and balance disorders in older adults are generally exhibited as a compromised ability to maintain steady-state balance/walking particularly when executing another cognitive/motor tasks simultaneously, as well as a reduced capacity for reactive balance/walking when encountering standing or locomotor perturbations (Granacher et al., 2011, 2010). The above-mentioned events commonly occur during daily life (e.g., carrying a filled cup from the living room to the kitchen, standing on a moving bus while talking to somebody, etc.) and typically require sufficient balance control mechanisms. As such, deficits in steady-state and reactive balance ability has been frequently reported to increase the risk of falling in older adults (Beauchet et al., 2009; Pijnappels et al., 2005). Apart from falls and its consequential injuries, balance and mobility disorders can have other serious consequences in physical (e.g. impaired ability to perform daily living activities) and psycho-social functioning (e.g. fear of falls, social isolation, avoidance of activity) (Zijlstra et al., 2010).

The impairments in gait and balance could be contributed by multiple factors, including underlying medical conditions (e.g., stroke, neurological disease, diabetes, vestibular deficit, etc.) and/or age-related processes, such as declined muscle strength (Moreland et al., 2004), sensorimotor responses (Bugnariu and Fung, 2007), sensory functioning (Shaffer and Harrison, 2007), or visual capacity (Berard et al., 2009). While efficient locomotion and postural control are achieved through a well-coordinated integration of visual, proprioceptive, vestibular, and other sensorimotor feedback (Lord, 2006; O’Connor and Kuo, 2009), Patla specifically argued that visual information largely governs such process (Patla, 1998, 1997, 1991). It has been suggested that visuospatial input is imperative for proactive planning and adjustments to maintain stability in dynamic and complex environment (e.g., different surfaces, change of route to the destinations) and allows preventative regulation of movement patterns that ensure safe locomotion and postural control (Patla, 1997, 1991).

Previous research has indicated that altered visual inputs tend to influence older adults at a greater extent than young adults (Hay et al., 1996; Pyykkö et al., 1990), and older adults have greater reliance on visual feedback for regulating balance control during gait (Berard et al., 2012; Franz et al., 2015). In addition, an earlier systematic review synthesized evidence showing that older adults, particularly those with high risk of falling, exhibited certain visual patterns that reflect reduced capacity to use online visual information than young adults when encountering unanticipated threats to stability during locomotion (Uiga et al., 2015). Taken together, age-related changes in visual capacity and/or processing function, specifically referring to the poorer perceptions of dynamic visual stimuli and the difficulty in incorporating multi-sensory information during complex motor tasks, may therefore contribute partly to the increase in falls in the aging population through coordination failure in gait and postural control (Berard et al., 2009; Lord, 2006). The impact of impaired visual processing to falls in older adults thus emphasizes a need to develop effective visual-related techniques or interventions to improve gait and balance ability in the population.

Visual-related training on balance and walking

One of the plausible visual-related techniques to improve gait and postural control is training with the use of visual feedback. Visual feedback is a noninvasive method that applies monitoring instruments to provide feedback to patients based on their physiologic responses, allowing them to acquire a sense of self-reliance in their ability to adjust these responses. This training method has previously been applied in stroke patients (Walker et al., 2000), frail older people living in residential homes (Sihvonen et al., 2004a), and healthy community-dwelling older adults (Lajoie, 2004). Sensorimotor integration could be enhanced by visual feedback training through a recalibration of the sensory systems that contribute to controlling balance (Hu and Woollacott, 1994). Given that individuals seem to have greater reliance on exteroceptive information and prioritize vision for postural control as they age (Redfern et al., 2001), visual feedback training may facilitate balance through increasing the awareness of body motions with reference to the external environment (Shea and Wulf, 1999).

Apart from visual feedback training, there is a growing body of aging research exploring the effectiveness of other innovative interventions that involve visual components to improve gait and balance ability. For instance, a previous study attempted to intentionally modify older adults' visual strategy during adaptive locomotion to gaze patterns that are closely similar to that in young adults through instructional intervention (Young and Hollands, 2010). This change in visual strategy in older adults has effectively led to improvement in stepping precision and accuracy when walking in complex environment and might reduce the incidence of falls in older adults. Another study by Althomali et al. (2019) was designed to train older adults with a structured visual attention task, based on the empirical evidence showing that visual attention in relation to the useful field of view was a good predictor of gait and balance performance in older adults (Owsley and McGwin, 2004). Visual attention is considered as the cognitive ability to pick relevant information while neglecting irrelevant details in a cluttered visual environment (Binder et al. 2009). However, this visual intervention program did not yield any improvements in balance and mobility among community-dwelling older adults.

Despite the emerging existence of studies attempting to support the use of visual components in training gait and balance, exhaustive investigations on the effectiveness of visual-related interventions in older adults have not been conducted yet. A recent systematic review with a similar scope included five relevant randomized controlled trials that examined whether biofeedback training, specifically relevant to video games, visual, augmented and virtual reality, is effective in improving balance in healthy older population (Alhasan et al., 2017). A total number of 181 participants were included. Outcome measures were any validated balance measures designed to measure static and dynamic balance in the older population. The majority of the included studies were rated as fair quality in the quality assessment. They concluded that these types of biofeedback training generally showed better outcomes in balance ability in healthy older adults against no intervention or traditional exercises. Yet, a conclusive statement can hardly be informed about the potential utilization of biofeedback training due to the great variation between studies in terms of intervention protocol, quality of methodology, and outcome measurements. Due to fast growing technologies, there are also existing systematic reviews that synthesize evidence regarding the application of exegaming (i.e., exercised-based computer games) and virtual reality training in improving balance and/or gait in the older population (Cano Porras et al., 2018; Fang et al., 2020). Unfortunately, these reviews have primarily focused on the domain of video games and virtual reality but lacked the synthesis of existing interventions with distinct visual or gaze manipulations.

There is unclear evidence with regard to the use of visual-related training as an intervention to improve mobility that could implicate fall prevention in older adults. While no systematic review has yet been conducted to summarize such evidence, the aim of the current review was therefore to investigate the training effects of visual-related interventions focusing on balance and walking ability for healthy older adults. Considering the high prevalence of falls in older adults, the findings of this review could have a significant implication on developing tailored fall-prevention or rehabilitative interventions with appropriate visual components that might be used to improve/maintain mobility in older adults, particularly during complex daily living situations.

2. Methods

The protocol for this review was previously registered with the International Prospective Register of Systematic Reviews (PROSPERO) (Registration ID: CRD42021251686).

