The Role of Balance Training on Risk and Prevalence of Falls in Community-Dwelling Older Adults: A Systematic Review

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Purpose Balance training and reducing falls have been studied in populations with specific pathologies or using exercise in general. The purpose of this systematic review was to evaluate and summarize the findings of quality randomized control trials using balance training to determine risk and prevalence of falls in community-dwelling older adults. ***Methods*** Studies that examined the effects of a balance intervention or balance and exercise intervention on fall risk and/or prevalence in people 65 years or older were included. Relative risk reduction (RRR) ratios were calculated for total number of falls and total number of participants who fell in the included studies. ***Results*** Nine randomized clinical trials (n= 4,703) published from 2002-2019 with Physiotherapy Evidence Database (PEDro) scale scores of ≥4/10 found that balance training programs alone and combined balance and exercise interventions had a significant impact on fall rates with RRR of .30 (.27-.33, 95% CI) and fall risk RRR of .42 (.38-.46, 95% CI). ***Conclusion*** Balance training of various forms can be beneficial in reducing risk and prevalence of falls in independent, community-dwelling older adults.

Key Words Older adults, Fall risk, Balance, Community Dwelling, Falls

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Received date 29 Nov 2021
Revised date 24 Jan 2022
Accept date 05 Feb 2022

Ⅰ. Introduction

The Population Reference Bureau (PRB) reports that the current 65 and older population in the U.S., driven largely by the baby boomers of 1946-1964, continues to grow at an unprecedented rate.[1)] The nation's average lifespan has experienced a consistent increase over decades as people are living longer and older adults are remaining in the workforce. Maintaining functional mobility and independence with age have become a medical priority and research continues to reveal more about the aging process, such as what can be deemed natural versus preventable. While deterioration of the body is ultimately inevitable, physical ability can be prolonged with proper self-care in order to maintain quality of life.

The natural aging process can lead to a decrease in muscle mass, tissue elasticity, and bone density which can increase the likelihood of developing osteoporosis, especially in women. This may leave the older population susceptible to fractures of the proximal femur, commonly as a result of falling. Mortality rates in older adults after one year of a fracture is 10-20%, an alarming statistic that has been a catalyst for numerous fall risk studies and prevention methods.[2)] According to the Centers for Disease Control (CDC), 25% of community dwellers 65 and older will experience one or more falls every year accounting for 36 million falls and 32,000 deaths.[3)]

With an aging population, Medicare costs are projected to increase six-fold by year 2040.[4)] Aging, fall risk, and medical costs are so intertwined that the CDC created the STEADI (Stopping Elderly Accidents Deaths and Injury) initiative that includes screening, fall risk identity, and various environmental and physical interventions.[5)] Thus, identifying effective balance interventions is imperative for initiatives like STEADI to succeed.

http:dx.doi.org/10.17817/2022.01.24.1111701

The past few decades have provided an explosion of research regarding the effects of exercise, comorbidities, gender, psychological state, nutrition, sedentary lifestyle, and education level on aging. Many systematic reviews on older adults are available, encompassing these broad topics as well as narrowing them down into smaller subgroups. However, the majority of these reviews focus on the effects of exercise in general or exercise in combination with cognitive training. The systematic reviews that pertain to the effects of balance training on fall risk were mostly performed on specific populations, such as those with multiple sclerosis or Parkinson's disease. There is a gap in the literature in terms of meta-analysis and systematic reviews identifying the role of balance training on falls in the 65 and older independent, community dwelling population.

Current fall prevention studies have primarily focused on testing intervention groups against control groups. These interventions target modifiable risk factors such as gait abnormalities, balance deficits, muscle weakness, poor vision, home hazards, and adverse drug effects.[6] This systematic review synthesizes ten select randomized controlled trials (RCTs) that have provided evidence on the effects of balance training in the 65 and older population. All ten RCTs implemented various balance interventions with the goal of improving functional mobility and decreasing risk of falls. Furthermore, the validity and methodological quality of each RCT has been evaluated. The goal of this review is to obtain findings on fall risk interventions and summarize resulting fall reduction rates in order to further inform the field of geriatrics and lead to more advanced studies.

II. Methods

This systematic review was conducted following the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines. The selected search strategy and methods of analysis were registered in the National Institute for Health Research's PROSPERO database (Ref: CRD42021229573).

2.1 Search strategy and eligibility criteria

Four electronic databases (Angelo State University Library, Texas A&M Library, U.S. National Library of Medicine: PubMed, and Physiotherapy Evidence Database: PEDro) were searched systematically in September 2020. In November 2020, a secondary search was conducted to update the initial search. The following search terms, Boolean operators, and combinations were used: "geriatric" OR "elderly" OR "community dwelling older adults" AND "balance exercise" OR "balance intervention" AND "fall risk" OR "falls".

Only English language RCTs conducted after the year 2000, were included in this systematic review. RCTs were included and considered eligible if they examined the effects of a balance intervention and/or balance program on fall risk and/or fall prevalence in adults greater than 65 years of age living in the community.

2.2 Study selection

Researchers independently performed a systematic review using the previously mentioned databases. The researchers screened titles and abstracts to determine eligibility. Studies were excluded if (a) participants were younger than 65 years of age; (b) participants lived in a nursing home, long-term care facility, hospital, or any non-independent residence; (c) the study did not examine the effect of the intervention on fall risk/prevalence; (d) the study did not focus on a specific balance intervention and/or balance program; (e) the results and conclusions were based on a single exercise training session; (f) the RCT was not rated for quality using the PEDro scale; (g) the full text of the study was not available; (h) the study was not written in English.

