Original Article

Effectiveness of a short-term and simple exercise training program for older adults

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ABSTRACT

While there have been many studies determining the effectiveness of training programs to decrease fall risk in the elderly, most of them require special equipment, leader training, or major time commitments (more than 8 weeks, multiple times per week). Individuals older than 66 years old identified an exercise program offered at home, twice a week, lasting 10 or 30 minutes, and with no associated cost as being more attractive than other training program options offered (Franco et al., 2015). The objective of this study was to determine the effectiveness of a simple six-week exercise program on fall risk factors. Thirty-eight older adults were assigned to a Training Group or a Control Group. Investigator-led balance and lower extremity strength exercises were performed twice a week. Mobility, leg strength and postural sway were measured before and after the six weeks for both groups. A survey determined perceptions of participant abilities and fear of falling at three different times. Timed Up and Go times decreased ($p = .008$), leg strength increased ($p = .022$), and postural sway decreased in the anteroposterior direction and overall, for the Training Group ($p < .05$) while the Control group displayed no differences. Surveys administered determined no differences for the Control group, but the Training Group perceived that they had better balance, mobility, and leg strength and a decreased fear of falling ($p < .05$). This simple training program led to changes that would likely decrease fall risk and did so in an extremely short time.

Keywords: Fall risk; Elderly exercise; Postural sway; Training program; Elastic bands.

Cite this article as:
LeBlanc, M., Linville, T., & Calkins, M. (2020). Effectiveness of a short-term and simple exercise training program for older adults. *Journal of Human Sport and Exercise*, *in press*. doi:https://doi.org/10.14198/jhse.2021.163.20

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Submitted for publication February 25, 2020
Accepted for publication May 04, 2020
Published *in press* May 15, 2020
JOURNAL OF HUMAN SPORT & EXERCISE ISSN 1988-5202

doi:10.14198/jhse.2021.163.20

INTRODUCTION

The number of adults that are over sixty years old is increasing drastically worldwide. It is projected to increase from 962 million in 2017 to 1.4 billion in 2030 and to 2.1 billion in 2050 (Ortman et al., 2014). Falls and the injuries associated with those falls are a major concern for this age group with about 30% of older adults (those at least 65 years old) experiencing a fall each year (Bergen et al., 2016). Falls are the second leading cause of non-intentional deaths with 646,000 individuals dying from falls globally each year (Burns & Kakara, 2018). Research has shown that older adults who are physically active experience fewer falls (Wright et al., 2012) as well as improvements in their quality of life (Barbosa et al., 2019).

The fear of falling has been correlated with the incidence of falls (Delbaere et al., 2004), with decreased quality of life (Chang et al., 2016), and with the avoidance of activity (Zijlstra, et al., 2007). Recent research has revealed that even when corrected for health status and falls, activity-limiting worry is associated with decreased informal and formal social engagement (Choi et al., 2019). The percentage of older adults that have a fear of falling has been reported to be 36.2% (Boyd & Stevens, 2009) and for those 70 years and older it is 54.3% (Zijlstra et al., 2007).

While many fall prevention programs include multiple components, such as exercise, education, socialization, specialist referral, and home modification, it has been concluded that programs that focus on exercise alone are about five times more effective than programs that involve multiple components (Petridou et al., 2009). Activities in previous exercise fall prevention training programs vary greatly and have included Pilates (Bird & Fell, 2014), Tai Chi (Yu & Yang, 2012), water activities (Fisher et al., 2004), high speed power movements (Pereira, et al., 2012), chair-based exercises (Vogler et al., 2009), strength training (Sousa & Sampaio, 2005), virtual reality (Park & Kim, 2016), and combinations of activities (de Oliveira et al., 2014; Justine et al., 2011; Kamide et al., 2009; Nagy et al, 2007; Patil et al., 2015). Some of these programs have been shown to be effective, yet many of these programs are quite demanding and/or complex and may not be appropriate for an older adult who is physically inactive. It is common for the aforementioned programs to require special, and sometimes expensive, equipment or instructors with particular leadership training. Additionally, transportation may hinder individuals' ability to participate in the program if classes are held outside the home at a community or fitness centre. Finally, with social activities and medical appointments, having a set schedule for exercise, both days of the week and time of the day, can create a roadblock for adherence. Program flexibility and simplicity are important to maximize adherence.

When reviewing elderly exercise program effectiveness, Cadore et al. (2013) recommended that programs that incorporate multiple factors be used, rather than one solely focused on balance or strength. A meta-analysis of factors related to fall risk concluded that gait deficits, muscle weakness, and balance deficits are strongly associated with fall risk and can increase the risk by 290%, 440%, and 290%, respectively (Rubenstein & Josephson, 2002). Thus, is it important that any future program incorporate activities that improve all three factors. Recent research has identified preferences that older adults have for exercise programs (Franco et al., 2015). Specifically, individuals older than 66 years old identified an exercise program that is offered at home, twice a week, lasting 10 or 30 minutes, and with no associated cost as being more attractive than other training program options offered. While many studies have investigated fall prevention programs, the current literature is lacking a proven program that meets the specific desired characteristics identified by Franco et al. (2015). Additionally, the existing programs require a much larger time commitment, both per training session and the number of weeks, and have not measured strength, balance, mobility, confidence and fear of falling with both a training group and a control group. A study that meets the desires of this population and tests these physical and psychological characteristics would be an important and novel addition to the existing literature.