2.1. Data Sources and Searches

An electronic search for relevant studies was conducted in the following databases: Pubmed (1985-present), Embase (1983-present), CINAHL Plus (1988-present), Web of Science (1991-present), PsycINFO (1986-present), and SportDiscus (1987-present). The search was performed on April 2021, using the following search strategy and key terms: (gaze OR visual OR vision OR “eye movement”) AND (gait OR walk* OR locomotion OR balanc* OR postur* OR mobility) AND (intervention OR training* OR program*) AND (old* OR older* OR “advanced age” OR senior* OR elder* OR geriatr* OR aging OR aged OR ageing).

2.2. Selection Criteria

The following inclusion criteria have been used: (1) the reported interventions adopt a longitudinal study design (pre-post) with at least one control group (or usual care, placebo, traditional exercises, etc.) for comparison; (2) the reported interventions target healthy older adults (age 60 or above) without any underlying medical conditions - e.g., those with poorer balance, movement difficulties, a higher risk of falling, a history of falls, etc. are included; (3)

the primary focus of the reported interventions should be about visual element (e.g., visual feedback, perception, attention, gaze exercise, etc.); and (4) the primary outcome(s) should be measures that indicate walking or balance ability. Studies were excluded if (1) the reported interventions adopt virtual reality or exergaming types of approach, (2) the reported interventions target participants with any brain injuries or cognitive impairments, or any major neurological, vestibular or musculoskeletal disorder, or chronic illnesses, (3) the primary focus targets clinical treatment or surgery to improve eye function, (4) they were published in a language other than English, (5) they were review papers, and (6) they were unpublished materials (e.g., dissertations and theses) or not peer-reviewed. **Table 1** describes the PICO (Population, Intervention, Comparison, Outcome) used for this review. The process of article selection was performed by two independent reviewers (TCTM and TWLW) and was based on the flow diagram of the Preferred Reporting of Items for Systematic Reviews and Meta-Analyses (PRISMA) Statement (Moher et al., 2009) (see **Figure 1**). The titles and abstracts of the results searched from the database were screened independently by the two reviewers. If the titles or the abstracts were deemed to be relevant, or if it was unclear whether they were relevant after reading the abstract, the full-text articles were retrieved and examined against the inclusion and exclusion criteria. Discussions were conducted when there was any disagreement between the reviewers until a consensus was reached. The reference lists of the selected articles were also screened to identify additional potential articles.

Table 1 near here

Figure 1 near here

2.3. Quality Assessment and Data Extraction

Cochrane Collaboration tool for assessing risk of bias (CCTARB) was used to assess the quality and the risk of bias in the included studies (Higgins et al., 2011). Six domains of bias are covered by this tool, namely selection bias, performance bias, detection bias, attrition bias, reporting bias, and other bias. Due to the difficulty of blinding the participants and researchers in all visual-related interventions, the ‘blinding of personnel and participants’ within the performance bias domain will not be considered as one of the key domains. Two reviewers (TCTM & TWLW) independently scored the methodological quality of the selected studies. Any disagreements were discussed between the reviewers until consensus was reached.

Data on participant selection and characteristics, type of visual-related intervention, frequency and duration of the intervention, variables and measurement, and findings and conclusions was extracted. **Table 2** provides a summary of all included studies, including authors, year of publication, participant characteristics, type and details of intervention, balance and/or gait-related outcome measurement, and conclusion. Data extraction was performed by one reviewer (TCTM), and the accuracy of extraction was verified by a second reviewer (TWLW).

Table 2 near here

3. Results

The electronic search strategy generated a total of 3,297 relevant articles. After removing 1,807 duplicates from different databases, 1,491 articles were screened based upon the titles and abstracts. A total of 1,458 articles were excluded for failing to meet the inclusion criteria, yielding 33 articles for full-text examination with respect to the objectives of the systematic review. A review of these full-text articles excluded a number of papers that were irrelevant to our research question, experimental design, or outcome of interest. For instance, we excluded cross-sectional studies, studies with primary outcomes not related to walking/balance ability, studies that were related to virtual reality or exergaming, and studies with interventions that mixed with other components (e.g., balance) but did not isolate the effect of visual components by means of the control groups. The final review identified 17 eligible studies that were relevant and suitable for this systematic review. Reference lists were also examined for other related studies that may have been missed by the electronic search. The process of selecting the studies in this systematic review is illustrated in **Figure 1**.

3.1. Quality assessment

Table 3 summarizes the assessment of risk of bias across all the included studies.

Table 3 near here

3.1.1. Random sequence generation

Ten studies had a low risk of bias as they reported a random component in the sequence generation process (e.g., computer generated random numbers) (Althomali et al., 2019; Anson et al., 2018; Bhardwaj and Vats, 2014; Hagedorn and Holm, 2010; Li et al., 2016; Oungphalachai and Siriphorn, 2020; Schwenk et al., 2014; Sihvonen et al., 2004a, 2004b; Sunny and Bhat, 2017). The remaining seven studies had an unclear risk of bias since the information about sequence generation process or the procedure of randomization was not reported (Buccello-Stout et al., 2008; Hatzitaki et al., 2009a, 2009b; Piao et al., 2009; Sairam et al., 2019; Yamada et al., 2013; Young and Hollands, 2010).

3.1.2. Allocation concealment

Four studies had a low risk of bias as the concealment procedures were clearly described (Althomali et al., 2019; Oungphalachai and Siriphorn, 2020; Schwenk et al., 2014; Sunny and Bhat, 2017). All of the remaining 13 studies had an unclear risk of bias as the method of allocation concealment was not reported (Anson et al., 2018; Bhardwaj and Vats, 2014; Buccello-Stout et al., 2008; Hagedorn and Holm, 2010; Hatzitaki et al., 2009a, 2009b; Li et al., 2016; Piao et al., 2009; Sairam et al., 2019; Sihvonen et al., 2004a, 2004b; Yamada et al., 2013; Young and Hollands, 2010)

3.1.3. Blinding of participants and personnel

All studies had an unclear risk of bias as they either reported blinding only the research personnel or participants (Anson et al., 2018; Bhardwaj and Vats, 2014; Schwenk et al., 2014; Sunny and Bhat, 2017), or did not report any blinding information (Althomali et al., 2019; Buccello-Stout et al., 2008; Hagedorn and Holm, 2010; Hatzitaki et al., 2009a, 2009b; Li et al., 2016; Oungphalachai and Siriphorn, 2020; Piao et al., 2009; Sairam et al., 2019; Sihvonen et al., 2004a, 2004b; Yamada et al., 2013; Young and Hollands, 2010). Yet, as stated earlier, this domain was not deemed one of the key domains.

