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Exercise Interventions on Balance in Older People: a Systematic Review

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Abstract
Introduction: Age-related changes in the sensorimotor and neuromuscular system negatively affect performance in static and dynamic postural control even in healthy older adults, leading to deficits in balance and gait performance with negatively impact on the functional ability of the older person. Regular exercise can elicit many favourable responses that contribute to balance improvement. **Objectives**: The objective of this systematic review is to present evidence for effectiveness of exercise interventions designed to improve balance in healthy older people. **Methods**: The studies were identified from four databases (PubMed, Web of Science, Cochrane Library and Sportdiscus) from January 2011 to January 2020. A total of 17 articles meet the inclusion criteria. **Results**: Statistically significant effects were reported for static and dynamic balance, translated into several balance abilities improve-

ments. The most used type of exercise was the gait, balance and functional training, followed by the strength/resistance training. There is a lack of consensus regarding to balance programs methodology. **Conclusion**: Exercise appears to have beneficial effects on balance ability. We considered fundamental that the studies should include the specifications of the intervention program regarding to intensity control, exercises performed, guidelines used in the balance exercises and the exercise progression and variation during training. This information will help instructors to provided validated routine exercises.

Keywords: exercise program; physical activity; balance; elderly

Introduction

Age-related changes in the sensorimotor and neuromuscular system negatively affect performance in static and dynamic postural control even in healthy older adults (Lesinski, Hortobagyi, Muehlbauer, Gollhofer & Granacher, 2015), leading to deficits in balance and gait performance (Boisgontier et al., 2017; Gschwind et al., 2013). These factors potentially negatively affect balance control and impact on the functional ability of the older person (Howe, Jackson, Banks, Blair, 2007). Preventing falls by improving balance in older people has been a public health issue in several studies (Thiamwong & Suwanno, 2014).

Balance is important for maintaining postural equilibrium and thus for the avoidance of falls (Gschwind et al., 2013). Balance is defined as the ability to maintain the projection of the body's center of mass within manageable limits of the base of support, as in standing or sitting, or in transit to a new base of support, as in walking (Winter, 1995). It is also important to distinguish static balance from dynamic balance, since some studies use this differentiation. Therefore, static balance can be defined like the ability to maintain postural stability and orientation with center of mass over the base of support and body at rest (O'Sullivan, Schmitz & Fulk, 2014). On the other hand, dynamic balance can be defined as the ability to maintain postural stability and orientation with center of mass over the base of support while the body parts are in motion (O'Sullivan et al., 2014).

Balance plays an essential role in tasks such as moving from sitting to standing, standing, walking, performing many activities of daily living, maintaining independence, as well as reacting to external disturbances (Treacy, Schurr, Lloyd & Sherrington, 2015). However, balance control is very complex and multifactorial, involving not only balance but other factors such as strength, proprioception, integrity of the neuromuscular system, pain, vision and in some instances, fear of falling.

Balance may be measured when the body has a constant, or static, base of support, or during movement from one base of support to another. It can be analyzed directly by quantifying the position of the center of mass in relation to the base of support. Alternatively, balance can be measured indirectly through observation, self-reporting or other reporting methods such as objective tests of functional activities (Howe et al., 2007).

Balance can decline with older age and pathology but can be improved with proper exercise (Treacy et al., 2015). Balance training primarily aims at improving postural control by challenging the alignment of the body's center of gravity with regard to the base of support and proved to be effective in improving measures of postural control and ultimately fall risk and rate in older adults (Lesinski et al., 2015).

Some exercise interventions with balance and muscle strengthening components have been shown to reduce fall rates, fall risk and fear of falling (Gillespie et al., 2009; Maughan, Lowry, Franke, Smiley-Oyen et al., 2012; Schoene, Valenzuela, Lord, & De Bruin et al., 2014; Sherrington, Tiedemann, Fairhall, Close & Lord, 2011; Taylor, 2014), although it is not clear which element or combination of elements is necessary to achieve this result (Howe et al., 2007).

This systematic review aims to present an updated evidence for effectiveness of exercise interventions designed to improve balance in healthy older people.

Methods

This systematic review is reported in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA) statement (Moher, Liberati, Tetzlaff & Altman, 2009) and other systematic reviews. An exhaustive search was conducted on four databases of literature (PubMed, Web of Science, Cochrane and SportDiscus), published between January 2011 and January 2020. The search strategy was conducted by using a keyword search of the following terms: (exercise OR physical exercise OR exercise program OR physical activity) AND (balance OR balance training OR balance exercise OR standing balance OR dynamic balance) AND (older adults OR older people OR elderly). Additional filters were added to the search: publication dates (9 years), age (65+ years), article type (clinical trial) and text availability (free full text).

Relevant publications containing at least one term from each of the three categories were identified. The documents selected for inclusion were analysed with a predetermined set criterion: *(i)* the study was a full text report published in a peer-reviewed journal, *(ii)* the study included a healthy and independent population, *(iii)* the study included papers published in English, Portuguese and Spanish, *(iv)* the study used a longitudinal or interventional design and *(v)* there were no exclusion criteria regarding ethnic origin. The flow of search results through the systematic review process is shown in Figure 1. Through database searching 2896 articles were identified. After removal of duplicates, a total of 962 papers were retrieved. The screened process was carried out by two independent reviewers (CP and VL).

The reviewers read every title and all the abstracts and doubtful decisions for inclusion/exclusion were resolved by a third reviewer (ECV). After the screening process, 928 articles were excluded due to *(i)* subject irrelevance, *(ii)* being meta-analysis/review papers, *(iii)* irrelevant endpoint outcomes, *(iv)* the inclusion of one or more health pathology, and *(v)* being a study conducted with dependent population. After screening the remained 34 full papers, a total of 17 articles were excluded for the following reasons: irrelevant age-range, a cross-sectional study design or no exercise intervention and absence of balance assessments or endpoint conclusions.

The 17 remaining articles were included in the review (Irez, Ozdemir, Evin, Irez & Korkusuz, 2011; Clemson et al., 2012; Gusi et al., 2012; Maughan et al., 2012; Zheng et al., 2013; Nicholson, McKean & Burkett, 2014; Oliveira, Silva, Dascal & Teixeira, 2014; Thiamwong & Suwanno, 2014; Mesquita, Carvalho, Freire, Neto & Zangaro, 2015; Ansai, Aurichio, Gonçalves & Rebelatto, 2016; Eckardt, 2016; Raj, Vadivelan & SivaKumar, 2016; Fraser et al., 2017; Ordnung, Hoff, Kaminski, Villringer & Ragert, 2017; Bernard et al., 2018; Hamed, Bohm, Mersmann & Arampatzis, 2018; Leem, Kim & Lee, 2019).

Information from the aforementioned articles were summarized with respect to: *(i)* demographic characteristics of participants (sample size, mean age, number of group participants and country), *(ii)* characteristics of the intervention (protocol, duration/frequency and exercise modalities) and *(iii)* the effects of the intervention on balance (Table 2).

The quality assessment was conducted on the basis of other standardized assessment lists (Castro-Piñero et al., 2010) and on our selection criteria. The list included six items (A-F) on peer reviewed journal, population, measurement, design and report of the results. Each item was rated as ‘‘2’’ (fully reported), “1” (moderately reported) or ‘‘0’’ (not reported or unclear). For all studies, a total quality score was calculated by counting the number of positive items (a total score between 0 and 12). Three levels of evidence were created: high quality, medium quality and low quality (Table 1).

