Sport Sciences for Health (2023) 19:733–742
https://doi.org/10.1007/s11332-022-00990-5

REVIEW

Effect of concurrent and multi-component training on balance, fear of falling, and muscle strength in older adults: a review

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Received: 25 March 2022 / Accepted: 8 July 2022 / Published online: 10 August 2022

Abstract
Background There is impairment in maintaining balance while doing activities of daily living in aging individuals due to deterioration in the sensory, cognitive, and musculoskeletal systems. The positive effects of aerobic and resistance exercise in older people have already been established. Nowadays, researchers are stressing over the importance of multicomponent exercise programs where a combination of exercises like aerobic, resistance, and balance and coordination exercises, etc., was used.
Purpose The present review summarizes the effects of concurrent exercise training (aerobic + resistance) and multicomponent exercise programs on balance, fear of falling, and muscle strength in older adults.
Methods MEDLINE (accessed by PubMed) and Web of Science (Web of Science Core Collection) were searched using a combination of keywords.
Results The result in a majority of the included studies showed positive improvement in balance, fear of fall, and strength of muscles. Improvement in muscle strength is more evident when subjected to resistance exercise training alone than concurrent training.
Conclusions Multicomponent exercise training program when compared with concurrent training is more effective in improving balance, fear of fall, and muscle strength in older adults.

Keywords Balance · Concurrent training · Multicomponent training · Older adults

Abbreviations

MCEP	Multicomponent exercise program
FoF	Fear of falling
BoS	Base of support
ProFANE	Prevention of falls netwrok Europe
RM	Repetition maximum

Introduction

Aging is a fundamental process that affects all of our systems and tissues. The rate and magnitude of change in each system may differ from person to person but the total decline is an inevitable part of life for every one [1]. Balance impairment and falls are among the most prevalent and morbid conditions affecting older adults. Complaints of balance impairments are common among older adults [2]. Nearly, 30% of older adults aged 65 and older fall each year, and recent data report that the mortality rate associated with falls has more than doubled from 51.6 per 100,000 persons in 2000 to 122.2 per 100,000 persons in 2016 [3]. Age-related deterioration in balance or postural control exerts a significant negative impact on the ability to perform everyday activities safely and is a major cause of falls [4].

The capacity to keep the body's center of mass within the base of support is characterized as balance [5]. With aging, changes occur in cognitive function [6] along with a decrease in muscle strength [7, 8], impaired proprioception [9], decreased range of motion [10], and sensory system dysfunction [11]. All these above-mentioned factors affect balance. Decreased ability to maintain balance is related to the risk of falling [11, 12] and may lead to falls which then ultimately leads to injury, increase in dependency, associated illness, and early death [11, 13–15]. Exercise programs that focus on balance have been shown to be beneficial in reducing the risk of falls in older individuals [16, 17]. The two most common types of exercise, aerobic and resistance

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exercise, have beneficial effects on fall rates and health care use in older adults [18]. Performing endurance and strength training of adequate intensity and volume reduces the decline in neuromuscular function and aerobic capacity associated with age [19, 20]. The increase in explosive and maximal strength of muscle has an indirect impact on the control of posture and balance [19–21]. The reduction in fear of fall (FoF) can be achieved through exercise-induced improvement in gait, strength, balance, and mood [22]. Research supports the positive effect of multicomponent intervention programs designed to target the systems that control the older adult's balance [2]. It is unclear whether one intervention component was more effective than others, although it is likely that it was a multicomponent approach and targeting of a functional task that older people themselves perceived as problematic that made the difference [23]. This review recapitulates the available literature on the effects of combined aerobic and resistance exercise and multicomponent exercise programs (MCEP) on balance, FoF, and muscle strength in older individuals.

Materials and methods

A search was performed by one reviewer (AP) in the following databases: MEDLINE (accessed by PubMed), Scopus, and Web of Science (Web of Science Core Collection) from the earliest records available till February 2022. Random search terms used were keywords, "multicomponent exercise, fear of fall, muscle strength, concurrent exercise, balance, older adults". The search was carried out from January 2022 to February 2022. Boolean operators 'OR' & 'AND' were used. The literature search was refined to find out which articles dealt with the role of concurrent exercise training and MCEP in improving balance, FoF, and muscle strength in older adults. Studies administering only aerobic or only resistance training were excluded. Trials published in languages other than English were also excluded.