Selected studies were compiled and discrepancies were resolved with consensus by all researchers. If the researchers were unclear whether a study met selection criteria, advice was sought from the research group until an agreement was reached. Full-text copies of all relevant studies were obtained through journal websites. If the full-text article was not accessible, the article was obtained by emailing the corresponding author. All 10 studies included in this review are

randomized control trials. The methodological quality of these studies was retrieved directly from the Physiotherapy Evidence Database (PEDro).

On the PEDro scale, numerous studies were rated 6/10 or above (Arantes et al.[7], Clemson et al.[8], 2010; Day et al.[9], 2002; El-Khoury et al.[10], 2015; Liu-Ambrose et al.[11], 2019; Lurie et al.[6], 2020; Miko et al.[12], 2017; Okubo et al.[13], 2019), while 2 studies were rated 4/10 or above (Duque et al.[14], 2013; Sakamoto et al.[2], 2013). The highest PEDro score was 8/10 and 3 studies were assigned this score (Clemson et al.[8], 2010; Liu-Ambrose et al.[11], 2019; El-Khoury et al.[10], 2015). A score of 6-8 is considered 'good' and 4-5 is considered 'fair' in terms of methodological quality. Thus, 80% of the studies in this review have good methodological quality and 20% have fair methodological quality.

2.3 Participants

Participants in the included studies were community-dwelling older adults. The definition of older adults varied across multiple studies, with 5 studies including individuals 65 years or older,[6,7,12,13,14] 3 studies including individuals 70 years or older[8,9,11] and finally 2 studies including individuals 75 years or older.[2,10] Three studies focused on women, ranging from pre-frail to osteoporotic female populations.[7,10,12]

2.4 Interventions

All 10 studies administered balance training. Examples of balance interventions included in this review are balance-based home exercise programs,[2] surface perturbation training on treadmills,[6] slips and trips reactive training on walkways,[13] and virtual-reality system balance training.[14] 4 studies conducted a mixed balance and strengthening program.[8,9,11,12] One study included strength and flexibility components to their balance training program.[10]

The duration of interventions ranged from 2 days[13] to 2 years.[10] Sessions were between 1 minute[2] to 60 minutes.[7,9,10] Frequency varied between 1[10] to 5 sessions per week.[2]

2.5 Completion rate, adherence and adverse effects

All 10 studies reported completion rates, ranging from 57.4%[2] (intervention group, IG) to 100%[7] (IG). Adherence to the intervention programs were reported in 4 studies and ranged from 63%[11] to 97%.[14] Three studies reported adverse events. [2,10,13] In one study, 5 participants reported knee pain2. In another study, 7 adverse events were reported including a wrist fracture, twisted ankle, and bruises.[10] In the final study, 8 participants reported adverse effects; 6 were considered minor including foot, groin, shoulder and back pain while 2 were considered major including a possible tear in groin and hamstring muscles.[13]

2.6 Data extraction

Information regarding the participants' characteristics, intervention and control groups, duration of the study, variables and outcome measures, completion rate and adherence, adverse effects, and significant differences were extracted from the gathered studies by the researchers and validated by the research team. The research lead obtained missing data through emailing the authors. Data that was unable to be obtained was considered not reported (NR).

2.7 Quality appraisal

Selected RCTs were directly retrieved from the Physiotherapy Evidence Database (PEDro). The PEDro database stores RCTs, systematic reviews, and evidence-based clinical practice guidelines relevant to physiotherapy. RCTs are rated for quality, validity, and interpretability using the PEDro scale and are awarded a point for an item on the scale if criterion is clearly satisfied. Items on the scale include (a) specified eligibility criteria; (b) random allocation of participants; (c) concealed allocation; (d) similarities in prognostic indicators and demographics between groups at baseline; (d) blinding of the participant; (e) blinding of the administrator; (f) blinding of assessors; (g) outcomes measured from more than 85% of participants; (h) analysis by intention to treat; (i) between-group statistical comparisons reported for at least one outcome and; (i) point measures and meas-

ures of variability for at least one outcome. The categorization of studies using the PEDro scale were excellent (9-10), good (6-8), fair (4-5), and poor (≤3). To eliminate low quality data, selected RCTs with a score less than 4/10 were excluded from further analysis.

2.8 Data synthesis

All studies measured the effects of a balance intervention group versus a control group with the following as a variable: (1) fall rates or (2) number of participant falls. Relative risk reduction (RRR) ratios were calculated with the following equation where CER is the control group event and EER is the experimental group event: RRR= (CER-EER)/CER. In this systematic review, RRR is the lowering of the risk of falls in the balance intervention group when compared to the control group. The 95% confidence intervals (CI) for the RRR ratios were obtained from each published study, corresponding author, or the confidence interval calculator on Creative Research Systems or Calculator.net.

The RRR and the corresponding 95% CI were calculated to assess change in the balance intervention group versus the control group for either fall rate or number of participant falls during the trial and are presented in forest plots respectively. RRR ratios were significant when the corresponding 95% CI excluded 1 (i.e. line of no effect). Positive RRR ratios were indicative of the balance intervention group having a positive treatment effect over the control group, i.e. “favors treatment” for the specified outcome measure.

III. Results

565 citations were recorded from database searches after removal of duplicates. Of these, 15 full text articles were screened against inclusion and exclusion criteria. Following this, a total of 10 studies remained and were included in this systematic review with publications from 2002-2019 (Figure 1) with total subjects of n= 4,703.

3.1 Characteristics of studies included

Information pertaining to the characteristics of participants, interventions, outcome measures, completion rate, adherence, adverse effects and findings from each study are summarized in Table 1.