Table 1. List of included studies with quality scores.

Authors and variables	A	B	C	D	E	F	Total Score	Quality Level
Irez et al. (2011). Pilates and dynamic balance, flexibility, strength, reaction time, number of falls	2	2	2	2	2	2	12	HQ
Clemson et al. (2012). Balance and strength training and rate of falls	2	2	2	2	2	2	12	HQ
Gusi et al. (2012). Biodex Balance System and dynamic balance, fear of falling	2	2	2	2	2	2	12	HQ
Maughan et al. (2012). Dose-response of balance training and static, dynamic balance	2	2	2	2	2	2	12	HQ
Zheng et al. (2013). Proprioception and cognitive exercise and falls	2	2	2	2	2	2	12	HQ
Nicholson et al. (2014). BodyBalance® and balance, functional tasks performance, fear of falling	2	2	2	2	2	2	12	HQ
Oliveira et al. (2014). Exercise modalities and postural balance	2	2	1	2	2	2	11	HQ
Thiamwong et al. (2014). Balance training and balance and fear of falling	2	2	2	2	2	2	12	HQ
Mesquita et al. (2015). PNF and Pilates exercise and balance	2	2	2	2	2	2	12	HQ
Ansai et al. (2016). Multicomponent and strength exercises and balance	2	2	2	2	2	2	12	HQ
Eckardt (2016). Resistance training on unstable surfaces and balance	2	2	2	2	2	2	12	HQ
Raj et al. (2016). Multisensory and strength exercises and balance	2	2	1	1	1	1	8	MQ
Fraser et al. (2017). Physical and Cognitive training and balance	2	2	2	2	2	1	11	HQ
Ordnung et al. (2017). Exergame training and balance	2	2	2	2	2	2	12	HQ
Bernard et al. (2018). Posture-Balance-Motricity program and balance	2	2	2	2	2	2	12	HQ
Hamed et al. (2018). Perturbation-based exercise and balance	2	2	2	2	2	2	12	HQ
Leem et al. (2019). Otago Exercise Program and balance	2	2	2	2	2	2	12	HQ

Note: Rating for total score: high quality (HQ)=9-12; medium quality (MQ)= 5-8; low quality (LQ)=0-4. A: The study was a full text report published in a peer reviewed journal. B: The study population was healthy and independent. C: The selected physical exercise and balance outcomes were clearly described. D: The population was 65 years of age or over. E: The study had a longitudinal or interventional design. F: The results were clearly reported.

Results

General findings

All studies were longitudinal and intervention studies. This review includes data from 1552 individuals and the sample size of the studies varied from 28 (Nicholson et al., 2014) to 338 (Bernard et al., 2018) participants. The samples were from 10 different countries: 3 studies were conducted in Brazil (Ansai et al., 2016; Mesquita et al., 2015; Oliveira et al., 2014), 3 in Germany (Eckardt, 2016; Ordnung et al., 2017, Hamed et al., 2018), 2 in Australia (Clemson et al., 2012; Nicholson et al., 2014), 1 in Canada (Fraser et al., 2016), 1 in China (Zheng et al., 2013), 1 in Corea (Leem et al., 2018), 1 in France (Bernard et al., 2018), 1 in India (Raj et al., 2016), 1 in Spain (Gusi et al., 2012), 1 in Thailand (Thiamwong et al., 2014), 1 in Turkey (Irez et al., 2011) and 1 in the United States of America (Maughan et al., 2012). Information about all the studies is presented in Table 2.

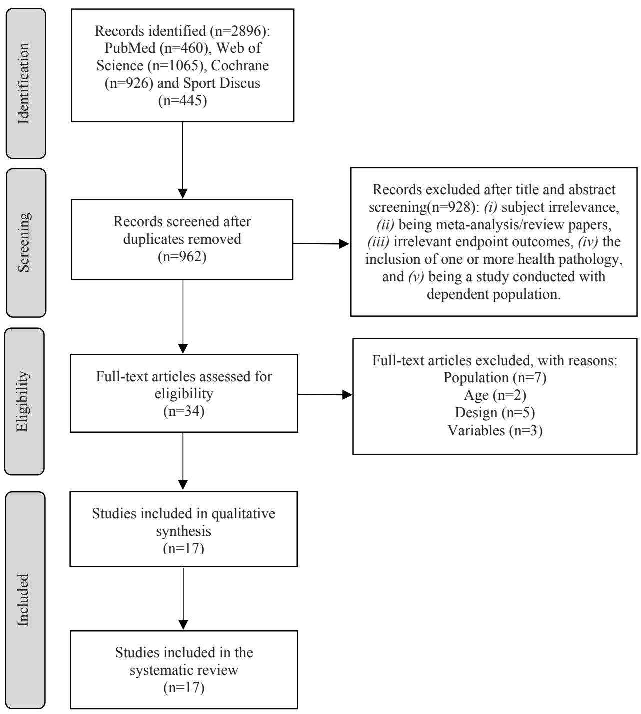

Figure 1. Flow chart of the articles through the selection process.

Table 2. Characteristics of analysed studies (N=17).

Study (Authors/Year/ Reference)	Intervention design / Duration	Sample / Mean age / Country	Physical fitness measures	Balance measures	Results
Irez et al. (2011). Pilates and dynamic balance, flexibility, strength, reaction time, number of falls	Interventional and longitudinal / 12 weeks - 3 sessions week	60 (IG=30; CG=30) / 75.4 / Turkey	Flexibility ("Sit-and-reach" test, Muscle strength (Muscle Manual Tester - Lafayette Company, Model 01160); Reaction time (New Test 2000, Co and Finland device).	Dynamic balance (MED-SP 300 platform in 30-second trials); Number of falls (self-report).	Significant main effect of time ($p<0.05$) and main effect of group ($p<0.05$) for dynamic balance, flexibility, muscle strength, reaction time and number of falls.
Gusi et al. (2012). Biodex Balance System and dynamic balance, fear of falling	Interventional and longitudinal / 12 weeks - 2 sessions week	40 (IG=20; CG=20) / 76 / Spain	Isometric strength of the knee extensor: Biodex System 3 dynamometer.	Dynamic balance (Biodex Balance System); Fear of falling (FES-I Questionnaire).	Dynamic balance: improved by 2.1% in the IG; Fear of falling: improved 7 points in the IG; Isometric strength of the knee extensor: increase of 7% in the IG.
Clemson et al. (2012). Balance and strength training and rate of falls	Interventional and longitudinal / 12 months	317 (LPG=107; IG=105; CG=105) / 83.4 / Australia	Isometric strength of the lower limb: Chatillon DMG250 dynamometer.	Static balance (2 developed balance hierarchy scales); Dynamic balance (3 meters tandem walk time); Rate of falls (self-report).	Static and Dynamic balance: significantly improved in the LPG compared with IG and CG with moderate to large effect sizes for the 2 balance scales; Rate of falls: LPG=1.66 person/year; IG=1.90 person/year; CG=2.28 person/year; Isometric strength: significantly improved in the LPG compared with IG and CG.