3.1.4. Blinding of outcome assessment

Four studies had a low risk of bias as they explicitly reported blinding of outcome assessors (Althomali et al., 2019; Anson et al., 2018; Oungphalachai and Siriphorn, 2020; Yamada et al., 2013). The remaining 13 studies did not report such information (Bhardwaj and Vats, 2014; Buccello-Stout et al., 2008; Hagedorn and Holm, 2010; Hatzitaki et al., 2009a, 2009b; Li et al., 2016; Piao et al., 2009; Sairam et al., 2019; Schwenk et al., 2014; Sihvonen et al., 2004a, 2004b; Sunny and Bhat, 2017; Young and Hollands, 2010). Yet, we still deem they had a low risk of bias since the outcome measurement was not likely to be affected by the lack of blinding; all of the targeted outcomes are derived from objective instrumental and/or functional measurements such as postural sway, gait parameters, task completion time, etc.

3.1.5. Incomplete outcome data

One study had an unclear risk of bias as it did not provide reason(s) for missing data (Yamada et al., 2013). All of the remaining studies had a low risk of bias as either no missing data were reported, similar reasons for missing data across groups, or appropriate methods had been used to handle missing data (Althomali et al., 2019; Anson et al., 2018; Bhardwaj and Vats, 2014; Buccello-Stout et al., 2008; Hagedorn and Holm, 2010; Hatzitaki et al., 2009a, 2009b; Li et al., 2016; Oungphalachai and Siriphorn, 2020; Piao et al., 2009; Sairam et al., 2019; Schwenk et al., 2014; Sihvonen et al., 2004a, 2004b; Sunny and Bhat, 2017; Young and Hollands, 2010).

3.1.6. Selective reporting

Four studies had a low risk of bias as they followed a pre-registered protocol (Althomali et al., 2019; Oungphalachai and Siriphorn, 2020; Schwenk et al., 2014; Yamada et al., 2013). One study had a high risk of bias as its reported primary outcomes did not entirely match with its pre-specified primary outcomes (Anson et al., 2018). The remaining 12 studies had an unclear risk of bias as there was insufficient information to make a judgment (Bhardwaj and Vats, 2014; Buccello-Stout et al., 2008; Hagedorn and Holm, 2010; Hatzitaki et al., 2009a, 2009b; Li et al., 2016; Piao et al., 2009; Sairam et al., 2019; Sihvonen et al., 2004a, 2004b; Sunny and Bhat, 2017; Young and Hollands, 2010).

3.1.7. Other bias

All studies had a low risk of bias as they appear to be free of other sources of bias.

3.2. Characteristics of included studies

3.2.1. Cohort characteristics

The samples of all 17 included studies ranged from 16 to 264 participants. The total number of participants was 816, with a mean age of 74.3 years (SD 6.3). One study only provided the age range of their sample but did not specify the overall mean age of participants or that for each group (Sairam et al., 2019).

Most studies included both genders, with a generally higher proportion of female participants. One study did not provide any information on the gender of their participants (Young and Hollands, 2010). Four studies exclusively used female participants (Hatzitaki et al., 2009a, 2009b; Sihvonen et al., 2004a, 2004b).

All studies included healthy older adult participants with normal cognitive function and without any neurological, and/or cardiovascular impairment, or other underlying medical conditions limiting their daily functions. Six studies included healthy participants with documented or self-reported balance and/or mobility difficulties (Althomali et al., 2019; Anson et al., 2018; Bhardwaj and Vats 2014; Hagedorn and Holm, 2010; Sairam et al., 2019; Schwenk et al., 2014), while nine studies included healthy participants with a history of falls (Althomali et al., 2019; Anson et al., 2018; Buccello-Stout et al., 2008; Hagedorn and Holm, 2010; Schwenk et al., 2014; Sihvonen et al. 2004a, 2004b; Yamada et al., 2013; Young and Hollands, 2010).

Four studies were conducted in North America (i.e., Canada, and the US) (Althomali et al., 2019; Anson et al., 2018; Buccello-Stout et al., 2008; Schwenk et al., 2014), while seven of them were from Asia (i.e., India, China, Thailand, and Japan) (Bhardwaj and Vats, 2014; Li et al., 2016; Oungphalachai and Siriphorn, 2020; Piao et al., 2009; Sairam et al., 2019; Sunny and Bhat, 2017; Yamada et al., 2013), and the remaining six of them were from Europe (i.e., the UK, Finland, Greece, and Denmark) (Hagedorn and Holm, 2010; Hatzitaki et al., 2009a, 2009b; Sihvonen et al., 2004a, 2004b; Young and Hollands, 2010).

3.2.2. Intervention characteristics

Ten of the included studies adopted visual feedback methods for training balance and/or walking ability (Anson et al., 2018; Hagedorn and Holm, 2010; Hatzitaki et al., 2009a, 2009b; Li et al., 2016; Oungphalachai and Siriphorn, 2020; Piao et al., 2009; Schwenk et al., 2014; Sihvonen et al., 2004a, 2004b). These visual feedback interventions mainly used computer screens to display feedbacks on participants' body motion, positions, lower limb force vector, centre of gravity, or centre of pressure etc. during balance or walking training sessions. While the remaining eight included studies adopted different type of visual-related intervention, four of them implemented it during balancing or walking (Bhardwaj and Vats, 2014; Buccello-Stout et al., 2008; Sunny and Bhat, 2017; Yamada et al., 2013) and three of them implemented it without performing any mobility-related movements (Althomali et al., 2019; Sairam et al., 2019; Young and Hollands, 2010). These visual-related interventions include training visual attention (Althomali et al., 2019), gaze stability (Bhardwaj and Vats, 2014; Sairam et al., 2019), sensorimotor adaptation (Buccello-Stout et al., 2008), and providing visual cues (Sunny and Bhat, 2017; Yamada et al., 2013), and visual sampling demonstration video (Young and Hollands, 2010).

The duration of visual-related interventions ranged from 2 weeks to 6 months. The frequency of sessions ranged from twice per week to 3 times daily. The length of treatment session ranged from 10 minutes to 90 minutes. Young and Hollands (2010) was the exception that reported two sessions in separate days as their intervention.

3.3. Outcome measures

Among the 17 included studies, three of them exclusively used instrumented measurement of postural sway as their outcome measure for balance (Hatzitaki et al., 2009a, 2009b; Piao et al., 2009) while five of them exclusively used functional measurement as outcome measures to represent balance and/or gait-related ability (Anson et al., 2018; Bhardwaj and Vats, 2014;

Hagedorn and Holm, 2010; Sairam et al., 2019; Sunny and Bhat, 2017). Two of them exclusively used outcome measures that represented walking and stepping performance under complex environment (Buccello-Stout et al., 2008; Young and Hollands, 2010). The remaining seven included studies used both instrumented and functional measurements as outcome measures to represent balance and/or gait-related ability (Althomali et al., 2019; Li et al., 2016; Oungphalachai and Siriphorn, 2020; Schwenk et al., 2014; Sihvonen et al., 2004a, 2004b; Yamada et al., 2013).