3.2 Number of falls

All studies measured the effects of a balance intervention group to a control group measuring either as a variable: (1) fall rates or (2) number of participants who fell. Each of the ten studies in this systematic review found significantly fewer fall rates of participants who fell in the balance intervention group when compared to the control group. Lurie et al.[6] (2020) reported injurious falls. Sakamoto et al.[2] (2013) differentiated gender and found significance for women participants. Forest plots are included in Figures 1 (for the six studies reporting total number of falls) and Figure 2 (for the four studies reporting total number of participants who fell) to provide a visual assessment of the heterogeneity or variation in results using like variables. For total number of falls, the control groups had 896.7 total falls while the experimental groups had 623.3 total falls with a relative risk reduction (RRR) ratio of .30 (.27-.33 95% confidence interval (CI)). For total number of participants who fell, the control group had 122.8 total people who fell while the experimental group had 66 people who fell with a RRR ratio of .42 (.38-.46 95% CI). The forest plots in Figures 1 and 2 demonstrate that fall risk and people who fall, respectively, are significantly reduced by balance interventions since none of the confidence intervals touch the line of no effect. All RRR ratios for Figures 1 and 2 fall on the “favors treatment” side of the line of no effect. The 95% confidence intervals for the RRR ratios were obtained from each published study, corresponding author, or the confidence interval calculator on Creative Research Systems or Calculator.net.

Table 1. General Characteristics of the Subjects

Authors	Study Design	Participants	Intervention	Variables	Results
Miko et al., 2017	RCT	*Sample:* n=100 pre, 97 post *Distribution, mean age (SD), % women:* IG: n = 49, 69 (4.56), 100% CG: n = 48, 69 (5.3), 100% *Living status:* Community-dwelling	*Duration*: 12 months *Intervention group (IG)*: 30 minute sessions, 2d/wk of Balance Training Programme in OP with PT, with 3 levels of progressivity performed in a stepwise manner: 1. *Static phase*: focus on stabilization 2. *Dynamic phase*: balance practice in addition to arm and leg exercises 3. *Functional phase*: automatic stabilization of the torso when performing activities of daily life + 60min of ex/day based on ex booklet *Control group (CG)*: Regular osteoporosis treatment with no intervention	• Berg Balance Scale • Timed Up and Go Test (TUG) • Static postural balance by Bretz stabilometer (Average radius of body movement (mm) circle in Romberg 1 & 2) • Dynamic postural balance by Bretz stabilometer (Mean time (seconds) to complete exercise at Dynamic 1 & 2, and % of assigned time spent within boundaries at Dynamic 3) • Frequency of falls	*Recruitment*: 69% (100 out of 144) *Completion rate*: IG: 98% (49 out of 50) CG: 96% (48 out of 50) *Adherence*: NR *Adverse effects*: NR *Significant differences: (P < 0.05)*: IG (pre vs post) • ↑ Berg Balance Scale • ↓ TUG IG when compared to CG: • ↑ Static postural balance (romberg 1&2) @1yrFU • ↑ Dynamic postural balance @1yrFU The relative risk of falling in the intervention group was 0.12 and 0.229 in the control group, respectively ($p < 0.05$).
Liu-Ambrose et al., 2019	RCT	*Sample:* n = 345 pre, 296 post *Distribution, mean age (SD), % women*: IG: n = 172, 81.2 (6.1), 64% CG: n = 172, 81.9 (6.0), 69% *Living status:* Community-dwelling	*Duration*: 12 months *IG*: Usual care plus a home-based strength and balance exercise retraining program delivered by a physical therapist (Otago Exercise Program consisting of 5 strengthening exercises and 11 balance retraining exercises) with exercises performed at home 3x/wk and walking 30+ mins 2x+/wk, with total 5 home visits by PT *CG*: Usual care (based on the American Geriatrics Society Fall Prevention Guidelines) consisting of fall prevention care provided by a geriatrician	• Number of self-reported falls over 12 months • Fall risk (z-score) • Short physical performance battery • Timed Up and Go (TUG)	*Recruitment*: 23% (345 out of 1475) *Completion rate:* IG: 85% (147 out of 172) CG: 87% (150 out of 172) *Adherence*: Balance and strength retraining: 63% Walking: 127% (due to exceeding 2x/wk threshold) *Adverse effects*: NR *Significant differences (P<0.05)*: • ↓ Fall rates in IG compared with CG (IRR, 0.64; 95% CI, 0.46-0.90; P=.009): IG 1.4 (95% CI, 0.1-2.0) per person-year vs CG 2.1 (95% CI, 0.1-3.2) per person-year
Lurie et al., 2020	RCT	*Sample:* n= 506 pre, 490 post *Distribution, mean age (SD), % Women:* *IG: n = 245, 78, 47%* CG: n = 245, 78, 47% *Living Status:* Community-dwelling	*Duration:* *2-3 sessions/week for 4-6 weeks; 45 min sessions* Number, content, and duration of treatment sessions at discretion of PTs Avg number of treatment sessions: 10.4 for IG and CG *IG & CG:* Patients received individualized programs after initial PT evaluation, which included some form of strengthening and flexibility exercises*, static and dynamic balance exercises, mobility training, patient education, and HEP (recommended to be performed 4-5x/week) *IG:* ~15-minute surface perturbation treadmill training sessions	*Primary outcome measures w/ follow-up at 3 mo, 6 mo, 9 mo, and 12 mo* • Number of self-reported falls • Number of self-reported fall related injuries *Secondary Outcome Measures* • Timed Up & Go Test (TUG) • Berg Balance Measure (BBS) • Dynamic Gait Index (DGI) • Activities-specific Balance Confidence (ABC) Scale	*Recruitment:* 60% (898/1507) 56% (506/898) randomized to IG (253) and CG (253) *Completion rate:* IG = 245/253 (96.8%) CG = 245/253 (96.8%) *Adherence:* NR *Adverse Effects:* NR *Significant Differences:* • ↓ fall-related injuries at 3 mo follow-up ($p < 0.003$) • Significant improvements in secondary outcome measures (ABC, BBS, DGI, and TUG) from pre to post-test in both IG and CG ($p < 0.0001$) but not between groups