Study (Authors/Year/ Reference)	Intervention design / Duration	Sample / Mean age / Country	Physical fitness measures	Balance measures	Results
Maughan et al. (2012). Dose-response of balance training and static, dynamic balance	Interventional and longitudinal / 6 weeks	60 (1-day=21; 3-day=20; CG=19) / 78.8 / United States of America	-	Static balance (Single-leg-stance; Tandem balance); Dynamic balance (Alternate stepping (Berg *et al.*, 1992);	SLS-R: main effect of session (p=0.002) with a 40%, 10% and 8% improvement, for 3-day, 1-day and CG respectively; SLS-L: main effect of session (p<0.001) with a 67%, 21% and 6% improvement, for 3-day, 1-day and CG respectively; Tandem balance: no main effects of group or session; Alternate stepping: main effect of session (p<0.001) with a 15%, 5% and 8% improvement, for 3-day, 1-day and CG respectively;
Zheng et al. (2013). Proprioception and cognitive exercise and falls	Interventional and longitudinal / 8 weeks - 3 sessions week	100 (IG=50; CG=50) / 68.1 / China	-	Static Balance (Biodex Balance System); Static/Dynamic Balance (Berg Balance Scale);	Static Balance Test: significant improvement in the IG, in the mediolateral sway distance with eyes open or closed (p<0.05) and in the anteroposterior sway distance with eyes open (p<0.05); BBS: significantly greater improvement (p<0.05) in BBS scores in the IG.
Thiamwong et al. (2014). Balance training and balance and fear of falling	Interventional and longitudinal / 12 weeks	104 (IG=52; CG=52) / 71.4 / Thailand	-	Dynamic Balance (TUG test; FRT). Fear of falling (FES-I Questionnaire).	FRT: distance of additional reach in the IG increased significantly (p<0.001); TUG: decreased significantly (p<0.001) in the IG; FES-I scores decreased significantly (p<0.001) in the IG.

Study (Authors/Year/ Reference)	Intervention design / Duration	Sample / Mean age / Country	Physical fitness measures	Balance measures	Results
Nicholson et al. (2014). BodyBalance® and balance, functional tasks performance, fear of falling	Interventional and longitudinal / 12 weeks - 2 sessions week	28 (IG=15; CG=13) / 66.5 / Australia	-	Dynamic Balance (30-second chair-stand; TUG; FRT); Static Balance (Single-leg balance); Fear of falling (10-item Iconographical FES-I);	Significant group-by-time interactions in favour of the IG, for the 30-second chair-stand (p=0.037), TUG (p=0.038), partial and mediolateral COP range in narrow stance eyes closed (p=0.017) and Single-leg stance left time (p=0.024). Significant time effect in favour of the IG, for lateral reach left (p=0.037), 30-second chair-stand (p=0.001) and mediolateral COP range with comfortable stance eyes closed (p=0.022). There were no significant group-by-time interactions for fear of falling.
Oliveira et al. (2014). Exercise modalities and postural balance	Interventional and longitudinal / 12 weeks - 2 sessions week	74 (MT=23; AG=28; GG=23) / 69.4 / 74 (MT=23; AG=28; GG=23) / 69.4 / Brasil	-	Static balance (Biomec 400 - EMG system from Brazil: two-legged stand with eyes open, two-legged stand with eyes closed, semi-tandem with eyes open, semi-tandem with eyes closed and one-legged stand in one leg).	Static balance significantly (p<0.05) improved after intervention with the 3 modalities. There was no significant interaction (p>0.05) between groups. No difference was found in favour of any modality over another in the post-intervention effect.

Study (Authors/Year/ Reference)	Intervention design / Duration	Sample / Mean age / Country	Physical fitness measures	Balance measures	Results
Mesquita et al. (2015). PNF and Pilates exercise and balance	Interventional and longitudinal / 4 weeks - 3 sessions week	63 (PNFG=21; PG=21; CG=21) / 69.1 / Brasil	-	Dynamic Balance (TUG; FRT); Static/ Dynamic Balance (Berg Balance Test);	PNFG had greater reductions in 4 of the 7 sway measures than the CG. No significant differences were found between the PG and the CG in any of the sway measures. Functional tests: women in the PNFG and PG exhibited improved performance in the TUG test and FRT compared with women in the CG. The BBS scores improved in the PNFG when compared to the CG (p=0.005).
Ansai et al. (2016). Multicomponent and Strength exercises and balance	Interventional and longitudinal / 16 weeks - 3 sessions week	69 (MTG=23; RT=23; CG=23) / 82.4 / Brasil	Muscle strength of the lower limbs: 5 repetition Sit-to-stand test.	Static Balance (one-leg standing and tandem tests); Dynamic Balance (TUG motor test (Hofheinz & Schusterschitz, 2010)); Number of falls (self-report).	Significant interaction between groups and assessments in the sit-to-stand (p=0.001) and the one-leg standing (right support) (p<0.001) tests. The MTG had a significant improvement in the sit-to-stand and one-leg standing (right support) tests. There was a significant main effect between times regarding the one-leg standing (left support) test (p=0.035).

Study (Authors/Year/ Reference)	Intervention design / Duration	Sample / Mean age / Country	Physical fitness measures	Balance measures	Results
Eckardt (2016). Resistance training on unstable surfaces and balance	Interventional and longitudinal / 10 weeks - 2 sessions week	75 (M-SRT=27; M-URT=26; F-URT=22) / 70.4 / Germany	Isometric strength of the lower limb (Takei A5002, cable pull device); Handgrip strength (Takei A5401, hand dynamometer); Chair raise test.	Dynamic Balance (10-m walkway test, TUG, FRT and Push and Release Test).	All groups showed improvements over time in the lower extremity muscle strength (*range Cohen's d*:.30-.55), with meaningfully better improvements for M-URT. Lower-extremity muscle power (chair rise test) showed improvements for all groups over time (*d*:.32-.95), though significantly best improvements were provided by F-URT. All groups improved the functional reach distance (*d*:.60-1.03), however F-URT revealed the highest effects. For the TUG, no interaction effect was found, indicating similar improvements across groups.
Raj et al. (2016). Multisensory and strength exercises and balance	Interventional and longitudinal / 6 weeks - 5 sessions week	45 (MSE=15; SE=15; W=15) / between 60-70 years / India	-	Dynamic Balance (TUG test); Static/ Dynamic (Short Physical Performance Battery test (SPPB)).	All groups showed improvements, with meaningfully better improvements for MSE group for both TUG (p<0.001) and SPPB battery test (p=0.05).
Fraser et al. (2017). Physical and Cognitive training and balance	Interventional and longitudinal / 12 weeks - 3 sessions week	72 (ACT=21; ACL=17; SCT=18; SCL=16) / 71.4 / Canada	6-minutes walking test; Short Physical Performance Battery; Dual-task walking;	Dynamic Balance (Dual-task walking). Static/Dynamic Balance (SPPB).	All groups improved on their 6-minutes walking test and there were no significant differences between the groups (p=0.21). Dual-task cost changes scores revealed significant differences between the groups (p=0.005); All groups improved (p<0.05) in several (but not all) mediolateral postural sway variables and in their cognitive accuracy during balance.