Instrumented measures for balance typically included medial-lateral (ML) and anterior–posterior (AP) sway in terms of maximum amplitude, velocity, path length, and area of the body (e.g., centre of pressure (CoP) / centre of gravity (CoG) / centre of mass (CoM)), trunk, hip and/or ankle. Functional measures for balance typically referred to Berg Balance Scale (BBS), Balance Evaluation System’s Test (BESTest), Mini-Balance Evaluation System’s Test (Mini-BESTest), One-Legged Stance test (OLST), Functional Reach (FR), and Fullerton Advanced Balance scale (FAB). Gait-related measures typically included temporal gait parameters, gait velocity, foot placement error and variability, and time to complete obstacle courses, whereas its functional measures typically referred to 6-minute walk test, 10-m walking test, Timed Up and Go test (TUG), and Dynamic Gait Index (DGI).

3.4. Training effects

In this current review, all but one studies showed that visual-related interventions effectively improve balance and/or walking ability in healthy older adults (Anson et al., 2018; Bhardwaj and Vats, 2014; Buccello-Stout et al., 2008; Hagedorn and Holm, 2010; Hatzitaki et al., 2009a, 2009b; Li et al., 2016; Oungphalachai and Siriphorn, 2020; Piao et al., 2009; Sairam et al., 2019; Schwenk et al., 2014; Sihvonen et al., 2004a, 2004b; Sunny and Bhat, 2017; Yamada et al., 2013; Young and Hollands, 2010).

Visual-related training on balance and walking

Eight studies compared visual-related intervention to no intervention (i.e., continue their everyday activities as usual) (Althomali et al., 2019; Hatzitaki et al., 2009a, 2009b; Oungphalachai and Siriphorn, 2020; Piao et al., 2009; Schwenk et al., 2014; Sihvonen et al., 2004a, 2004b). Oungphalachai and Siriphorn (2020), Piao et al. (2009), and Schwenk et al. (2014) collectively found that visual feedback balance training significantly improves postural control ability, namely static and dynamic balance that was performed by standing on a force plate and shifting the body towards different directional targets respectively (indicated by e.g., CoP and CoM sway velocity, path, and area), and functional performance (indicated by e.g., FAB, BBS). Sihvonen et al. (2004a, 2004b) also found that visual feedback balance training significantly improves static, dynamic, and functional balance specifically in frail older women. Hatzitaki et al. (2009a, 2009b) compared visual feedback balance training among medial-lateral (ML), anterior–posterior (AP) directional weight shifting regimens and no intervention. They discovered that visually induced weight shifting training in the AP direction improves static balance while training in the ML direction seems to be more efficient in postural adjustments during avoidance of obstacle in older women. Only one study did not reported any significant improvement in any of the functional mobility and instrumented balance measures following visual attention training (Althomali et al., 2019).

Three studies compared visual-related intervention to a ‘placebo’ intervention (Anson et al., 2018; Bhardwaj and Vats, 2014; Buccello-Stout et al., 2008). Anson et al. (2018) compared walking training with and without visual feedback (placebo) on trunk motion and discovered that the visual feedback intervention significantly improves over-ground dynamic balance. Bhardwaj and Vats (2014) compared gaze stability exercise with and without visual targets (placebo) and discovered that the intervention significantly improves functional balance. Buccello-Stout et al. (2008) compared viewing rotating and static virtual scene (placebo) and discovered that the intervention significantly improves mobility and balance under challenging environment.

Five studies compared the combination of visual-related intervention and physical training with physical training only (Hagedorn and Holm, 2010; Li et al., 2016; Sairam et al., 2019; Sunny and Bhat, 2017; Yamada et al., 2013). Hagedorn and Holm (2010), Li et al. (2016), and Sairam et al. (2019) combined visual-related training with balance exercises as the intervention. Sunny and Bhat (2017) combined visual-related training with balance and walking exercise while Yamada et al. (2013) combined visual-related training with multicomponent physical exercise as the intervention. All five studies observed significant improvement in static balance, functional balance, functional gait and mobility, and walking endurance following visual-related intervention combined with physical training. One study compared the combination of visual-related intervention and visual-unrelated element with visual-unrelated element (Young and Hollands, 2010). They discovered that the intervention altered gaze behavior and leads to a significant improvement in stepping accuracy during adaptive locomotion.

4. Discussion

The current systematic review represents the first overview of available intervention studies that targeted visual-related training on mobility that implicates fall prevention in healthy older adults. We focused on existing interventions that implemented distinct visual elements (instead of exergaming and virtual reality type of components) and examined whether they demonstrated a beneficial effect on balance and walking ability (including any instrumental and/or functional measures). After an extensive literature search, 17 studies published between 2004 and 2020 were identified as relevant to our research topic and included in this review. Overall, a vast majority of the included studies (94%) reported that visual-related training significantly improved balance and/or walking ability compared to no intervention or a control/placebo group. The current findings add to the emerging evidence suggesting that visual-related intervention may likely benefit healthy older adults by improving their balance and/or walking ability and could be an important tool for fall rehabilitation.

4.1. The effect of visual feedback interventions

All 10 included studies that used visual feedback training during balance or walking tasks have shown significantly positive results on balance and/or walking ability (Anson et al., 2018; Hagedorn and Holm, 2010; Hatzitaki et al., 2009a, 2009b; Li et al., 2016; Oungphalachai and Siriphorn, 2020; Piao et al., 2009; Schwenk et al., 2014; Sihvonen et al., 2004a, 2004b). These studies generally displayed visual feedbacks of participants' body motion, positions, lower limb force vector, centre of gravity, or centre of pressure, etc. on computer monitors. Most of them focused on improving balance ability while the improvement in walking ability has been shown in three of these studies (Hagedorn and Holm, 2010; Li et al., 2016; Schwenk et al., 2014). This finding is largely in line with previous systematic review by Zijlstra et al. (2010), in which they have identified positive effects for balance training tasks on a force/pressure platform that displays visual feedback among different cohorts of older adults (without a specific medical problem). While the theory of motor learning has highlighted the role of feedback when learning various motor skills, previous studies have demonstrated the significance of vision to produce effective movement and postural responses (Hu and Woollacott, 1994; Rose and Clark, 2000).

The current review adds support to the perspective that enhanced visual information on where and how the center of pressure is situated and moved during different tasks serves as a tool to facilitate volitional postural control and balance skills. As such, individuals can potentially improve their ability to manipulate other sensory information and adopt more effective postural strategies (Sihvonen et al., 2004a). In addition, visual feedback is typically implemented for fine-tuning biomechanical controls, comparing movements with motor inaccuracies, executing the proper movement, and building body experience and postural control technique (Oungphalachai and Siriphorn, 2020). As evidenced by Hatzitaki et al. (2009b) and Schwenk et al. (2014), participants preferred to utilize visual information for controlling stability and were able to adjust their movement properly during visual feedback training.