Table 1. General Characteristics of the Subjects (Continued)

Authors	Study Design	Participants	Intervention	Variables	Results
			harnessed in ActiveStep.		
Day et al., 2002	RCT	*Sample:* n = 1090 pre, 971 post *Distribution, mean age (SD), % Women:* IG: n = 1090, 76.1 (5.0), 59.8% CG: n=137, 75.4 (4.7), 77% *Living status:* Community-dwelling	*Duration:* 18 months *IG:* 7 intervention groups *Exercise:* (n=135) 1-hour exercise class, once per week for 15 weeks; daily home exercise plan designed by PT to improve flexibility, leg strength, and balance *Home Hazard Management:* (n=136) homes inspected and hazards removed by participants themselves or via the city's home maintenance program for free (value up to $54 USD) *Vision:* (n=139) Vision tested and participants referred to usual eye care provider, general practitioner, or local optometrist with vision assessment results. *Exercise & home hazard management (n=135), exercise & vision (n=136), vision & home hazard management (n=137), all three interventions (n=135)* *CG:* n=137 Monthly fall surveillance log without intervention	• Demographic questionnaire • Self-reported health status • Number of previous falls • Modified falls efficacy scale • ADL/IADL performance • Quadriceps strength using spring gauge (weight in kg - best of 3 attempts) • Balance (postural sway, maximal balance range, and coordinated stability using Lord Swayometer) • Timed up and go (TUG) • Visual acuity • Stereopsis (random dot butterfly test, crossed disparity circles) • Glaucoma screening (field of view) • Home hazard assessment tool • Monthly log of falls/injuries during study	*Recruitment:* 55.4% (1090/1967) *Completion Rate:* 89.0% (971/1090) *Adherence:* Exercise IG: 74% (401/541) Home IG: 88% (478/543) Vision IG: 52.5% (287/547) *Adverse Effects:* NR *Significant differences (P < .001):* • ↑ coordinated stability testing and maximal balance range (IG) • ↑quadriceps strength (IG) • ↓ maximal balance range at 18 months (CG) • Decreased home hazards (IG and CG) • ↑ visual acuity (IG) • Exercise, vision, and home hazard management IG resulted in 14% reduction in fall (95% CI 3.7 to 22.6)
Sakamoto et al., 2013	RCT	*Sample:* n=1,788 pre, 865 post *Distribution, mean age (SD), % women:* IG: n = 410, male 80.5 (±4.1), female 80.1(±4.0), 79% CG: n = 455, male 80.7 (±4.0), female 80.5 (±4.1), 82.8% *Living status:* Community-dwelling	*Duration: 6 months* *IG:* HEP of a one-leg standing exercise with eyes open for 1 minute 3 times per day on both legs,with an allowance of 2 days off a week. Participants were allowed to stand near a table or chair for safety. If their free leg touched the ground, they lifted it once more so their total one-leg standing time was 1 minute. *CG*: no HEP given (other activities not listed)	*Initial Baseline Survey* • Self-reported completion of HEP, number of falls, and fracture (fractures were confirmed and recorded by a doctor) • Single-leg stance time with eyes open, without holding on to anything • Number of falls in the last year (using McNemar's test) • Number of fractures in the last year (using paired t-test) • Level of ADL independence (defined by Long Term Care Insurance Act from The Ministry of Health, Labor and Welfare of Japan, 1997; using paired t test)	*Recruitment:* 76.3% (1,365/1,788) eligible *Completion Rate:* *IG*: 57.4% (410/714) *CG*: 69.9% (455/651) *Adherence: NR* *Adverse Effects:*Knee pain (1 male and 4 female in IG) *Significant differences:* • *Male IG* improved single-leg standing time significantly more than the CG (p=0.004 R leg; p=0.011 L leg) • *Female IG* improved single-leg standing time significantly more than CG (p<0.000 for both legs) • DF (body weight) exercise did not seem to prevent falls in male older adults, but a significant difference in falls was seen in women ≥75 years of age (p=0.025) • No significant difference in fracture rate in either group, male or female.
Arantes et al., 2015	RCT	*Sample:* n=30 pre, n=28 post *Distribution, mean age (SD), % women:* IG: n=15, 73.9,	*Duration:* 12 weeks *IG*: 2x/week, 1 hour session (avg # of sessions = 22.1) Balance exercises including static and dynamic standing, single-leg stance, weight	• Number of self-reported falls (patients contacted monthly for 1 year after randomization) *Gait Variables at Minimum and Maximum Speed:* • Speed (cm/s) • Cadence	*Recruitment:* 34.8% (30/86) *Completion rate:* IG: 100% (15/15) CG: 86.6% (13/15) *Adherence:* NR *Adverse Effects:*NR *Significant Differences:* *(p<0.05)*

Table 1. General Characteristics of the Subjects (Continued)