Results

Out of the total 1434 records, 580 duplicates were removed. 15 articles were found to be relevant based on the eligibility criteria and were assessed by two independent reviewers (AP and SP) for study characteristics. Out of the total 15 retrieved articles, 9 articles [24–32] incorporated MCEP as an intervention, and the rest of the studies investigated the effect of concurrent exercise training [18, 33–37]. The selection of the studies was illustrated in the flow diagram (Fig. 1). An overview of the included studies is presented in Table 1.

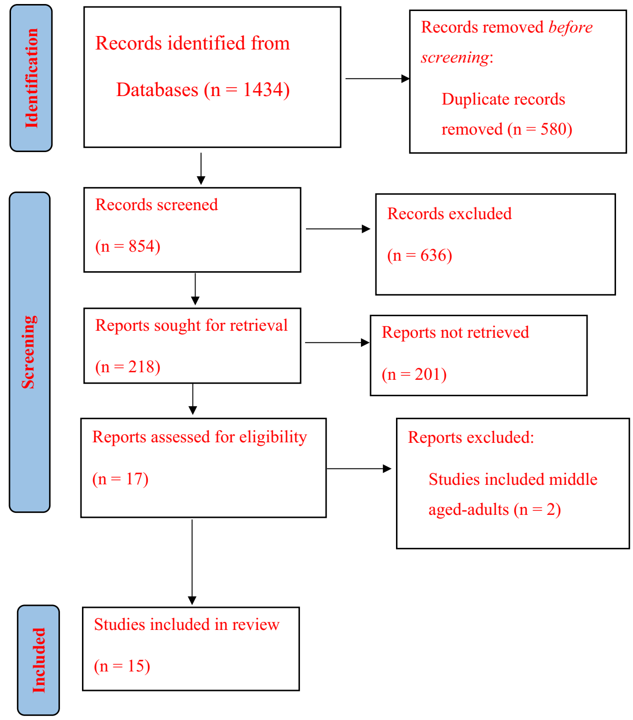

Fig. 1 Flow diagram of search strategy, retrieval of records, and evidence synthesis

Discussion

Exercise appears to be an effective strategy for improving balance, FoF, and muscle strength in the elderly.

Balance, FoF, and muscle strength in elderly

Balance and postural control

Balance is the ability of an individual to maintain the body's center of gravity over the base of support (BoS) [2], whereas postural control is a complex process that results from a dynamic interplay between the specific postural tasks to be accomplished the functional level of an individual's physiological systems and the given environment [38]. Individuals require balance in order to maintain posture, react to voluntary movements, and respond to external perturbations [39]. To remain balanced, an individual's center of mass must remain within the changing BoS [40]. This limit of stability depends on an individual's biomechanics, the requirements of the task, and the type of surface the individual is standing on [41].

Different postural tasks are controlled by different central and peripheral nervous system networks and can be categorized into the following three types: steady-state