Study (Authors/Year/ Reference)	Intervention design / Duration	Sample / Mean age / Country	Physical fitness measures	Balance measures	Results
Ordnung et al. (2017). Exergame training and balance	Interventional and longitudinal / 6 weeks - 2 sessions week	30 (IG=15; CG=15) / 69.2 / Germany	3-minute step test; Rowing (upper body muscular endurance); Grip strength (SEAHAN® hydraulic dynamometer); Ruler Drop Test (motor reaction time) (Del Rossi *et al*., 2014); JTT (Jebson *et al*., 1969); Back Scratch Test (Konopack *et al*., 2008).	Static balance (Wii balance board (Nintendo® Co., Ltd.)).	Significantly greater improvements for the IG in the JTT performance of the left hand (p=0.001), in the assessment of static balance with eyes closed (COP AP, p=0.044; COP ML, p= 0.046). Within-group comparison, the CG only showed significant performance improvements in one assessment of static balance (COP AP, p=0.005).
Bernard et al. (2018). Posture-Balance-Motricity program and balance	Interventional and longitudinal / 12 weeks – 2 sessions week	338 (IG=338; CG=0) / 74.4 / France	Individual Motor Profile (Posture-balance-motricity) (Bernard *et al*., 2008);	Static balance (Unipedal Stance; Stabilometric evaluation (Medicapteurs SFP 40Hz/16b force platform): two-legged stand with eyes open and eyes closed); Dynamic balance (TUG).	Significant positive evolution of all parameters measured; The three dimensions of "Posture-Balance-Mobility" increased significantly (p<0.001); The time taken in the TUG test decreased significantly (p<0.001); Unipedal stance time analysis showed significant evolution in eyes-open (p<0.004) and eyes closed (p<0.001) conditions; For the stabilometric evaluation was observed a significant decrease of the surface (p<0.02) and the length (p<0.001) of the COP.

Study (Authors/Year/ Reference)	Intervention design / Duration	Sample / Mean age / Country	Physical fitness measures	Balance measures	Results
Hamed et al. (2018). Perturbation-based exercise and balance	Interventional and longitudinal / 14 weeks – 2 sessions week	47 (MSG=15; Perturbation-based Group=16; CG=16) / 71.2 / Germany	Maximum strength of the knee extensor and ankle plantar flexor muscles (Biodex dynamometer).	Static balance (COP AP two test trials: AMTI BP 400600-2000 force platform);	Only the Perturbation-based group showed significant improvement of standing balance ability (38%, d=1.61); Plantar flexor strength increased 20% (d=0.72) in the MSG and 23% (d=1.03) in the Perturbation-based group; Muscle strength of the knee extensors increased only in the MSG (8%, d=1.61).
Leem et al. (2019). Otago Exercise Program and balance	Interventional and longitudinal / 12 weeks - 3 times week	30 (AO+Otago =10; Otago=10; CG=10) / 79 / Korea	Muscle strength of hip flexion, ankle dorsiflexion and plantar flexion (Lafayette, model 01163 Dynamometer)	Dynamic balance (TUG).	Both the AO+Otago and the Otago groups showed significant increases in right side plantar flexion muscle strength (p<0.05); In the TUG test, both intervention groups showed significant improvements (p<0.05), reducing the time by 4.08 seconds (AO+Otago) and 3.76 seconds (Otago).

1-day = 1 day intervention group; 3-day = 3 day intervention group; ACL = aerobic and computer lessons; ACT = aerobic and cognitive training; AG = Aquatic gymnastic; AO = Action observation; BBS = Berg Balance Scale; CG = control group; COP = Centre of Pressure; COP AP = Centre of Pressure Anterior-Posterior; COP ML = Centre of Pressure Medio-Lateral; FES-I = Falls Efficacy Scale International; FRT = functional reach test; F-URT = free-weight unstable resistance training; GG = General gymnastic; IG = intervention group; JTT = Jebson-Taylor Hand Function Test; LPG = LiFE programme group; MT = Mini-trampoline; MSE = multisensory; MSG = Muscle strength group; MTG = Multicomponent training group; M-SRT = machine-based stable resistance training; M-URT = machine-based unstable resistance training; PG = Pilates group; PNFG = proprioceptive neuromuscular facilitation group; RT = Resistance training; SCL = stretch and computer lessons; SCT = stretch and cognitive training; SE = strengthening; SLS-R = single-leg-stance on right leg; SLS-L = single-leg-stance on left leg; SPPB = Short Physical Performance Battery; TUG = timed up-and-go; W = walking.

Physical Fitness, balance and exercise assessment

Physical fitness measures used in each study are shown in Table 2: 10 studies used objective measures to assess physical fitness (Ansai et al., 2016; Bernard et al., 2018; Clemson et al., 2012; Eckardt, 2016; Fraser et al., 2017; Gusi et al., 2012; Hamed et al., 2018; Irez et al., 2011; Leem et al., 2019; Ordnung et al., 2017).

From the 10 studies, that assess physical fitness, 8 assessed muscular strength (Bernard et al., 2018; Clemson et al., 2012; Eckardt, 2016; Gusi et al., 2012; Hamed et al., 2018; Irez et al., 2011; Leem et al., 2019; Ordnung et al., 2017); 2 flexibility (Irez et al., 2011; Ordnung et al., 2017); 2 cardiorespiratory fitness (Fraser et al., 2017; Ordnung et al., 2017); 2 Reaction Time (Irez et al., 2011; Ordnung et al., 2017); 1 assessed the fine motor skills (Ordnung et al., 2017); and 1 assessed posture and motricity (Bernard et al., 2018). From the 8 studies that assessed the muscular strength, 7 assessed lower limbs muscular strength (Ansai et al., 2016; Clemson et al., 2012; Eckardt, 2016; Gusi et al., 2012; Hamed et al., 2018; Irez et al., 2011; Leem et al., 2019); 2 hand grip muscular strength (Eckardt, 2016; Ordnung et al., 2017) and 1 upper body muscular endurance (Ordnung et al., 2017). To evaluate the lower limbs muscular strength, 6 studies used dynamometer (Clemson et al., 2012; Eckardt, 2016; Gusi et al., 2012; Hamed et al., 2018;

Irez et al., 2011; Leem et al., 2019) and 2 studies use the five-repetition sit-to-stand test (Ansai et al., 2016; Eckardt, 2016). To evaluate the hand grip strength the 2 studies used dynamometer (Eckardt, 2016; Ordnung et al., 2017). The upper body muscular endurance was evaluated in 1 study with rowing with dumbbell's (Ordnung et al., 2017). To assess flexibility, 1 used the sit-and-reach test (Irez et al., 2011) and other used the back-scratch test (Ordnung et al., 2017). The cardiorespiratory fitness was evaluated with the six minutes walking test (Fraser et al., 2017) and the 3-minute step test (Ordnung et al., 2017). With regard to reaction time, 1 study used a test with light and sound stimuli (Irez et al., 2011) and other use the ruler drop test (Ordnung et al., 2017). The fine motor skills were assessed with Jebson-Taylor Hand Function Test (Ordnung et al., 2017). Finally, posture and and motricity were assessed by 10 specific motor exercises. Each dimension was tested on 30 points and the addition of the dimensions constituted the "Individual Motor Profile" (Bernard et al., 2018).

Exercise interventions

Regarding the exercise interventions and to group the several studies, we use the fall prevention classification system that has been developed by the Prevention of Falls Network Europe (ProFaNE) and already used by other studies (Gillespie et al., 2009; Kumar et al., 2016). Therefore, exercise modalities are grouped into six categories using the ProFaNE taxonomy: gait, balance and functional training; strength/resistance training; flexibility training; 3D training; general physical activity; and endurance training.