Authors	Study Design	Participants	Intervention	Variables	Results
		100% CG: n=15, 72.2, 100% *Living Status:* community-dwelling	shifts, dynamic weight transfers, and stepping over obstacles. Sensorial conditions were changed as patient progressed (eyes open vs closed, firm vs. unstable surface) *CG:* 1x/week, 1 hour session (avg # of sessions = 10.8) Upper limb exercises including cervical spine, shoulder, and wrist muscle stretches, shoulder rotation, shoulder elevation, and scapular retraction exercises, and relaxation exercises.	• Stride (cm) *Balance, Functional Mobility, and Fear of Falling:* • Falls Efficacy Scale-International (FES-I) • Semi-tandem standing test • Sit-to-stand test • Step test • Risk factors for falling associated with above balance tests	• IG experienced fewer falls than CG during period of intervention (p=.029) *IG: (significant interactions)* • ↑ gait speed (usual and maximal speed) • ↑ stride length (usual and maximal speed) • ↑ Semitandem standing time • ↓ Sit-to-stand time • ↓ Step test time • ↓ Risk factors • ↓ FES-I scores (decreased fear of falling)
Clemson et al., 2010	RCT	*Sample*: n=34 pre, 26 post *Distribution, mean age (SD), % women:* IG: n=81 (5.6), 50% CG: n=82 (6.3), 44% *Living status:* Community dwelling	*Duration*: 6 months *IG*: LiFE intervention with 4 balance strategies and 7 strength strategies used during ADLs. Balance strategies included: *reduced base of support; move to the limits of sway; shift weight from foot to foot; step over objects* (ex. Leaning to one side as far as possible while cleaning teeth). Strength strategies included: *bend your knees; on your toes; on your heels; up the stairs; sit to stand; move sideways; tighten muscles.* (ex. Bend your knees could include squatting to pick up an object). 5 home visits with 2 booster visits over 3 months, w/ 2 phone calls. *CG*: Did not receive any additional contact from the investigators except for falls and follow-up assessments.	(Baseline, 3mo and 6mo): • Rate of falls Physical capacity: • Timed narrow base stance • Timed half tandem stance • Timed tandem stance • Timed one leg stance • Timed tandem walk (3m) • Max isometric lower limb strength using dynamometer (hip flexors, abductors, knee extensors and ankle dorsiflexors) Self efficacy: • Modification falls efficacy scale • activities -specific balance confidence scale • Marcus exercise self-efficacy scale Quality of life: • SF-36 Health status survey • Life Space Assessment	*Recruitment*: 46% (34 out of 74) *Completion rate*: IG: 78% (14 out of 18) CG: 75% (12 out of 16) *Adherence*: NR *Adverse effects*: NR *Significant differences:* IG when compared to CG: • ↓ Fall rate • ↑ Dynamic balance @3mo • ↑ Left knee strength @3mo IG (pre vs 3mo) • ↑ Modification falls efficacy scale (IG) IG (pre vs 6mo) • ↑ Activities-Specific Balance Confidence Scale (IG) •
El-Khoury et al., 2015	RCT	*Sample:* n=706 pre, 600 post *Distribution, mean age (SD), % women:* IG: n=352, 79.8 (2.8), 100% CG: n=354, 79.6 (2.8), 100% *Living status:* Community-dwellin g	*Duration:* 2 years *IG:* Physical activity sessions 1x per week for 1-hour sessions (designed to improve postural stability, muscle extensibility, balance, reaction time, strength, proprioception). Participants performed individualized HEP 1x per week for balance training *CG:* Received baseline and 2-year follow-up examination without intervention and were required to report any incidence of falls.	*Baseline, 1-year midterm, and 2-year follow-up:* • Self-reported fall history • Fear of falling (FES-I) • 6 meter walk test • Tandem walk test (4 steps) • Timed up and go (TUG) • 5x sit-to-stand • Physical functional capacity (balance and motor function tests) • Fear of Falling (FES-I) • Physical activity level (casual walking, walking for exercise, leisure activities) • Perceived health-related quality of life (HRQoL) *Continuous monitoring:* • Incidence of injurious and minor falls (calendar postcard method)	*Recruitment:* 16.7% (706/4221) *Completion rate:* IG: 83.5% (294/352) CG: 86.4% (306/354) *Adherence:* IG: Offered 94.9 (SD 11.6) exercise sessions, 16.5% never started program, median number of sessions attended was 53 (IQR 16-71) *Adverse effects:* 7events; 4 occurred during exercise sessions (wrist fracture, twisted ankle, two bruises), one before exercise (bruise from a fall), two after exercise session (bruise from fall, lumbago) *Significant differences:* Fall Outcomes: • Injurious fall rate 19% lower in IG than CG (hazard ratio 0.81, 95%

Table 1. General Characteristics of the Subjects (Continued)