It is also important to note that a lack of visual feedback training effects were found when testing in less demanding standing positions in the studies by Hagedorn and Holm (2010) and Sihvonen et al. (2004a). This suggests that assessments presenting no challenge to postural control may be insensitive for changes in balance ability. These findings are consistent with previous studies (Judge et al., 1993; Lichtenstein et al., 1989), where body sway measurements under simple standing posture have not shown substantial alterations after interventions. Moreover, the specificity of the training effect should also be taken into consideration. The limited training effect in the static balance assessments observed in Hagedorn and Holm (2010) and Sihvonen et al. (2004a), compared to a clear improvement in training results of dynamic balance and computer-based performances in the intervention groups, might be indicative of how specific the visual feedback training effects are. These findings were supported by earlier work suggesting that the balance training effects were attributed to task-specific skills (Giboin et al., 2015; Hubbard et al., 2009; Seo et al., 2014).

4.2. Interventions with other visual components

When looking at interventions with other distinct visual elements in the current review, gaze stability (Bhardwaj and Vats, 2014; Sairam et al., 2019), sensorimotor adaptation (Buccello-Stout et al., 2008), visual cue (Sunny and Bhat, 2017; Yamada et al., 2013), and visual sampling training (Young and Hollands, 2010) have been shown as effective ways to improve balance and/or walking ability in older adults. Only visual attention intervention did not produce significantly positive results in balance or walking ability after structured training sessions (Althomali et al., 2019).

4.2.1. Gaze stability

Gaze stability training refers to an exercise where individuals have to execute active, quick head rotations while viewing a visual target, under a constraint that the target stays in focus throughout the head movements. It has been argued that gaze stability training as an adaptation exercise can stimulate and alter the magnitude of vestibulo-ocular reflex; an essential element involved in the aging process where its degeneration is the major consequence of natural aging of the vestibular system (Iwasaki and Yamasoba, 2014). Both studies that investigated gaze stability training have illustrated the effectiveness of gaze stability exercises as a therapeutic approach for the vestibular system to improve functional balance in healthy older adults (Bhardwaj and Vats, 2014; Sairam et al., 2019).

4.2.2. Sensorimotor adaptation

In addition to the vestibular system, training the adaptation of the perceptual-motor systems in the study of Buccello-Stout et al. (2008) has also been shown to improve locomotor performance in a challenging environment. Individuals in their study were visually trained under a perceptual-motor mismatch condition between biomechanical movements and visual information received from the environment (i.e., walking straight on a treadmill while viewing a rotating virtual scene as continuous self-motion being the same as walking along the boundary of a room).

4.2.3. Visual cue

Older adults who are more susceptible to falls often exhibit maladaptive gaze behavior that further implicates inaccuracy in foot placements (Ellmers et al., 2020). For example, they tend to prioritize the upcoming steps over the precise placement of ongoing steps which may result in falls and trips especially in a cluttered environment. To address such issue, Sunny and Bhat (2017) and Yamada et al. (2013) implemented visual cue technique into training balance and walking in healthy older individuals. Both studies provided colored markings (e.g., lines, squares) on the floor to facilitate participants' steps during walking training. Sunny and Bhat (2017) showed that visual cue training improves functional balance and gait while Yamada et al. (2013) demonstrated improvements in stepping accuracy, walking ability, and functional mobility in a complex environment. It has been suggested that visual cues are extrinsic feedback mechanisms used to facilitate motor learning and aid in optimizing gaze behaviour that could minimize fall risks (Sunny and Bhat, 2017). Considering that gaze is mechanistic in guiding the control of foot placements (Hollands et al., 2015), these findings has indicated that visual cues can be an effective treatment paradigm in eliciting adjustments in the control of walking when adapting to the environment in the healthy older population (Bank et al., 2011).

4.2.4. Visual sampling

Another study by Young and Hollands (2010) investigated whether suboptimal gaze behaviour and its associated stepping performance can be improved through an intervention where older adults were instructed to alter their visual sampling pattern to the way that closely resembles the gaze behavior of young adults. Their results suggested that after training older adults to maintain their gaze on every stepping target until heel contact was landed within it, significantly less stepping errors were observed in conjunction with the anticipated improvement in gaze behavior during adaptive locomotion. They proposed that the improvement in stepping performance can be partly attributed to the enhanced planning during late stance and/or the opportunity to make online visually guided adjustments to foot trajectories or body posture during swing.

4.2.5. Visual attention

The only intervention that did not produce significantly positive results in this review involved purely visual attention training in which participants had to perform a series of attention tasks requiring them to visually identify certain targets on a monitor with the useful field of view and the attended field of view (Althomali et al., 2019). Although previous literature has discovered that visual attention (as evaluated by the useful field of view) was a good predictor of balance and walking ability for community-dwelling older adults (Owsley and McGwin, 2004), the current findings provide evidence indicating that training visual attention alone is not effective for improving balance or walking ability in this population.

It is reasonable to suggest that this insignificant result might be explained by the lack of involvement of physical movements in the training modality. In our systematic review, there are two other studies that implemented visual components without performing any mobility-related movements (Sairam et al., 2019; Young and Hollands, 2010). However, the intervention group in Sairam et al. (2019) received gaze stability exercises together with conventional balance exercises while Young and Hollands (2010) provided visual sampling videos in which the content was closely related to the walking motion in the same environmental condition. As such, it is possible that visual attention, or visual-related training in general, may be effective when implemented in combination with a physical movement component, or as a part of a multi-component training in healthy older adults, as opposed to designing training tasks that are irrelevant to any mobility-related movements.

4.3. Clinical implications

When considering the implications for clinical practice on developing tailored fall-prevention or rehabilitative interventions, training static and dynamic balance with visual feedback is suggested to be one of the more common and effective methods to improve mobility, given that monitoring equipment are available. It is important to note that such training effects will be more likely attributed to task-specific skills, implying that one should consider specific design of balance training tasks that is closely related to dynamic posture or functional movements that resemble daily living challenges so as to better prepare patients to adapt to more complex real-life situations.

While most of these visual feedback interventions require costly and customized technical devices for measuring and displaying feedbacks during training period, the current systematic review also identified several visual-related training modalities that could be relatively cost-effective and more feasible to apply in clinical settings that prefer simpler set-up. For example, one should consider providing gaze stability exercises if clinicians in geriatric practice mainly focuses on the improvement of functional balance. The use of visual cues, stepping programs, and visual sampling demonstrations are effective approaches if clinicians are designing training methods that mainly target the improvement of patients' stepping accuracy and functional gait. These methods typically require inexpensive equipment and do not necessarily have to be conducted in a laboratory setting. Nevertheless, to be able to apply experimental findings to geriatric practice, future studies are still warranted to identify the most beneficial visual-related interventions or optimal clinical practice recommendations that improves balance and mobility in order to address the sprouting public health issue of falls in older people.