Analysing the different interventions, 9 studies included the gait, balance and functional training (Ansai et al., 2016; Bernard et al., 2018; Clemson et al., 2012; Hamed et al., 2018; Leem et al., 2019; Maughan et al., 2012; Raj et al., 2016; Thiamwong et al., 2014; Zheng et al., 2013), 6 included the strength/resistance training (Ansai et al., 2016; Clemson et al., 2012; Eckardt, 2016; Hamed et al., 2018; Leem et al., 2019; Raj et al., 2016), 5 included the 3D training (Gusi et al., 2012, Irez et al., 2011; Mesquita et al., 2015; Nicholson et al., 2014; Ordnung et al., 2017), 1 included general physical activities (Oliveira et al., 2014) and 1 included endurance and flexibility training (Fraser et al., 2016). In 12 trials, the exercise intervention fell in only one category (Bernard et al., 2018; Eckardt, 2016; Fraser et al., 2016; Gusi et al., 2012; Irez et al., 2011; Maughan et al., 2012; Mesquita et al., 2015; Nicholson et al., 2014; Oliveira et al., 2014; Ordnung et al., 2017; Thiamwong et al., 2014; Zheng et al., 2013). The remain 5 trials (Ansai et al., 2016; Clemson et al., 2012; Hamed et al., 2018; Leem et al., 2019; Raj et al., 2016) included more than one category of exercise.

Frequency and duration of the exercise interventions

Eight of the studies had the duration of 12 weeks (Bernard et al., 2018; Fraser et al., 2016; Gusi et al., 2012; Irez et al., 2011; Leem et al., 2019; Nicholson et al., 2014; Oliveira et al., 2014;

Thiamwong et al., 2014) and 3 studies had an intervention period of 6 weeks (Maughan et al., 2012; Ordnung et al., 2017; Raj et al., 2016). One study had a duration of 16 weeks (Ansai et al., 2016), 1 study had a duration of 14 weeks (Hamed et al., 2018), 1 study had a duration of 10 weeks (Eckardt, 2016), 1 study had a duration of 8 weeks (Zheng et al., 2013) and 1 study had a duration of 4 weeks (Mesquita et al., 2015). Only 1 study had a longer intervention period with 12 months (Clemson et al., 2012).

Regarding the frequency of the interventions, 7 studies performed their exercise program 2 times/week (Bernard et al., 2018; Eckardt, 2016; Gusi et al., 2012; Hamed et al., 2018; Nicholson et al., 2014; Oliveira et al., 2014; Ordnung et al., 2017), 6 studies performed 3 times/week (Ansai et al., 2016; Fraser et al., 2016; Irez et al., 2011; Leem et al., 2019; Mesquita et al., 2015; Zheng et al., 2013), and 1 study performed 5 times/week (Raj et al., 2016). The rest of the trials (n=3) were left out of this information (Clemson et al., 2012; Maughan et al., 2012; Thiamwong et al., 2014).

Balance assessment

All studies used objective measures to assess balance and other associated variables, like number of falls and fear of falling. Thus, 14 studies assessed dynamic balance (Ansai et al., 2016; Bernard et al., 2018; Clemson et al., 2012; Eckardt, 2016; Fraser et al., 2016; Gusi et al., 2012; Irez et al., 2011; Leem et al., 2019; Maughan et al., 2012; Mesquita et al., 2015; Nicholson et al., 2014; Raj et al., 2016; Thiamwong et al., 2014; Zheng et al., 2013) and 12 studies assessed static balance (Ansai et al., 2016; Bernard et al., 2018; Clemson et al., 2012; Fraser et al., 2016; Hamed et al., 2018; Maughan et al., 2012; Mesquita et al., 2015; Nicholson et al., 2014; Oliveira et al., 2014; Ordnung et al., 2017; Raj et al., 2016; Zheng et al., 2013), being that 9 studies assessed both types of balance in the same investigation (Ansai et al., 2016; Bernard et al., 2018; Clemson et al., 2012; Fraser et al., 2016; Maughan et al., 2012; Mesquita et al., 2015; Nicholson et al., 2014; Raj et al., 2016; Zheng et al., 2013). The number of falls was assessed in 3 studies (Ansai et al., 2016; Clemson et al., 2012; Irez et al., 2011), by self-report of the individuals. Fear of falling was assessed also in 4 studies (Gusi et al., 2012; Leem et al., 2019; Nicholson et al., 2014; Thiamwong et al., 2014), with the particularity of the study of Nicholson et al. (2014), to have used the version 10-item Iconographical of the FES-I.

From the 14 studies that evaluated the dynamic balance, 8 used the TUG test (Bernard et al., 2018; Eckardt, 2016; Fraser et al., 2016; Leem et al., 2019; Mesquita et al., 2015; Nicholson et al., 2014; Raj et al., 2016; Thiamwong et al., 2014), being the most used test in the studies. In 1 study (Ansai et al., 2016), was used the TUG-motor, which is a variation of the TUG, but in which participants must carry a full cup with water. Then, 4 studies used the Functional Reach Test (FRT) (Eckardt, 2016; Mesquita et al., 2015; Nicholson et al., 2014; Thiamwong et al., 2014), 2 used the Berg Balance test (Mesquita et al., 2015; Zheng et al., 2013), 2 used the SPPB test (Fraser et al., 2016; Raj et al., 2016), 1 used the 3-meters tandem walk time (Clemson et al., 2012), 1 used the alternate stepping (Maughan et al., 2012), 1 used the 30-second chair stand (Nicholson et al., 2014), 1 used the 10-meter walkway test (Eckardt, 2016), 1 used the push-and-release test (Eckardt, 2016), 1 used the dual-task walking (Fraser et al., 2016), 1 used a force platform (Irez et al., 2011) and 1 used a balance system platform (Gusi et al., 2012).

Regarding the static balance, 5 studies used a single-leg stance test (Ansai et al., 2016; Bernard et al., 2018; Maughan et al., 2012; Nicholson et al., 2014; Oliveira et al., 2014), 2 used the Short Physical Performance Battery test (SPPB) (Fraser et al., 2016; Raj et al., 2016), 2 used the Berg Balance Test (Mesquita et al., 2015; Zheng et al., 2013), 1 used 2 developed balance hierarchy scales (Clemson et al., 2012), 1 used the tandem stance (Maughan et al., 2012), 1 used the Biodex Balance System device (Zheng et al., 2013), 1 used the Wii balance board (Nintendo® Co., Ltd.) (Ordnung et al., 2017) and 2 used a force platform (Hamed et al., 2018; Oliveira et al., 2014), with the following tests: semi-tandem with eyes open (Oliveira et al., 2014), semi-tandem with eyes closed (Oliveira et al., 2014), two-legged stand with eyes open (Hamed et al., 2018; Oliveira et al., 2014) and two-legged stand with eyes closed (Oliveira et al., 2014).

Exercise and Dynamic Balance

Four studies (Bernard et al., 2018; Maughan et al., 2012; Thiamwong et al., 2014; Zheng et al., 2013) from the category gait, balance and functional training, investigated the effects of their interventions on dynamic balance. The TUG motor test, the 3 meters tandem walk time, the alternate stepping, the FRT, the SPPB and BBS tests, were used to assess these interventions. Bernard et al. (2018) found a significantly (p<0.001) decreased time taken in the TUG test. Maughan et al. (2012) reported a main effect of session (p<0.001) with a 15%, 5% and 8% improvement, for the group that completed 3 sessions/week, 1 session/week and CG respectively. Thiamwong et al. (2014), mentioned that in the FRT, the distance of additional reach in the IG increased significantly (p<0.001) and the time in the TUG test decreased significantly (p<0.001) in the IG. Finally, Zheng et al. (2013), registered significantly greater improvement (p<0.05) in BBS scores in the IG.