Authors	Study Design	Participants	Intervention	Variables	Results
					CI 0.67-0.99; p=0.04) • Average number of prevented injurious falls per participant in IG was 0.24 (95% CI 0.02-0.47) Other Outcomes: • ↑ balance and gait performance tests at 1 and 2 years (IG) • ↑ FES-I in IG and CG, with less increase in IG compared to CG • ↓ HRQoL in both IG and CG, with less increase in IG compared to CG • Mean difference between IG and CG was significant for vitality and general health at 1 year and for physical function at 1 and 2 years
Okubo et al., 2019	RCT	*Sample:* n=44 pre, 41 post *Distribution, mean age (SD), % women:* IG: n=22, 73.3 (5.9), 59% CG: n=22, 70.8 (4.9), 55% *Living status:* Community-dwelling	*Duration:* Three, 40 minute sessions plus post assessment (IG) or one 40 minute session plus post assessment (CG) *IG:* Three 40-min sessions (120 min total) to expose (1) 20 trips, (2) 20 slips and (3) 10 trips and 10 slips in mixed order, over 2 days. **Slips were induced by a movable tile on two hidden rails that could slide forward up to 70cm upon foot contact, and trips were induced using a 14cm height tripping board that flipped up from the walkway at missing using a hidden foot sensor. Slipping tile and tripping board were movable to maintain unpredictability** *CG:* One 40 minute session of "sham training" - participants walked on the same walkway with a harness, without perturbations. Sham training involved stepping on target tiles.	*Primary Outcomes:* • Falls (harness load >30% body weight in harness) when exposed to trips and slips at post-assessment *Secondary Outcomes:* • Gait speed (m/s) • Cadence (steps/min) • Step length (cm) Trips: • Margin of stability (cm) • XCoM (extrapolated center of mass) position (cm) • Step length (cm) • Step height (cm) • Trunk sway range (deg) Slips: • Margin of stability (cm) • XCoM position (extrapolated center of mass) (cm) • Step length (cm) • Foot contact angle (deg) • Trunk sway angle (deg) • Slip speed (cm/s) • Slip distance (cm)	*Recruitment:* 47% (44/94) *Completion rate:* 93% (41/44) *Adherence:* NR *Adverse effects:* 8 participants reported adverse events; 2 experienced foot pain due to trips, 5 complained of groin, shoulder and/or back pain due to impact of being caught by harness, 1 aggravated hamstrings pain when a slip accidentally occured following a trip. 6 cases were minor (solved within a week) and 2 were major (possible tear in groin and hamstring muscle) *Significant differences: (p<0.05)* • Fall incidences in post assessment: IG had lower incidences of all falls (p=0.005) and slip falls (p=0.029) compared to CG During recovery form trips: • IG's XCoM position (extrapolated center of mass) less anterior vs. CG • IG's recovery stepping foot higher compared to CG • IG's trunk sway range smaller compared to CG During recovery from slips: • IG less posterior XCoM position compared to CG • IG had shorter backward step length compared to CG • IG had smaller trunk sway range compared to CG
Duque et al., 2013	RCT	*Sample:* n= 60 pre, 58 post *Distribution, mean age (SD), % women:* IG: n=30, 79.3 (10), 63% CG: n=30, 75 (8), 61% *Living status:* Community-dwelling	*Duration:* 9 months *IG:* 30 mins of BRU (Balance Rehabilitation Unit) training 2x/week for first 6 wks on top of usual care* for 9 months BRU training protocol: Combination of visual-vestibular rehabilitation (saccadic, optokinetic stimulation, vestibular optokinetic and vestibular-ocular reflex exercises performed while standing) and postural training virtual reality exercises (3 different postural games with increasing levels of complexity, max 15	*Fall related measures:* • Incidence of falls • Survey of Activities and Fear of Falling in the Elderly (SAFFE) *Parameters of posturography:* • Limits of stability (LOS); maximum sway on platform before losing stability • Center of pressure (COP) at 6 different conditions: Open eyes & closed eyes on hard surface, eyes closed on foam, various visual stimuli using 3D virtual-reality goggles (saccadic condition combined with optokinetic bars in 4 different directions and visual-vestibular conditions)	*Recruitment:* 60 recruited (rate not reported) *Completion rate:* 97% (58 out of 60) *Adherence:* 97% *Adverse effects: Significant differences: (p<0.05)* After 6 weeks of BRU training: • ↑ LOS • ↓ elliptical areas of COP: eyes closed on hard surface, eyes closed on foam, optokinetic stimuli, and vertical and horizontal VVC (visual vestibular condition) IG when compared to CG @9mo • ↑ LOS • ↓ COP areas in optokinetic

Table 1. General Characteristics of the Subjects (Continued)

Authors	Study Design	Participants	Intervention	Variables	Results
			levels, with the goal of reaching level 10 in every game by the end of training period. *CG:* 9 months of usual care* *Usual care = invitation to join an exercise program (Otago protocol), medication review, home visit by an occupational therapist, hearing and visual assessment, nutritional supplements, vit D supplement, and educational materials on falls prevention.		stimuli • Vertical and horizontal VVC Fall related measures @9mo: • Both groups showed significant reduction in falls with IG reporting significantly lower number of falls • IG reported significantly lower SAFE score compared to CG

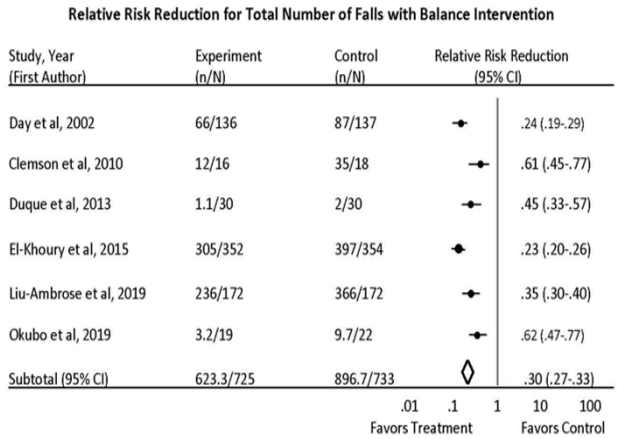

Figure 1. Forest plot displaying the relative risk reduction (RRR) of falls due to balance interventions. The vertical line represents the line of no effect, such that there is no association between the experimental group and the control group if studies touch that line. Circles represent relative risk reduction due to the balance interventions for each study with larger circles indicating more impact due to larger sample size and/or smaller CI. Horizontal lines are the 95% confidence intervals. Diamond represents subtotal data of all balance interventions on rate of falls reduction. N=total participants in that group, and n=number of falls in that group. RRR= (CER-EER)/CER; CER=control group rate, EER=experiment group rate