Table 1 Summary of study characteristics

Study	Sample size	Age (in years)	Gender (M/F)	Type of exercise training program	Details of exercise intervention	Duration	Outcome measures
Bird et al. [24]	45	60–75 years	Not reported	MCEP	Resistance and flexibility exercise	12 months	TTSTS, TUG, step-test, medio-lateral sway range, & sway velocity
Holviala et al. [33]	108	56.3 ± 9.9	All men	Concurrent	Endurance training: using cycle ergometer where duration of exercise was increased per week. Strength training: 8 exercises for trunk, upper and lower body, session lasted for 60–90 min. Combined strength and endurance training: 2 session each of strength and endurance training using the same protocol	21 weeks	Strength: 1 RM. Balance: posturography
Kovács et al. [26]	86	Exercise group: 76.39 ± 9.63. Control group: 79.29 ± 12.67	16/70	MCEP	Strengthening exercise: starting weight is 0.5 kg; progression was made in weight after subjects can complete 3 sets of 10 reps. Balance exercise: stepping forward, sideway, and backward, timed stand practice, and sit to stand	12 months	Balance: performance oriented mobility assessment scale
Barnett et al. [27]	163	Intervention: 74.4 ± 4.9. Control: 75.4 ± 6.0	Not reported	MCEP	Balance and coordination exercises. Strength exercise Aerobic exercise	12 months	Muscle strength Balance: coordinated balance test, step-up ability, sit-to-stand performance
Gitlin et al. [28]	319	79.0 ± 5.9	58/261	MCEP	Balance exercise. Strengthening exercise	6 months	Fear of fall: Falls Efficacy Scale
Buchner et al. [18]	105	68–85	54/51	Concurrent	ST: 2 sets of 10 reps [1 set (50–60% of 1RM), 2 set (75% of 1 RM)] ET: 75% of HRR ST + ET: 20 min of endurance training + 1 set of ST exercises (at 75% of 1RM)	6 months	Muscle strength: Isokinetic dynamometer Balance: Ability to walk on wide and narrow balance beams, ability to stand on one-directional & omni-directional tilt boards, ability to stand in parallel, semi-tandem, & tandem stances
Cadore et al. [36]	23	65 ± 4	All men	Concurrent	SG: 2 sets of 18–20 RM, progressed to 12–14 RM, followed by 3 sets of 12–14 RM. EG: cycling at an intensity relative to HR_{VT}, progression was made by cycling for 20 min at 80% of HR_{VT}, followed by cycling for 6 min at 100% of HR_{VT}. CG: SG + EG	12 weeks	Maximal dynamic strength: 1RM Maximal isometric strength: maximal voluntary contraction
Chittrakul et al. [29]	72	Exercise: 69.14 ± 3.55. Control: 68.89 ± 3.86	Not reported	MCEP	Proprioception training. Muscle strength training. Reaction-time exercises with auditory cues. Postural balance training	12 weeks	Fear of falling: Thai Fall Efficacy Scale. Balance: Physiological Profile Assessment
Ferketich et al. [37]	21	C: 69.8 ± 2. E: 69.2 ± 1.7. E & S: 67.2 ± 1.5	All women	Concurrent	E: Cycling for 30 min at 70–80% of VO_2 peak. E & S: Cycling for 30 min at 70–80% of VO_2 peak + 2 sets of 12–15 reps at 80% of 10RM, progression was made by increasing the load by one-half of a plate on the weight stack with 12 reps	12 weeks	Muscle strength: 10RM for leg extension
Bastami and Azadi. [30]	50	68.48 ± 10.28	21/29	MCEP	Strength and balance exercise: single-limb stance, heel-to toe walking, wall pushups, sit-to-stand exercises, clock reaches, single-limb stance with arm, back, and side-leg raises. Walking. Pilates	8 weeks	Fear of falling: Falls Efficacy Scale
Zijlstra et al. [31]	540	Intervention: 77.8 ± 4.6. Control: 78.0 ± 5.0	152/388	MCEP	Strengthening exercise. Stretching	8 weekly sessions + 1 booster session	Fear of falling
Marques et al. [25]	72	Exercise group: 70.1 ± 5.4. Control group: 68.2 ± 5.7	Only women	MCEP	Light stretching + warm-up exercises, weight bearing activities, endurance exercise, balance training, agility training	60 min of two sessions per week for 32 weeks	Muscle strength: grip, lower extremity. Balance: OLS, 8-foot Up & Go test

Table 1 (continued)

Study	Sample size	Age (in years)	Gender (M/F)	Type of exercise training program	Details of exercise intervention	Duration	Outcome measures
Shiotsu et al. [101]	63	AR-L: 68.3 ± 4.2. RA-L: 69.0 ± 4.1. AR-M: 70.4 ± 4.1. RA-M:. 69.6 ± 4.6. CON: 71.0 ± 4.4	Only women	Concurrent	AE: using cycle ergometer at 50–55 rpm at intensity of 60% HRR for 20 min. RE: performed at 40–50% of 1RM, 3 sets of 10–15 reps in AR-L and RA-L group. 3 sets of 8–12 reps at 60–70% of 1RM in AR-M and RA-M group	2 times/week for a period of 10 week	Balance: OLB, FRT. Strength: 1RM
García-Pinillos et al. [35]	90	CG: 72.09 ± 5.78. EG: 73.50 ± 5.58	26/64	Concurrent	High-intensity circuit strength training + high-intensity interval endurance training	3 times/week for 12 weeks, each session lasted for ~ 35–40 min	Strength: 30-s CST, HS. Balance: FreeMed© BASE model baropodometric platform
Brouwer et al. [32]	38	Exercise group: 77.1 ± 5.1. Education group: 78.0 ± 5.5	9/25	MCEP	Resistance exercise (low-resistance exercise using elastic band) + stretching exercise, each session lasted for 1 h	6 weeks	Fear of fall: activities-specific balance confidence scale & human activity profile