4.4. Limitations and future directions

One of the limitations for this review, despite the systematic approach, is that some potential sources of bias, such as publication bias, may have affected the results of this review as positive, statistically significant results tend to be more frequently reported and published. In addition, there are likely to be studies beyond the published literature database that the present review may have overlooked. Another limitation is that a quantitative statistical data pooling of different studies was not possible due to the heterogeneous methodologies and study characteristics of the reviewed articles. In addition, it is important to consider whether the physical function of participants could have an influence in the training effects of visual-related interventions. Although all participants were regarded as healthy (i.e., without underlying medical conditions) in the current review, participants from some of the studies were reported to have documented balance and mobility problems, history of falls, or self-reported balance difficulties. Yet, the variety and the lack of clear and detailed reporting/defining of the abovementioned characteristics by some of these studies makes it difficult to allow subgroup analysis and generate a definite conclusion of how different and specific these effects might be when compared to cohorts without these characteristics.

There appears to be a lack of conclusive evidence for an optimum amount of duration and frequency of effective interventions. Studies in the current review delivered training sessions with a duration varying from 2 weeks to as long as 6 months and a frequency of twice per week to as frequent as 3 times daily, from 10 to 90 minutes per session. These aspects of the training protocol should be investigated and addressed in future clinical trials to allow more robust and standardized practice recommendations. Future training interventions should also consider performing long-term follow-up assessments (e.g., 6-month to 1-year follow-up after the end of intervention) as current studies do not yet provide strong indications regarding the long-term retention benefit of visual-related interventions for balance and mobility in the older populations. The moderate quality of most of the reviewed studies also emphasizes a need for future studies to report allocation concealment of participants in their groups and detailed information on blinding of the research personnel. After reviewing the effects of visual-related interventions on healthy older adults without underlying medical conditions, it is recommended for future reviews to examine and compare the effectiveness and feasibility of visual-related interventions on different clinical populations, such as post-stroke patients, patients with Parkinson’s disease, diabetes, hypertension, etc., providing that there are sufficient studies available in the literature for systematic evaluation in the future.

5. Conclusions

Significant improvements on balance and/or walking ability have been shown in healthy older adults after visual-related training. Results have indicated that visual-related training may be effective when incorporated with a physical movement component, or as a part of a multi-component training rather than general visual tasks that are independent from mobility-related movements. While visual feedback technique has been proven to be effective, adopting training with other visual components such as gaze stability exercises and visual cue programs seems to be more feasible for clinical application in the community where costly and customized technical equipment is not necessary to perform adequate training sessions. Due to the variation in intervention protocols, methodologies, and outcomes between the reviewed studies, further intervention studies are still warranted to inform definitive statements regarding the potential application and effectiveness of visual-related training particularly on mobility measures in older adults with different rehabilitation needs.

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Declaration of Interest

There are no conflicts of interest for any authors to report.

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Figure captions

Figure 1 Preferred Reporting Items in Systematic Reviews (PRISMA) Flow Diagram for Selecting the Studies.

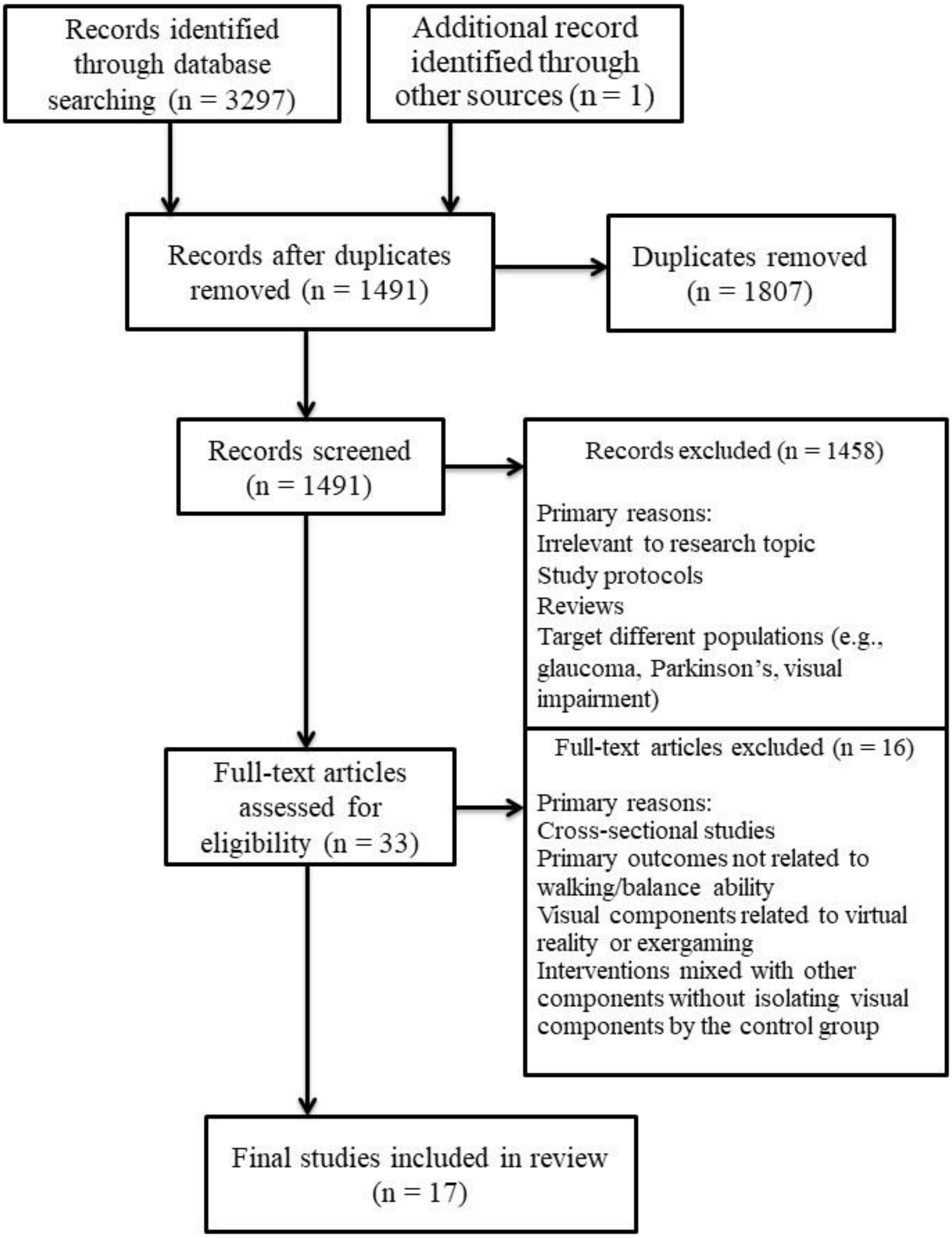
Records identified through database searching (n = 3297)
Additional record identified through other sources (n = 1)
Records after duplicates removed (n = 1491)
Duplicates removed (n = 1807)
Records screened (n = 1491)
Records excluded (n = 1458)
Primary reasons:
Irrelevant to research topic
Study protocols
Reviews
Target different populations (e.g., glaucoma, Parkinson's, visual impairment)
Full-text articles assessed for eligibility (n = 33)
Full-text articles excluded (n = 16)
Primary reasons:
Cross-sectional studies
Primary outcomes not related to walking/balance ability
Visual components related to virtual reality or exergaming
Interventions mixed with other components without isolating visual components by the control group
Final studies included in review (n = 17)