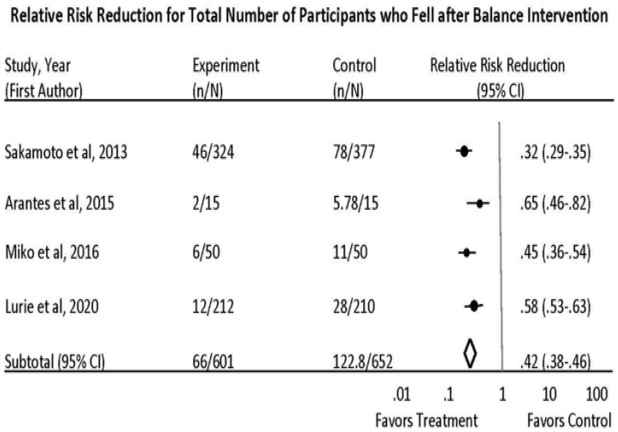

Figure 2. Forest p1ot displaying the relative risk reduction (RRR) of participants falls in the group with balance interventions. The vertical line represents the line of no effect such that there is no association between the experimental group and the control group if studies touch that line. Circles represent relative risk reduction due to the balance interventions for each study with larger circles indicating more impact due to larger sample size and/or smaller CI. Horizontal lines are the 95% confidence intervals. Diamond represents subtotal data of all balance interventions on rate of falls reduction. N=total participants in that group, and n=number people who fell in that group. RRR= (CER-EER)/CER

3.3 Other common outcomes

Secondary measures were used in all 10 RCTs to assess the effectiveness of balance training programs on various outcomes other than falls, such as functional mobility and fear of falling. The following results were found significant in intervention groups compared to control groups.

El-Khoury et al. (2015), Liu-Ambrose et al. (2019), Lurie et al. (2020), and Miko et al. (2017) Five studies[6,10,12] included the Timed Up and Go test, with significant improvements recorded in 3 of 4. Three studies utilized the Falls Efficacy Scale, with significant improvements in all three.[7,8,10] Two studies included the Berg Balance Scale with significant improvements in both.[6,12] Two studies utilized the Activities-specific Balance Confidence scale with significant improve-

ments in both.[6,8] Two studies used the Sit-to-stand test, with significant improvements in both.[7,10] Two studies used instrument-assisted balance measures (ex. postural sway using a sway meter), with significant improvements (in at least one measure).[9,12]

Ⅳ. Discussion

The aim of this review was to examine current literature in order to identify the effects of various balance training programs on fall risk and number of falls in the community dwelling older adults. These two criteria, balance training and community dwelling older adults, distinguish this systematic review from others that have primarily focused on other populations and diagnoses (stroke, Parkinson's disease, multiple sclerosis, children, etc) or numerous modes of physical activity in older adults (aerobic exercise, resistance exercise, balance and functional training). To achieve this objective, 10 studies with fair to good methodological quality, determined by the PEDro scale, were included in this review after a thorough screen against exclusion and inclusion criteria established by the researchers. Only RCTs were considered for selection, providing a stronger comparison of the results of each study. To minimize bias in the selection process, each independently selected study was reviewed by the remaining researchers and research advisor before final acceptance into this review. Additionally, this review was submitted to the PROSPERO database to register the results for appraisal.

Each of the 10 studies included a form of balance training with participants residing in the community, as opposed to a nursing home or long-term living facility. The required age ranges varied slightly with 5 studies including participants 65 years or older, 3 including participants 70 years or older, and 2 including participants 75 years or older. Completion rates for the intervention and control groups in the 10 studies ranged from 57.4% to 100% and 69.9% to 100%, respectively. When the completion rates were averaged, there was only a 2.11% difference between the intervention (86.74%) and control (88.85%) groups. Sakamoto et al. (2012) reported the lowest completion rates for both their intervention group (57.4%) and control group (69.9%). Interestingly, this study only prescribed the intervention group one balance exercise to be performed at home without the guidance of a clinician. In comparison, five studies required participants in the intervention group to attend balance training sessions comprised of multiple exercises in the outpatient setting.[6,7,9,10,12,14] One study utilized a research lab.[13] Lastly, two studies required participants to perform the intervention in their own homes with a visiting physical therapist.[8,11] A home exercise program was also prescribed in addition to the in-person clinician-guided sessions in most of these studies. It is possible clinician guidance and support played a role in completion rates. Adverse events were only reported in three of the ten studies, and ranged from minor to severe.[2,10,13] Okubo et al.[13] (2019) reported adverse events in both the intervention group and control group, likely due to both groups participating in activity with the control group receiving a "sham training". Conversely, the control groups in the studies performed by Sakamoto et al.[2] (2012) and El-Khoury et al.[10] (2015) did not participate in the intervention and therefore injuries were limited to the intervention groups.

The forms of balance exercise and length of the intervention period varied among the ten studies. The intervention duration ranged from 2 days[10] to 2 years.[13] Six studies inquired about the number of falls or participants who fell during the intervention period or immediately after the intervention ended. Only 4 studies followed up with participants a significant time after the treatment period had ended.[6,7,9,14] These time periods ranged from 6 weeks to 14 months. Each of the studies can be grouped by the type of balance training utilized. Lurie et al.[6] (2020) and Okubo et al.[13] (2019) included surface perturbation training. Arantes et al.[7] (2015) and Sakamoto et al.[2] (2012) incorporated static and dynamic balance training with or without changing sensorial conditions. Duque et al.[14] (2013) investigated virtual reality balance training. The remaining five studies used a combination of static

and dynamic balance training, muscle strengthening, and flexibility training.[8,9,10,11,12]

Of these categories of balance training, the surface perturbation and virtual reality programs required more costly equipment, including a treadmill, virtual reality system, motion-capture system, and electronic walkway, compared to the remaining studies that utilized more simple balance and/or strengthening interventions with less expensive equipment, such as foam pads or stopwatches. In both Lurie et al.[6] (2015) and Duque et al.[14] (2013), physical therapists were responsible for guiding the interventions. This is also true of the studies included in both the static and dynamic balance training and combination groups. The surface perturbation training included in the Okubo study was administered by trained research assistants. Lurie et al.[6] (2015) confirmed no additional education was required prior to the study for the physical therapists involved in the treadmill perturbation training. While not explicitly stated by Duque et al.[14] (2013), it is likely the physical therapists received additional training to administer the virtual reality system balance training. In summary, the majority of balance interventions utilized in these studies could be replicated by other clinicians with no further training.