M/F Male/Female; *MCEP* Multicomponent Exercise Program; *TTSTS* ten times sit-to-stand; *TUG* timed-up and go; *RM* repetition maximum; *EO* eyes open; FRT functional reach test; *CST* chair-stand test; *HS* handgrip strength test; *CoP* center of pressure; min minutes; *UG* up-and-go test; *OLS* one leg stand; reps repetitions; ST strength training; *ET* endurance training; *SG* strength group; *EG* endurance group; *CG* concurrent group; HR_{VT} heart rate at ventilatory threshold; *E* endurance; *S* strength; VO_2 peak peak oxygen uptake; *AR-L* aerobic exercise before low-intensity resistance training; *AR-M* aerobic exercise before moderate-intensity resistance training; *RA-L* low-intensity resistance training before aerobic exercise; *RA-M* moderate-intensity resistance training before aerobic exercise; *CON* control; *AE* aerobic exercise; *RE* resistance exercise; *CG* control group; *EG* exercise group; *OLB* one leg balance

posture [42, 43]; reactive postural responses to unanticipated, external postural perturbations [44]; proactive postural control [38, 45]. An individual's sensory, motor, cognitive, psychological, and cardiovascular health form the basis for how an individual performs postural tasks in a particular environment. Moreover, the brain's integration of various sensorimotor cues is critical for balance control; indeed, several studies have noted that multisensory integration is predictive of balance function and falls [46, 47]. In addition, the cognitive load, environmental, and emotional conditions will affect an individual's balance control [48, 49].

People are vulnerable to alterations in both static and dynamic balance while doing daily activities. The capacity to control such alterations is a difficult task for the neuromuscular system, which deals with the changing environmental conditions. Visual, vestibular, proprioceptive, and tactile senses provide correct sensory input and work together with the neuromuscular system to give proper motor output [50, 51]. Prior to the appearance of destabilizing pressures on the body, the proactive balancing technique stimulates postural modifications. After an external disruption, the reactive balance strategy triggers postural modifications, ensuring balance recovery. As a result of the physiological and cognitive changes, with aging the ability to apply these techniques, particularly the reactive balancing strategy, deteriorates [52].

Peripheral and central vision influences postural function [53]. Visual information is a powerful source of information for controlling balance and locomotion as well as navigating the environment [2]. Visual input distinguishes between head translation and rotation. Static visual cues control re-orientation or displacement slowly, whereas dynamic visual cues contribute to rapid body stabilization [54]. One of the key sources of information for (Fig. 2) postural control and balance is the vestibular system. The otoliths respond to gradual head movements and positional changes concerning gravity, while the semi-circular canals are sensitive to quick (phasic) head motions. The vestibular system aids in the modulation of postural tone and postural muscle activation by the vestibulospinal reflex and helps to stabilize gaze during head movements through the vestibulo-ocular reflex [55].

The somatosensory system gives information about the position and motion of the body and its parts in relation to each other and the support surface. For the maintenance of balance, sensory inputs were provided by muscle proprioceptors (Golgi tendon organs and muscle spindle), joint receptors, and skin mechanoreceptors [56]. Profound dorsal muscles support the upper half of the body while maintaining balance. When the center of gravity shifts forward due to poor posture, the dorsal muscles come into play and restore balance [57]. Proprioception, vestibular