One study included the strength/resistance training (Eckardt, 2016). Outcome measures used to evaluate this intervention were 10-m walkway test, TUG, FRT and push and release test. All groups improved the functional reach distance (d:.60-1.03), however F-URT revealed the highest effects. For the TUG, no interaction effect was found, indicating similar improvements across groups. Gait analysis revealed meaningful main effects of "time" (d: .54–1.40) for stride velocity, stride length, stride width and double support and a main effect "group" for stride length (d = .70). Non-parametric analysis of the push and release test revealed meaningful improvements over time (d = 1.46) but little effects between groups and interaction effects.

Four studies (Ansai et al., 2016; Clemson et al., 2012; Leem et al., 2019; Raj et al., 2012) investigated the effect of multicomponent exercise programs involving gait, balance, functional training and strength/resistance training, on dynamic balance. Ansai et al. (2016) mentioned significant interaction between groups and assessments in the sit-to-stand (p=0.001) and Clemson et al. (2012) found moderate to large effect sizes for the 2 balance scales used in his trial. Leem et al. (2019) registered significant improvements ($p<0.05$) through the time to complete the TUG test. Raj et al. (2016) referred that all groups showed improvements, with meaningfully better improvements for MSE group for both TUG ($p<0.001$) and SPPB battery test ($p=0.05$).

Four studies investigated the effect of 3D training (Gusi et al., 2012; Irez et al., 2011; Mesquita et al., 2015; Nicholson et al., 2014) on dynamic balance. Outcome measures used to evaluate these interventions where the Biodex Balance System, a force platform, the 30-second chair-stand, the TUG test and the FRT. Gusi et al. (2012) found improved dynamic balance by 2.1% in the IG. Irez et al. (2011) reported a significant main effect of time ($p<0.05$) and main effect of group ($p<0.05$) for dynamic balance. Mesquita et al. (2015) mentioned improved performance in the TUG test and FRT and improved BBS scores in the PNFG when compared to the CG ($p=0.005$). In a within-group comparison, women in both the PNFG and PG showed significant improvements in the FRT, timed up-and-go test and BBS scores. Nicholson et al. (2014) found significant group-by-time interactions in favour of the IG, for the 30-second chair-stand ($p=0.037$), TUG ($p=0.038$) and significant time effects in favour of the IG, for lateral reach left ($p=0.037$), 30-second chair-stand ($p=0.001$).

Finally, 1 study (Fraser et al., 2016) investigated the effects of exercise programmes involving endurance and flexibility training on dynamic balance. To assess those effects, the author used the TUG test and the dual-task walking test. All groups improved on their 6-minutes walking test and there were no significant differences between the groups ($p=0.21$). Dual-task walking scores revealed significant differences between the groups ($p=0.005$) in favour of the IG.

Exercise and Static Balance

Three studies from the category gait, balance and functional training, investigated the effects of their interventions on static balance (Hamed et al., 2018; Maughan et al., 2012; Zheng et al., 2013). Different outcome measures were used to evaluate these interventions like, limits of stability, single-leg-stance, tandem stance, the Berg Balance Scale and the Biodex Balance System. Statistically significant differences were observed in these measures. Hamed et al. (2018) found a significant improvement (38%, d=1.61) of the standing balance ability. Maughan et al. (2012) denoted a main effect of session (p=0.002) in the single-leg-stance test, but no main effects of group or session in the tandem stance. Zheng et al. (2013) reported a significantly greater improvement (p<0.05) in the BBS scores and significant improvement in the mediolateral sway distance with eyes open or closed (p<0.05) and in the anteroposterior sway distance with eyes open (p<0.05).

Three studies (Ansai et al., 2016; Clemson et al., 2012; Raj et al. 2016) investigated the effect of multicomponent exercise programs involving gait, balance, co-ordination and functional task activities and strengthening exercises on static balance. Outcome measures were used to evaluate these interventions like, single-leg-stance, tandem stance and the SPPB battery test. Ansai et al. (2016) reported significant interaction between groups and assessments in the one-leg standing (right and left support) tests (p<0.001) and a significant main effect between time regarding the one-leg standing (left support) test (p=0.035). Clemson et al. (2012) referred moderate to large effect sizes for the 2 balance scales used in his trial. Raj et al. (2016) declared meaningfully better improvements through the SPPB battery test results (p=0.05). Zheng et al. (2013) mentioned significant improvement in the intervention group, in the mediolateral sway distance with eyes open or closed (p<0.05) and in the anteroposterior sway distance with eyes open (p<0.05).

Three studies investigated the effect of 3D training (Mesquita et al. 2015; Nicholson et al., 2014; Ordnung et al., 2017) on static balance. BBS, Wii balance board (Nintendo® Co., Ltd). tandem stance, single-leg stance were the outcome measures used. Mesquita et al. (2015) found that PNFG had greater reductions in 4 of the 7 sway measures than the CG. No significant differences were found between the PG and the CG in any of the sway measures. The BBS scores improved in the PNFG when compared to the CG (p=0.005). In a within-group comparison, women in both the PNFG and PG showed significant improvements in the BBS scores. Women in the CG did not show significant differences in the evaluated parameters. Nicholson et al. (2014) denoted a significant group-by-time interaction in favour of the IG, for the partial and mediolateral COP range in narrow stance eyes closed (p=0.017) and single-leg stance left time (p=0.024). Ordnung et al. (2017) reported significantly greater improvements for the IG in the assessment of static balance with eyes closed (COP AP, p=0.044; COP ML, p= 0.046). Within-group comparison, the CG only showed significant performance improvements in one assessment of static balance (COP AP, p=0.005).

One study (Oliveira et al., 2014) investigated the effects of exercise programmes involving mini-trampoline, aquatic gymnastics and general floor gymnastics as general physical activity on static balance. Two-legged stand with eyes open, two-legged stand with eyes closed, semi-tandem with eyes open, semi-tandem with eyes closed and one-legged stand in one leg were the outcome measures used, assessed in a force platform. Static balance significantly (p<0.05) improved after intervention with the 3 modalities. There was no significant interaction (p>0.05) between groups. No difference was found in favour of any modality over another in the post-intervention effect.

One study (Fraser et al., 2016) investigated the effects of endurance and flexibility training on static balance. The Short Physical Performance Battery test (SPPB) was used. All groups improved (p<0.05) in several (but not all) mediolateral postural sway variables and in their cognitive accuracy during balance.

Discussion

This systematic review has researched recent evidence for effectiveness of exercise interventions designed to improve balance in healthy older people and found that physical exercise has positive effects on static and dynamic balance. All the trials reported statistically significant effects for static and dynamic balance. These results are in accordance with another reviews that show that participation in regular physical activity programs plays a key role in maintaining balance and preventing falls in older adults (De Labra, Guimarães-Pinheiro, Maseda, Lorenzo & Millan-Calenti, 2015; Ishigaki, Ramos, Carvalho & Lunardi, 2014; Tiedemann, Sherrington & Lord, 2013; Lesinski et al., 2015; Schoene et al., 2014; Sherrington et al., 2011; Howe et al., 2007; Gillespie et al., 2009).

Improvements were seen in several abilities like, stand on one leg and in two legs with eyes open or closed, sit-to-stand, leaning forward, backward and sideway, regain balance after a sudden perturbation, gait speed and walk and balance in tandem.