All studies revealed significantly fewer fall rates or number of participants that fell after completing balance training compared to the control groups regardless of type of balance training or length of the training program. Both Lurie et al.[6] (2015) and El-Khoury et al.[10] (2015) reported on the proportion of participants with an injurious fall and those with an injurious or non-injurious falls (any fall). This is unique from the other studies in this review that only reported on falls in general. Injurious falls have greater consequences than non-injurious falls, often leading to hospitalization with the associated medical costs, loss of independence, and decreased quality of life.[15] Balance interventions that could reduce fall-related injuries would be of great value to clinicians and patients alike. Sakamoto examined the effects of the single leg stance balance exercise and found a significant reduction in the proportion of female participants who fell. However, there was no significant difference for male participants. The disproportionate ratio of men to women in both the intervention (86 men, 324 women) and control (78 men, 377 women) groups may partially explain this result. When considering baseline characteristics of participants in the intervention groups, there was a higher prevalence of osteoporosis in women (77.5%) compared to men (19.8%). Additionally, less women reported participation in regular physical activity than men. With a higher prevalence of osteoporosis and a lower activity level at baseline, the balance intervention may have posed a greater challenge to the female participants leading to improvements in single leg standing and significantly less falls.

Six of the studies reported the total number of falls while the remaining 4 studies reported the total number of participants who fell after the balance intervention. Because of this difference in outcome variables, two forest plots, Figure 1 and Figure 2, were created to visualize the results. These forest plots are unique from others that solely represent the risk ratio, or the probability of an undesirable outcome to the intervention group divided by the probability of an undesirable outcome in the control group. The forest plots created for this review illustrate the relative risk reduction (RRR) and the extent to which the balance interventions reduced either the total number of falls (Figure 1) or total number of participants who fell (Figure 2) relative to the control groups. For all 10 studies, the RRR ratios and their corresponding 95% confidence intervals favored balance intervention and remained clear of the line of no effect. When the data was pooled together for the 6 studies that examined total number of falls, the RRR ratio was calculated as .30. In contrast, the RRR ratio was .42 for the combined data of the 4 studies that measured the total number of participants who fell.

Falls are the leading cause of injury in older adults aged 65 and older and, as the older population grows, fall-related injuries and the associated healthcare costs are expected to increase.[16] Various outcome measures have been created to predict fall risk in the older population and are frequently used by physical therapists in the clinical setting. Many of the

studies included in this review utilized both performance-based and self-reported outcome measures to assess fall risk. Five studies[6,9,10,11,12] included the Timed Up and Go (TUG) test as an outcome measure. Two studies6,12 utilized the Berg Balance Scale. Two studies[7,10] included the Sit to Stand (STS) test. Two studies measured gait speed. [7,13] The Activities-specific Balance Confidence (ABC) scale was used in two studies6,8, and the Dynamic Gait Index (DGI) was utilized in one study.[6] Only two of the ten studies did not include any secondary fall risk assessment measures.[13,14] The prevalence of the use of these outcome measures throughout the studies supports the idea that fall risk assessment can be an important first step in establishing a fall prevention program.[17,18,19]

The findings of this systematic review support balance training and the combination of balance and exercise training as an effective intervention in reducing falls. As previously stated, the type of balance training and length of the intervention period varied throughout the 10 studies. A majority of the studies implemented common balance exercises, either alone or in combination with typical upper and lower body strength and flexibility training. Additionally, in five studies[6,7,9,10,12], physical therapists either assisted in the design of the balance program or had full discretion on the prescription of balance exercises. It can be presumed that current practicing clinicians most likely implement balance training similar to that utilized in these studies. However, further research is necessary to identify the most effective balance interventions to reduce fall risk and occurrence of falls.

4.1 Limitations

There are several limitations of this review that must be addressed. During the process of searching for literature, relevant studies may have been excluded if the full text could not be accessed or if the language could not be translated to English. Additionally, 2 studies with PEDro scores of 4/10 or 5/10, which represents “fair” methodological quality, were included due to the difficulty locating RCTs that met the inclusion and exclusion criteria. Of the 10 selected studies, 5 had relatively small sample sizes, ranging from 15 to 50 participants. When analyzing the data, if the confidence intervals (CI) were not provided within the study or from the corresponding authors after they were contacted, Calculator.net or Creative Research Systems were used to calculate the CIs. Due to the difference in outcome variables, 2 forest plots were created to demonstrate the relative risk reduction of the total number of falls (6 studies) and total number of participants who fell (4 studies). However, because of this separation, these groups of studies cannot be directly compared or combined. The final limitation to consider is the variety of interventions utilized throughout the 10 studies. Four studies combined balance and strengthening exercises. Additionally, 1 study combined balance, strength, and flexibility training. For these 5 studies, it is unlikely the pure effects of balance training were being assessed. Some utilized common balance exercises while others explored more complex interventions with costly equipment. Regardless of these differences, they all demonstrated significantly fewer falls or participants who fell after the intervention. Additionally, many of the studies found improvements for baseline to follow-up in outcome measures that assess fall risk. This supports that balance training of various forms can be beneficial in reducing fall risk and number of falls in community dwelling older adults. Future research should focus on establishing the most effective, feasible form of balance training to decrease fall risk and fall rates in community dwelling older adults.

Ethics approval and right to participate

N/A.

Consent for publication

All authors provide consent for publication.

Availability of data and material

This research was a systematic review with a systematic methodology. Therefore, no data is available.

Funding resource

This report is independent research and did not re-

quire funding. The views expressed in this publication are those of the authors.

Declaration of competing interests

There are no competing interests.

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