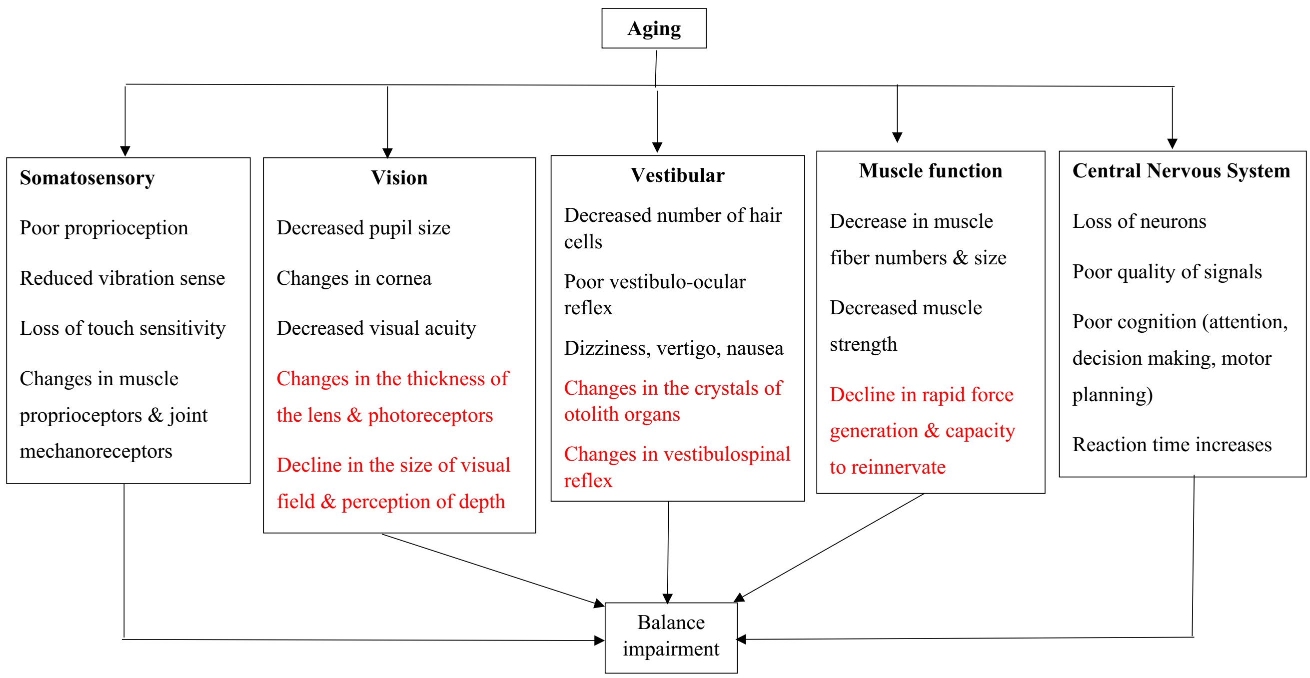

Fig. 2 A schematic diagram illustrating the main systems involved in balance control and how they are affected by aging

system, and vision, and their afferent pathways within the central nervous system are the main sensory system related to postural control [58]. The spinal cord, cerebellum, parts of the midbrain, and sensorimotor cortex are involved in efferent routes [59].

Effect of aging on balance, FoF, and muscle strength

Aging involves gradual, progressive, and spontaneous deterioration of most physiological functions [4]. Aging is linked to a decline in balance [60]. Aging has an effect on the sensory, motor, neural, and cognitive system, all of which plays an important for the control of balance (Fig. 1). Impairment in these above-mentioned systems results in reducing stability and predisposing older people to falls [61].

With the attenuation of sensory feedback, the task becomes more difficult, and balance impairment can be detected at a younger age. When compared with young women, elderly women present with more sway velocity while standing with eyes closed [62]. While maintaining balance, older individuals tend to activate their antagonist muscles more inappropriately than younger people. Along with that, older peoples' muscles activate in proximal to distal fashion and they might use different strategies when subjected to perturbations of low amplitude [63].

Falls are defined by the Prevention of Falls Network Europe (ProFANE) as 'an unexpected event in which the participants come to rest on the ground, floor, or lower level' occurs once or more annually in 29% of the community-dwelling adults who are 65 years old [64]. Falls result in injury, hospitalization, disability, loss of independence in older people [22]. Around 30–50% of falls in old age results in mild injuries like bruises or lacerations, whereas 10% result in catastrophic injuries including fractures or traumatic brain injury [65]. A persistent feeling associated with the risk of falling during one or more daily activities can be characterized as a FoF. It is a number of constructs such as fall self-efficacy, balance confidence, any worry or concern for falling [66]. Among older people, about one in three without a fall history and two in three with a falls history report some FoF [67]. Impaired vision [68], the presence of psychological disorders like depression and anxiety [67], balance and gait impairment [69], and cognitive dysfunction [70] were some of the risk factors for FoF. FoF can have some bad consequences like falls, increase dependency, a decrease in social activity, decrease quality of life, depression, and the person avoiding doing daily activities [67, 71].