Analysing the different studies, we found that the most used type of exercise was the gait, balance and functional training, followed by strength/resistance training. According to the ProFaNE exercise classification, the gait, balance and functional training involves specific correction of walking technique and changes of pace, level and direction, efficient transfer of bodyweight from one part of the body to another or challenges specific aspects of the balance systems and functional activities as the training stimulus based on the theoretical concept of task specificity. Some examples are: heel raises, toe raises, walking on the toes/ heels, heel to toe walking, walking backward, forwards, sideways, turning, bending, stepping and side stepping; vestibular and proprioceptive retraining exercises in different head and eye positions; reaction games; obstacle courses; standing on unstable surfaces; standing in one leg or tandem standing. On the other hand, strength/resistance training involves all types of weight training i.e., contracting the muscles against a resistance and bring about a training effect in the muscular system. Illustrative examples are weight training (free weights, resistance bands or body weight), functional training with added weight, exercise on machines and cable pulleys.

The majority (70.6%) of the studies used only one type of exercise and only 29.4% included more than one category of exercise, associating gait, balance and functional training and strength training. Those types of exercise provide a moderate to high challenge to balance, reducing the base of support, movement of the centre of gravity and reduced need for upper limb support, which are according with the methodology accessed by other reviews (Sherrington et al., 2011; Tiedemann et al. 2013). The inclusion of strength training can produce many benefits, as reduced muscle strength is an important risk factor for falls there may also be longer-term falls prevention benefits (Fisher, Steele, Gentil, Giessing, & Westcott, 2017).

Regarding to the duration and frequency of the interventions, there is no consensus among the analyzed studies and none of them reported detailed information on training volume, like the number of exercises per training session, or the number of sets or repetitions per exercise. The literature does not provide a clear guideline but there is an indication from Sherrington et al. (2011), that there are greater benefits from higher doses of exercise, suggesting that exercise should be undertaken for at least 2 hours per week and ongoing exercise would be necessary for a lasting falls prevention effect because the benefits of exercise are rapidly lost when exercise is ceased. Lesinski et al. (2015) refers that a training period of 11–12 weeks, a frequency of 3 sessions per week, a total number of 36–40 training sessions, a duration of a single training session of 31–45 min, and a total duration of 91–120 min of balance training/week is most effective to improve balance. In our review, most of the interventions (42.86%), had a duration of 12 weeks and performed their exercise program with a frequency of 3 times/week (35.71%), which are in accordance with the guidelines presented by Lesinski et al. (2015). Concerning to exercise intensity, also none of the analysed studies reported any detailed information. Exercise intensity should be progressed in a tailored manner that considers individual tolerances and preferences. Perhaps this is why the studies analysed do not provide any detailed information about this parameter. Methods to increase the intensity and effectiveness of balance challenging exercises include (Gschwind et al., 2013): using progressively difficult postures with a gradual reduction in the base of support (two legged stand, semi-tandem stand, tandem stand, one-legged stand); using movements that perturb the centre of gravity (tandem walk, circle turns, leaning and reaching activities, stepping over obstacles); specific resistance training for postural muscle groups (heel stands, toe stands, hip abduction with added weights to increase intensity, unsupported sit to stand practice); and reducing sensory input standing with eyes closed, standing/walking on an unstable surface such as foam mats). Further challenge can be provided using dual tasks, such as combining a memory task with a gait training exercise or a hand-eye co-ordination activity with a balance task (Tiedemann et al., 2013).

From the studies included in this review, 52.9% evaluated both types of balance in the same investigation. The dynamic balance was evaluated by 82.4% of the studies and the static balance by 70.6%. The most used test to assess the dynamic balance was the TUG test, used by 57.1% of the studies, followed by the FRT (33%).

According to Eckardt (2016), both tests showed excellent test-retest reliability (TUG: ICC=.99; FRT: ICC=.92). Regarding to the static balance, the most used test in the evaluations was the single-leg stance test, used in 41.7% of the studies.

This review found that exercise has statistically significant positive effects on balance. The identified studies are heterogeneous about the protocols implemented on the interventions and assessments. Nevertheless, program delineation should be tailored to the needs and abilities of the target population to ensure challenging and safe exercise. We considered essential that the studies should include the specifications of the intervention program regarding to duration of the study protocol, frequency, volume, intensity, exercises performed, guidelines used in the balance exercises, information about the exercise progression and variation during the training period. Other aspects are the need to clearly mentioned the training status of the participants in the beginning of the interventions. In addition, the sample of the analysed studies are very different; the smallest group consisted of 28 participants and the biggest of 338. Moreover, the sample size of the examined studies varies greatly. This makes it hard to represent a general community, as a sample size of 9 is rather small. Furthermore, the manuscript aimed to understand the effects of exercise on static balance in healthy elderly, and due to such specific inclusion criteria a very limited number of studies have been included in this article.

Conclusion

The present review analysed the association of exercise interventions and balance in healthy older people. The investigated studies exhibited that exercise appears to have positive effects on balance. Multicomponent exercise interventions based on gait, balance and functional training combined with strength/resistance training appears to be more effective. Significant improvements were observed in balance assessed across a variety of outcome measures for exercise interventions. The regular practice of supervised physical exercise should be promoted with the intention of promoting balance and reducing the future risk of falling.

References

1. Ansai J., Aurichio T., Gonçalves R. & Rebelatto J. (2016). Effects of two physical exercise protocols on physical performance related to falls in the oldest old: A randomized controlled trial. *Geriatr Gerontol Int*, 16 (4): 492-499. DOI:10.1111/ggi.12497.

2. Bernard, P., Blain, H., Gerazime A., Maurelli O., Bousquet J. & Ninot G. (2018). Relationship between a three-month physical conditioning "posture-balance- motricity and health education" (PBM-HE) program on postural and balance capacities of sedentary older adults: influence of initial motor profile. *European Review of Aging and Physical Activity,* 15 (14). DOI: 10.1186/s11556-018-0203-0.

3. Boisgontier, M., Cheval, B., Chalavi, S., Ruitenbeek, P., Leunissen, I., Levin, O., . . . Swinnen, S. (2017). Individual differences in brainstem and basal ganglia structure predict postural control and balance loss in young and older adults. *Neurobiology of Aging*, 50, 47-59. DOI:10.1016/j.neurobiolaging.2016.10.024.

4. Clemson, L., Fiatarone Singh, M. Bundy, A., Cumming, R. Manollaras, K., O'Loughlin, P. & Black, D. (2012). Integration of balance and strength training into daily life activity to reduce rate of falls in older people (the LiFE study): randomised parallel trial. *BMJ,* 345, e4547. DOI:10.1136/bmj.e4547.

5. De Labra, C., Guimarães-Pinheiro C., Maseda A., Lorenzo T. & Millán-Calenti J. (2015). Effects of physical exercise interventions in frail older adults: a systematic review of randomized controlled trials. *BMC Geriatrics*, 15:154. DOI:10.1186/s12877-015-0155-4.

6. Eckardt, N. (2016). Lower-extremity resistance training on unstable surfaces improves proxies of muscle strength, power and balance in healthy older adults: a randomised control trial. *BMC Geriatr*, 16 (1): 191. DOI:10.1186/s12877-016-0366-3.

7. Fisher J., Steele J., Gentil P., Giessing J., & Westcott W. (2017). A minimal dose approach to resistance training for the older adult; the prophylactic for aging. *Experimental Gerontology* 99: 80–86. DOI:10.1016/j.exger.2017.09.012.