Figure 1.

Table 1. The Framework of PICO.

P: Population	Healthy older adults aged 60 years or above, with no specific disorders or health conditions
I: Intervention	Visual-related training with the aim of improving walking or balance
C: Comparison	No intervention, usual care, placebo, or traditional exercises
O: Outcomes	Objective measures indicating walking or balance ability

Table 2. Summary of included studies.

Study (Authors, year, and country)	**Population (n) Mean age ± SD (years)**	**Intervention Group (IG)**	**Control Group (CG)**	**Frequency, Duration**	**N of sample analyzed**	**Relevant Outcome measures**	**Conclusion**
Althomali et al. 2019; Canada	healthy older adults; include those with poorer balance status, low visual attention scores, fallers IG = 15 78.7 ± 5.8; CG = 15 81.7 ± 6.1	visual attention training (targets and distractors on a computer monitor)	continue their everyday activities as usual	6 sessions; 3 wks, 2x wk, 45 min	IG = 15 CG = 15	Sway: ML and AP CoP maximum sway, SD of ML and AP CoP, ML and AP CoP range and cumulative path length) Mini-BESTest OLST 5MWT TUG TUGco	no improvement following visual attention training for any of the mobility and/or balance measures
Anson et al. 2018 USA	healthy older adults; include those with self-reported balance difficulties, fallers IG = 23 75.7 ± 5.3; CG = 21 75.8 ± 6.5	visual feedback (VFB) (displayed on a TV screen) while walking on a treadmill; feedback on trunk motion	same training schedule without interacting with the VFB	12 sessions; 4 wks, 3x wk, 30 min	IG = 20 CG = 20	BESTest Mini-BESTest BBS TUG 6MWT	Trunk motion VFB training during treadmill walking are effective in improving over-ground dynamic balance
Bhardwaj and	healthy older	gaze stability	placebo eye	6 wks, 3x	IG = 15	BBS	Gaze stability

Vats 2014 India	adults (60-70 yrs old); include those with documented balance or mobility problems IG = 15 65.8 ± 3.3; CG = 15 64.6 ± 2.6	exercises (perform rapid, active head rotations while watching a visual target)	exercises (saccadic eye movements without visual targets against a plain white wall while keeping the head stationary)	daily	CG = 15		exercises are effective in improving balance
Buccello-Stout et al. 2008 USA	healthy older adults; include fallers IG = 8 72.6 ± 5.4; CG = 8 71.8 ± 5.1	viewed a rotating virtual scene while walking on a treadmill	viewed a static scene while walking on a treadmill	8 sessions; 4 wks, 2x wk, 20 min	IG = 8 CG = 8	Time to complete an obstacle course	IG moved faster through the obstacle course with fewer penalties
Hagedorn and Holm 2010 Denmark	Patients referred to a geriatric falls and balance clinic; include those with poorer balance status, fallers IG = 15 81.5 ± 7.7;	progressive resistance muscle strength training with high intensity weight shifting	progressive resistance muscle strength training with high intensity one-legged balance training,	24 sessions; 12 wks, 2x wk, 1.5 hours	IG = 15 CG = 12	Muscle Force tests TUG 6MWT OLST MCTSIB Tandem test BBS DGI	VFB training only resulted in significant improvement of physical endurance (6MWT); no improvement for other measures

	CG = 12 81.1 ± 6.0	games using a computer VFB system; feedback on position of the body	walking on a line, and passing an obstacle course				
Hatzitaki et al. 2009a Greece	healthy female older adults; AP = 19 70.7 ± 5.4; ML = 15 70.6 ± 5.9 CG = 14 71.4 ± 6.0	AP: shift body weight from toe to heel while standing on a platform ML: shift body weight between sides while standing on a platform; visually guided on a computer screen, feedback on each limb force vector	continue their everyday activities as usual	12 sessions; 4 wks, 3x wk, 25 min	AP = 19 ML = 15 CG = 14	Normal Quiet Stance (NQS) Sharpened Romberg Stance (SRS) Peak-to-peak amplitude (CoP max) and SD of CoP displacement in the AP and ML directions Peak-to-peak amplitude and SD of the lower leg, pelvis and trunk angular excursions in the AP and ML direction	Only visually induced weight shifting training in the AP direction seems to be more efficient for improving static balance in older women
Hatzitaki et al. 2009b Greece	healthy female older adults; AP = 20 70.8 ± 5.4; ML = 20 70.6 ± 5.9	AP: shift body weight from toe to heel while standing on a platform	continue their everyday activities as usual	12 sessions; 4 wks, 3x wk, 25 min	AP = 20 ML = 20 CG = 16	Postural responses to the moving obstacle: Peak CoP amplitude Time to peak CoP amplitude	Only visually induced weight shifting training in the ML direction resulted in a reduction of the ML sway amplitude and an increase of the

	CG = 16 71.4 ± 6.0	ML: shift body weight between sides while standing on a platform; visually guided on a computer screen, feedback on each limb force vector				Maximum trunk velocity	trunk's velocity during avoidance of obstacle
Li et al. 2016 China	Healthy older adults (aged over 60); IG = 40 68.2 ± 5.5; CG = 40 69.4 ± 6.2	one-leg standing balance exercise force platform balance training with VFB on a computer screen; feedback on movement of CoG	one-leg standing balance exercise	30 sessions; 3 mths, 10 days/mth, 10 min	IG = 39 CG = 38	TUG CoG parameters: total path length, ML path length, AP path length, average center displacement deflection along ML, average center displacement deflection along AP	VFB force platform balance training in combination with one-leg standing exercise improves balance control in older adults
Oungphalachai and Siriphorn 2020 Thailand	Healthy older adults; IG = 17 69.7 ± 2.4;	VFB training using a custom-made device; feedback on	continue their everyday activities as usual	12 sessions; 4 wks, 3x wk	IG = 17 CG = 17	Unilateral Stance (US): CoP velocity one-leg standing duration without a	VFB training significantly improves sway velocity and increases the limits of