The aim of this study was to determine the effectiveness of a simple and short duration in-home training program on older adults' fall risk by measuring their mobility, strength and balance. In particular, the study desired to determine if significant improvements could be made in six weeks with the program taking place only twice a week for approximately 20 minutes per session in the participants' home. Additionally, participants' fear of falling and their perception of their own intrinsic factors related to fall risk were assessed.

METHODS

Participants

Thirty-eight individuals were recruited from local senior community centres and churches to participate in this study. Most of these participants lived independently, but some lived in a senior residential facility. All participants read and signed a consent form that had been approved by the university's Institutional Review Board prior to participating in the study. To be included in the study, participants had to be at least 65 years old, and not participating in an exercise program. Participants who had been hospitalized or had surgery within a year of the start of the study were excluded. If a participant had a major illness (e.g. cancer), was unable to stand unassisted for at least five minutes, or had any other health conditions that would prevent them from being able to do simple physical activities they were excluded from the study. Their health status was confirmed by a health questionnaire that each participant filled out after giving consent. The questionnaire was reviewed by the principal investigator to verify the appropriateness of the participants' engagement in the study.

Once they were deemed eligible, each participant was assigned to either the Control Group (N = 19; 13 females, 6 males) or the Training Group (N = 19; 12 females, 7 males). Group assignment was quasi-random with both age and gender being matched between the two groups. There was no significant difference in the two group's ages (76.8 ± 6.1 years vs. 78.2 ± 5.7 years for the Control Group and Training Groups, respectively) or masses (70.9 ± 19.4 kg vs. 77.9 ± 18.9 kg for the Control Group and Training Groups, respectively). The Control Group was instructed to continue their normal lifestyle and to not begin a regular exercise program during the duration of the study.

Procedures

The Training Group participated in six weeks of training that was held twice a week in the participants' home. Two investigators directed the participants through a series of exercises with the same investigator working with a particular participant for each training session for the duration of the study. The training sessions were separated by at least one day but no more than four days. All participants were tested before and after the six weeks of normal activity (Control Group) or of training (Training Group). Participants were not given any information about their testing values until the entire study was completed. Control Group members were later offered the opportunity to participate in a similar training study.

Training consisted of nine simple exercises that used either an elastic band for resistance or the participant's body weight. Additionally, participants used a stable (non-rolling) backed chair for many of the exercises. Table 1 provides a list of the exercises and the desired number of sets and repetitions. An investigator led the participant through all of the exercises, giving verbal encouragement, and logging the number of repetitions and sets that were completed. This log was used to plan for subsequent training sessions.

Participants began by performing Step Ups which required them to step up completely onto and then completely down from a stair step with alternating lead legs. Participants used a railing, wall or the investigator for stability, if needed. Participants then completed the next four exercises with each leg using an elastic band with a looped end and a free end. The Hip Abduction and Knee Flexion exercises began with the participant standing behind a stable, high backed chair with their hands resting on the chair for stability. They placed the band's looped end around one ankle and stepped on the free end with their other (support) foot. For Hip Abductions they raised their non-support leg to their side (hip abduction) in a slow, controlled fashion to approximately 30 degrees and then slowly lowered their leg. For the Knee Flexion exercises they flexed the knee of their non-support leg to approximately 90 degrees in a controlled fashion and then extended their knee slowly. Investigators were careful to avoid having participants flex their knee more than 90 degrees to avoid hamstring cramping. The Seated Knee Extension exercise began with the participant sitting upright in the chair with both hips and knees flexed approximately 90 degrees. With the looped end of the band around the ankle of their extending leg and the free end under the foot of their stationery leg, they slowly extended their knee so that it was almost fully extended and then slowly lowered it to its starting position. The last exercise that used an elastic band was the Leg Press which participants performed seated near the front edge of their chair while leaning back against the chair back. Each hand held a different end of the band with the middle of the band passing under one foot. With their hip flexed so their knee was at about chest level and their knee flexed approximately 90 degrees, they extended their hip and knee simultaneously so their foot was at about hip height. If a participant was unable to perform any of these four elastic band exercises, they would simply use their own leg weight to create adequate resistance. In contrast, if the movement felt extremely easy for the participant, they were encouraged to increase the band resistance by decreasing the length of the band or using a stiffer elastic band.

The final exercises were all weight-bearing exercises. To perform a Chair Sit, participants stood in front of their chair, squatted down slowly as if to sit down in the chair, then prior to touching the chair, stood back up. Participants held their arms in front of them to assist in their balance. The last three exercises were performed while participants stood behind their chair with both hands on the chair back. For the Toe Raises and Heel Raises the participant stood with their feet shoulder width apart and raised both toes or heels off the floor. The final exercise, Single-Leg Balances, required participants to stand on one foot for as long as they could maintain their balance. Participants alternated the support foot and were encouraged to count how long they could maintain their balance on a single foot. For all of the exercises that used the chair for stability, participants were encouraged to lessen their dependence on the chair for stability as they progressed.