8. Fraser, S. A., Li, K. Z., Berryman, N., Desjardins-Crepeau, L., Lussier, M., Vadaga, K., ... Bherer, L. (2017). Does Combined Physical and Cognitive Training Improve Dual-Task Balance and Gait Outcomes in Sedentary Older Adults? *Front Hum Neurosci, 10*, 688. DOI:10.3389/fnhum.2016.00688.

9. Gillespie L., Robertson M., Gillespie W., Lamb S., Gates S., Cumming R., Rowe B. (2009). Interventions for preventing falls in older people living in the community. *Cochrane Database of Systematic Reviews*, Issue 2. Art. No.: CD007146. DOI: 10.1002/14651858.CD007146.pub2.

10. Gschwind, Y., Kressig, R., Lacroix, A., Muehlbauer, T., Pfenninger, B., & Granacher, U. (2013). A best practice fall prevention exercise program to improve balance, strength/power, and psychosocial health in older adults: study protocol for a randomized controlled trial. *BMC Geriatrics*, 13 (105). DOI: 10.1186/1471-2318-13-105.

11. Gusi, N., Carmelo, J., Corzo, H., del Pozo-Cruz, B., Olivares, P., & Parraça, J. (2012). Balance training reduces fear of falling and improves dynamic balance and isometric strength in institutionalised older people: a randomised trial. *Journal of Physiotherapy,* 58 (2), 97-104. DOI:10.1016/s1836-9553(12)70089-9.

12. Hamed, A., Bohm, S., Mersmann, F., & Arampatzis, A. (2018). Exercises of dynamic stability under unstable conditions increase muscle strenght and balance ability in the elderly. *Scand J Med Sci Sports* (28), 961–971. DOI:10.1111/sms.13019.

13. Howe T., Rochester L., Jackson A., Banks P. & Blair V. (2007). Exercise for improving balance in older people. *Cochrane Database of Systematic Reviews* (4). DOI:10.1002/14651858.

14. Irez, G., Ozdemir, R., Evin, R., Irez, S., & Korkusuz, F. (2011). Integrating pilates exercise into an exercise program for 65+ year-old women to reduce falls. *Journal of Sports Science and Medicine*, 10 (1), 105–111.

15. Ishigaki E., Ramos L., Carvalho E., Lunardi A. (2014). Effectiveness of muscle strengthening and description of protocols for preventing falls in the elderly: a systematic review. *Braz J Phys Ther,* 18 (2):111-118. DOI:10.1590/ S1413-35552012005000148.

16. Kumar, A., Delbaere, K., Zijlstra, G., Carpenter, H., Iliffe, S., Masud, T., . . . & Kendrick, D. (2016). Exercise for reducing fear of falling in older people living in the community: Cochrane systematic review and meta-analysis. *Age and Ageing, 45*(3), 345-352. DOI:10.1093/ageing/afw036.

17. Leem, S., Kim, J., & Lee, B. (2019). Effects of Otago exercise combined with action observation training on balance and gait in the old people. *Journal of Exercise Rehabilitation*, *15*(6), 848–854. DOI:10.12965/jer.1938720.360.

18. Lesinski M., Hortobágyi T., Muehlbauer T., Gollhofer A. & Granacher U. (2015). Effects of Balance Training on Balance

Performance in Healthy Older Adults: A Systematic Review and Meta-analysis. *Sports Med*. DOI:10.1007/s40279-015-0375-y.

19. Maughan, K., Lowry, K., Franke, W., & Smiley-Oyen, A. (2012). The Dose-Response Relationship of Balance Training in Physically Active Older Adults. *J Aging Phys Act,* 20 (4), 442–455. DOI:10.1123/japa.20.4.442.

20. Mesquita, L., Carvalho, F., Freire, L., Neto, O., & Zangaro, R. (2015). Effects of two exercise protocols on postural balance of elderly women: a randomized controlled trial. *BMC Geriatr,* 15 (61). DOI:10.1186/s12877-015-0059-3.

21. Moher D., Liberati A., Tetzlaff J. & Altman D. (2009). Preferred Reporting Items for systematic reviews and meta-analysis: The PRISMA Statement. *BMJ*, 339 (b2535). DOI:10.1136/bmj.b2535.

22. Nicholson, V., McKean, M., & Burkett, B. (2014). Twelve weeks of BodyBalance(R) training improved balance and functional task performance in middle-aged and older adults. *Clin Interv Aging,* 9, 1895-1904. DOI:10.2147/CIA.S71769.

23. Oliveira M., Silva R., Dascal, J. & Teixeira, D. (2014). Effect of different types of exercise on postural balance in elderly women: a randomized controlled trial. *Arch Gerontol Geriatr,* 59 (3), 506-514. DOI:10.1016/j.archger.2014.08.009.

24. Ordnung, M., Hoff, M., Kaminski, E., Villringer, A., & Ragert, P. (2017). No Overt Effects of a 6-Week Exergame Training on Sensorimotor and Cognitive Function in Older Adults. A Preliminary Investigation. *Front Hum Neurosci, 11*, 160. DOI:10.3389/fnhum.2017.00160.

25. O'Sullivan, S., Schmitz, T., & Fulk, G. (2014). *Physical Rehabilitation (Sixth Edition)*. Philadelphia: F.A. Davis.

26. Raj, Y., Vadivelan, K., & SivaKumar, V. (2016). Comparison of Multisensory vs. Strenghthening Exercises on Functional Mobility and Balance in Elders. *Int J Physiother, 3* (5), 557-561. DOI:10.15621/ijphy/2016/v3i5/117439.

27. Sherrington C., Tiedemann A., Fairhall N., Close J., & Lord, S. (2011). Exercise to prevent falls in older adults: an updated meta-analysis and best practice recommendations. *NSW Public Health Bulletin.,* 22, 3-4. DOI: 10.1071/NB10056.

28. Schoene D., Valenzuela T., Lord S., & De Bruin, E. (2014). The effect of interactive cognitive-motor training in reducing fall risk in older people: a systematic review. *BMC Geriatrics*, 14 (107). DOI: 10.1186/1471-2318-14-107.

29. Taylor D. (2014). Physical activity is medicine for older adults. *Postgrad Med J*, 0: 1–7. DOI:10.1136/postgradmedj-2012-131366.

30. Thiamwong L. & Suwanno J. (2014). Effects of Simple Balance Training on Balance Performance and Fear of Falling in Rural Older Adults. *International Journal of Gerontology*, 8 (3), 143-146. DOI:10.1016/j.ijge.2013.08.011.

31. Tiedemann, Sherrington, & Lord. (2013). The role of exercise for fall prevention in older age. *Motriz,* 19 (3), 541-547. DOI: 10.1590/S1980-65742013000300002.

32. Treacy D., Schurr K., Lloyd B., & Sherrington, C. (2015). Additional standing balance circuit classes during inpatient rehabilitation improved balance outcomes: an assessor-blinded randomised controlled trial. *Age and Ageing*, 44, 580-586. DOI:10.1093/ageing/afv019.

33. Winter, D. (1995). *A.B.C. Anatomy, biomechanics and control of balance during standing and walking.* Waterloo, Ont.: Waterloo Biomechanics.

34. Zheng, J., Pan, Y., Hua, Y., Shen, H., Wang, X., Zhang, Y., . . . & Yu, Z. (2013). Strategic targeted exercise for preventing falls in elderly people. *J Int Med Res, 41*(2), 418-426. DOI:10.1177/0300060513477297.