	CG = 17 69.4 ± 3.4	performance using a video camera & results of the movements achieved on the target using a photoelectric sensor				fall Limits Of Stability (LOS): CoP velocity towards the target endpoint excursion maximal excursion ratio between direction toward the target and away from the target FAB	balance during static balance and backward directional control during dynamic balance
Piao et al. 2009 South Korea	Healthy older adults; IG = 15 68.4 ± 2.4; CG = 15 69.9 ± 3.7	postural training in various directions on an unstable platform; guided by visual feedback on CoP	continue their everyday activities as usual	24 sessions; 8 wks, 3x wk, 1 hour	IG = 15 CG = 15	sway path of CoP sway area of CoP	The training resulted in a significant improvement in the postural control ability
Sairam et al. 2019 India	Healthy older adults (60-70 yrs old); include those with documented balance or mobility problems IG = 20	gaze stability exercises (perform rapid, active head rotations while watching a visual target)	conventional physiotherapy exercises for balance	2 wks, 3x daily	IG = 20 CG = 20	BBS	Gaze stability exercises are effective in improving balance

	n/a; CG = 20 n/a	conventional exercises for balance					
Schwenk et al. 2014 USA	Healthy older adults; include those with high fall risk, fallers IG = 17 84.3 ± 7.3; CG = 16 84.9 ± 6.6	Interactive balance training with VFB from sensor (ankle reaching and virtual obstacle crossing task); feedback on ankle movement and lower limb stick figure	continue their everyday activities as usual	8 sessions; 4 wks, 2x wk, 45 min	IG = 15 CG = 15	CoM sway, area CoM sway, ML CoM sway, AP hip sway ankle sway Reciprocal Compensatory Index (RCI) AST TUG Gait speed (normal and fast) Stride velocity variability (normal and fast)	The training is effective for improving postural control and functional performance
Sihvonen et al. 2004a; Sihvonen et al. 2004b Finland	Healthy female older adults living in residential care; include fallers IG = 20 80.7 ± 6.1; CG = 8 82.9 ± 4.2	dynamic balance exercise sessions on a force platform (in different stance positions and different support surfaces); feedback on CoP movement	continue their everyday activities as usual	12 sessions; 4 wks, 3x wk, 20-30 min	IG = 20 CG = 7	AP sway velocity ML sway velocity velocity moment Time to complete in 3 dynamic tests Distance completed in 3 dynamic tests BBS	VFB balance training improves the balance control and functional balance in frail older women

Visual-related training on balance and walking

Sunny and Bhat 2017 India	Healthy older adults IG = 20 68.4 ± 3.3; CG = 20 68.5 ± 3.7	balance and walking training balance and walking training with visual cues (bright fluorescent colored tapes, and cones on the floor, and balls for reaching)	balance and walking training	12 sessions; 4 wks, 3x wk, 30 min	IG = 20 CG = 20	BBS DGI	Visual cue training is effective in improving balance and gait in community-dwelling older adults
Yamada et al. 2013 Japan	Healthy older adults; include fallers IG = 132 76.2 ± 8.5; CG = 132 77.2 ± 7.6	physical exercise sessions multitarget stepping (MTS) program (walk while stepping on	physical exercise sessions indoor walking program	48 sessions; 24 wks, 2x wk, ~40 min	IG = 112 CG = 118	MTS test performance: stepping failure avoidance failure performance time spin turns TUG FR 10-m walking test	MTS program (combined with multicomponent exercise) is effective in improving stepping accuracy, and functional balance and mobility in community-dwelling older adults

		the colored target square on each line and avoid stepping on the colored distractors)					
Young and Hollands 2010 UK	Healthy older adults; include fallers IG = 8 74.8 ± n/a; CG = 8 75.4± n/a	a video related to falls prevention a video instructing to maintain gaze on each target box until they made heel contact inside it (slow motion, and examples with visual scene)	a video related to falls prevention	2 sessions on separate days	IG = 8 CG = 8	AP foot placement error ML foot placement error AP foot placement variability ML foot placement variability number of missed steps foot stance duration foot swing duration walking velocity foot pitch / yaw number of AP/ML foot trajectory adjustments	The training is effective in improving stepping accuracy

Abbreviations: BBS = Berg Balance Scale; Mini-BESTest = Mini-Balance Evaluation System's Test ; BESTest = Balance Evaluation System's Test ; OLST = One-Legged Stance test; 5MWT = 5 Meter Walking test; 6MWT = 6 minute walk test; STST = Sit to Stand test; TUG = Timed Up and Go test; TUGco = TUG with a cognitive task ; MCTSIB = Modified Clinical Test of Sensory Interaction and Balance; DGI = Dynamic Gait Index; FAB = Fullerton Advanced Balance scale; AST = Alternate Step Test; FR = Functional Reach test; CoP = Centre of Pressure; CoG = Centre of Gravity; CoM = Centre of Mass; ML = medial-lateral; AP = anterior–posterior.

Table 3. Summary of the assessment of risk of bias across all included studies.

	Random sequence generation	**Allocation concealment**	**Blinding of participants and personnel**	**Blinding of outcome assessment**	**Incomplete outcome data**	**Selective reporting**	**Other bias**
Althomali et al. 2019	L	L	?	L	L	L	L
Anson et al. 2018	L	?	?	L	L	H	L
Bhardwaj and Vats 2014	L	?	?	L	L	?	L

Visual-related training on balance and walking							
Buccello-Stout et al. 2008	?	?	?	L	L	?	L
Hagedorn and Holm 2010	L	?	?	L	L	?	L
Hatzitaki et al. 2009a	?	?	?	L	L	?	L
Hatzitaki et al. 2009b	?	?	?	L	L	?	L
Li et al. 2016	L	?	?	L	L	?	L
Oungphalachai and Siriphorn 2020	L	L	?	L	L	L	L
Piao et al. 2009	?	?	?	L	L	?	L
Sairam et al. 2019	?	?	?	L	L	?	L
Schwenk et al. 2014	L	L	?	L	L	L	L
Sihvonen et al. 2004a	L	?	?	L	L	?	L
Sihvonen et al. 2004b	L	?	?	L	L	?	L
Sunny and Bhat 2017	L	L	?	L	L	?	L
Yamada et al. 2013	?	?	?	L	?	L	L

Visual-related training on balance and walking							
Young and Hollands 2010	?	?	?	L	L	?	L

Abbreviations: L, low risk of bias; H, high risk of bias; ?, unclear risk of bias.