The weakness of skeletal muscle is an undesirable consequence of aging [72]. Sarcopenia, which is age-associated loss of muscle mass, brings loss of independence [73], leads to disability, and hospitalization [74], frailty, and poor functional status [72]. Apart from age, other factors like sex, education level, cognitive function, obesity, physical activity also influence deterioration in muscle strength [61]. Dynapenia, which is an age-related decline in muscle strength, is independent of muscle atrophy [75].

Lower muscle strength, particularly of legs, has been identified as one of the leading causes of falls [76–78].

Previous research has revealed the physical prerequisites for avoiding a fall after stumbling over an obstruction [79, 80]. Due to lower maximal ankle moments and lower rates of moment production around all leg joints during the push-off phase of balance recovery, older individuals were shown to be less able to properly regain balance than younger adults [81]. These findings imply that leg strength may be the most important element in avoiding a fall [82].

Role of exercise in balance, FoF, and muscle strength

Exercise in older adults is one of the key components of a healthy lifestyle [83]. Adults who are practitioners of physical activities had a higher postural function, according to studies comparing multiple groups of participants. Younger individuals [84], as well as older adults [85–87] who are physically active, have good postural performance when compared with sedentary individuals. Previous research has shown that regular walking has a positive effect on postural control in healthy older people when compared to older adults with a sedentary lifestyle [88]. Engagement in physical activity on a regular basis tends to prevent age-related balance deterioration. Bird and colleagues reported that older individuals who perform resistance training showed maintenance of balance improvement. They also stated that older adults who were involved in the 1-year MCEP showed improved mobility for 1 year [24]. Postural performance is affected by the amount of time spent practicing, for example, individuals who had always practiced performed better in posture tests than those who had only recently practiced [87]. How an individual performs on postural tests depends on the type of activities being practiced [84]. There are activities that specifically target a particular part of balance control, for example, older adults who practiced Tai Chi performed better on the balance test and showed maximal stability [89] along with better proprioception at ankle and knee joints [90]. All this indicates the importance of physical activity, and how older adults who exercised regularly performed better on postural control tests. Posturographic measurements revealed that multicomponent training regimens improved balance control in older adults who were diagnosed as fallers [91].

Strength and endurance training of proper intensity and volume has indirect positive effects on postural control and thereafter, balance [20]. Holviala and colleagues in their study compared three different types of exercise training: strength training, endurance training, and combined strength and endurance training and examined their effect on static and dynamic balance. The result showed no improvement in static balance among all the three groups indicating that improvement in the lower body or trunk strength alone does not seem to improve static standing balance: however, there was an improvement in dynamic balance in all the three different training groups [33]. There are studies where concurrent training was effective in producing improvement in balance [33–35]. One study where 12 weeks of combined aerobic and resistance exercise training produced improvement in balance capacity, and also reported more improvement in dynamic balance capacity with moderate intensity concurrent training than lower-intensity concurrent training in healthy older women [34]. However, 12 weeks of high-intensity concurrent training produced a more pronounced improvement in balance than low-moderate intensity concurrent training in elderly people older than 65 years [35]. There was one study on the elderly where 6 months of concurrent training did not result in any improvement in balance. According to them, the subjects included in their study were above of threshold where the age-related decline in aerobic capacity and strength begin to cause substantial balance problems [18].

When it comes to the role of multicomponent training, there were several studies reporting improvement in balance capacity among older adults [25–27]. MCEP is effective even in improving balance in cognitively impaired older adults [26] and individuals at risk of falling [27]. Multicomponent interventions with different durations of training were effective in increasing balance capacity in aging individuals after 8 months of training [25]. One study administered multicomponent training for 12 weeks only [26], whereas Barnett and colleagues used 6 months of multicomponent intervention [27], and another study used 8 months of intervention [25].

Based on the specific effects of strength and aerobic exercise training, a combination of these two training modes could potentially minimize the effects of aging more extensively than either alone [37]. However, this is not the case when it comes to improvement in strength. As compared to strength training alone, combined strength and endurance exercise training slows the improvement in muscle strength and may negatively impair endurance adaptation when compared to endurance training alone (interference effect) [92, 93]. Indeed, in one clinical trial where older adults in the strength training group showed more improvement in strength than people in the endurance and concurrent training group. All the patients performed the exercise 3 times per week for 12 weeks [36]. Holviala and colleagues reported similar results where strength gain was more evident in the strength exercise training group, where older adults performed strength exercise training for 21 weeks at 40–60% of 1RM (repetition maximum) initially which was followed by exercising at 60–80% of 1RM and 70–85% of 1RM [33]. The possible explanation for this is the type of muscle fiber activation by endurance and strength training. Endurance training activates type I muscle fibers while strength training activates type II muscle fibers. Therefore, endurance training may inhibit increment in muscle fiber strength, especially in those muscle fibers that are recruited during concurrent training [94]. Apart from that, other mechanisms have been responsible for the interference of endurance training on improvement in muscle strength resulting from strength training. These include negative effects on neural adaptations [95] and low glycogen content resulting in a chronic catabolic state [92, 94].

The decline in physical activity among older adults is often related to FoF, while participation in physical activity is believed to contribute to the promotion of health in several domains (e.g., physical, cognitive, cardiovascular health, and even survival rate) [96]. Exercise has a direct influence on fear of falling or it indirectly has an impact on the associated factors of FoF and risk of falling like gait impairment, sarcopenia, anxiety, and balance impairment [22]. Exercise has been demonstrated to be the single most effective technique for reducing the number of falls in older persons [97] by improving gait and balance, increasing capacity to get up following a fall, and improving mood [98, 99]. Through these mechanisms, exercise may lower the FoF [97] and facilitate everyday tasks without falling, leading to a more positive appraisal of the ability to maintain balance [100]. Multicomponent exercise programs have been used in clinical trials and were shown to be effective in reducing FoF [28, 30, 31]. These kinds of interventions address modifiable environmental and behavioral risk factors and are effective in reducing perceived functional difficulties and enhancing self-efficacy and fall-related concerns in older people who may be transitioning to frailty [28]. In one study, a MCEP proved to be beneficial in decreasing FoF in older adults who presented with FoFs and restriction in activities [32]. Reduction in FoF was reported after a MCEP for 12 weeks in pre-frail older adults aged 65 years or above [29].

Three studies administered concurrent training 3 times/week for 12 weeks [35–37], whereas participants in the rest of the trials exercised 3 times/week for 24–26 weeks [18], 2 times/week for 10 weeks [34], and 2 times/week for 21 weeks [33]. Studies delivering MCEP were inconsistent with the frequency of exercise sessions. In three studies participants exercised for 8 weeks [30–32], and in another two trials, the subjects exercised for 12 months [24, 26, 27]. One study offered exercise sessions for 8 months [25], one offered for 12 weeks [29], and one offered for 6 months [31]. No difference in the outcomes was observed from the varied frequency of exercise. A similar pattern was observed with varied exercise intensity. Seven out of nine studies included in this review reported follow-up [18, 24, 27, 29–32]. The duration for follow-up varied among the trials.

Three studies assessed balance using a force platform system [24, 33, 35], three trials used a one-leg stand test [25, 34], two studies used a step test [24, 27], and only one study used Performance-Oriented Mobility Assessment Scale (POMA) for the assessment of balance. Four studies used repetition maximum for the assessment of muscle strength [33, 34, 36, 37]. Dynamometers were used by five studies for strength testing [18, 24, 33, 34, 36], and two studies used 30 s CST [25, 35]. FoF was evaluated using Falls Efficacy Scale [30], the Activities-specific Balance Confidence (ABC) and the Human Activity Profile (HAP) [32], and the Physiological Profile Assfessment (PPA) [29].

Conclusion

A multifactorial balance assessment including fall history, physical examination, gait evaluation, and environmental assessment is recommended for all older adults presenting with balance impairment. Multicomponent exercise programs and concurrent training have all been shown to be effective in improving balance capacity, reducing FoF, and muscle strength.

Authors' contributions AP nd SP contributed to assembling relevant literature, critical review of the paper, and writing the original draft. SP and MMN reviewed and edited the final draft.

Funding The authors did not receive support from any organization for the submitted work.

Declarations

Competing interests The authors declare no competing interests.

Conflict of interest The authors declare no conflicts of interest pertaining to this article.

Ethical approval This article does not contain any studies with human participants or animals performed by any of the authors.

Research involving human and animal rights Not applicable.

Informed consent Not applicable.

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