Table 1. Training Program Description. Training exercises performed during each session for each leg.

Exercise	**Goal**
1. Step Ups (alternating R leading with L leading)	3 sets of 10-12
2. Standing Hip Abductions with elastic band (R and L)	3 sets of 10-12
3. Standing Knee Flexions with elastic band (R and L)	3 sets of 10-12
4. Seated Knee Extensions with elastic band (R and L)	3 sets of 10-12
5. Seated Leg Press with elastic band (R and L)	3 sets of 10-12
6. Chair Squats	3 sets of 2-10
7. Standing Heel Raises	3 sets of 10-12
8. Standing Toe Raises	3 sets of 10-12
9. Single Leg Balances (R, then L = 1 cycle)	5-8 cycles

Note: R = right leg, L = left leg.

Measurements

A series of three tests measuring each participant's static balance, mobility, and leg strength were administered prior to and after the six weeks of training that took place for the Training group. Data from the first testing session was not shared with the participants or investigators before the second testing session. Each testing session took approximately 45 minutes to complete.

Static balance was measured using a single Kistler 9281CA force plate (Amherst, NY) which was embedded in the laboratory floor. Participants stood in socks or barefoot on the force plate which collected data at 100 Hz. Participants used a self-selected stance determined by first marching in place a few steps to obtain their own natural stance width. Participants were asked to focus on a large black dot which was 3 meters away and instructed to try to stand as still as possible with their arms relaxed and laying by their sides. The dot's height was adjusted for each participant to ensure a consistent relative height (at approximately eye level). An investigator stood next to each participant during this testing in case of a loss of balance. After the first trial, each participant's foot placement was traced onto a piece of paper which was already affixed to the force plate surface to ensure consistent foot placement for all of that participant's trials. Four trials lasting 40 seconds each were collected with participants resting in a chair for approximately two minutes between trials. Centre of pressure data collected using BioWare 3.0 software (Amherst, NY) was filtered using a fourth order zero phase Butterworth filter with a cut-off frequency of 5 Hz. Each trial was analysed for the last 30 seconds to ensure that participants were steady during the analysis time period. The mean distance, anteroposterior mean distance, and mediolateral mean distance from the average location of the centre of pressure was computed (Prieto et al., 1996). Additionally, the root mean square (RMS) distance, anteroposterior RMS distance, and mediolateral RMS distance were also computed (Prieto et al., 1996). Finally, the overall range of the anteroposterior centre of pressure and mediolateral centre of pressures were calculated. Values from the four trials were averaged for each participant for analysis. Each participants' foot tracing was affixed to the force plate for post-testing to ensure their foot placement was consistent for all balance measurements.

Mobility was measured using the Timed Up and Go Test (Podsiadlo & Richardson, 1991). Participants sat in a chair with seat height 44 cm with their back against the chair back. The chair was placed against a wall to prevent the chair from sliding on the floor. When instructed to "Go" by a simultaneous visual and audio cue, participants got up out of the chair, walked to and then around a mark on the floor which was 3 meters away, walked back towards the chair, and then sat down in the chair. Participants were instructed to walk as quickly as they felt comfortable, but not to run. The time for each trial was measured from the start cue to when the participants' back contacted the chair back after they returned from their walk around the mark. Each participant completed three trials with seated rest for at least a minute between trials. Trials were timed with a stopwatch and a digital video camera set at 60 Hz. The video data was used to confirm the stopwatch times and to use in case of an error in starting or stopping the watch. The stopwatch data was used for analysis due to its ability to measure to the nearest hundredth of a second, as opposed to the nearest 1/60th of a second for the video. The fastest time, rather than the average, was used for analysis because the investigators encouraged participants to become accustomed to the activity first and then focus on increasing their speed.

Isometric leg strength was measured using a Biodex System 3.0 isokinetic dynamometer (Shirley, NY). Participants sat upright in the machine's chair with approximately 90 degrees of hip flexion and 90 degrees of knee flexion. Two straps were placed across the participant's chest, one strap was placed across their hips and one across their right thigh to prevent contributions from other body parts. The dynamometer axis was aligned with their right knee joint centre. Participants completed three sets of five repetitions which included 5 seconds of maximum effort isometric knee extension at their right knee, followed by 15 seconds of rest. Ninety seconds of rest was given between each set. Participants were verbally encouraged during the contractions and were instructed to gently ramp up their force and not to violently kick their leg out. The maximum torque (in Nm) produced during any of the trials was used for analysis.

Approximately nine weeks after post-testing, participants attended a reception held to share the study results and individual data. Prior to any results or data being shared, each participant was asked to complete a survey. The survey asked participants to rate their balance, mobility, leg strength and concern about falling at three different times: (1) at their pre-testing; (2) at their post-testing; (3) on the day of the reception. For the balance, mobility and leg strength questions, a score of one indicated the worst and a score of ten indicated the best. For the concern for falling, a score of one indicated greatest fear and a score of ten indicated no fear at all.

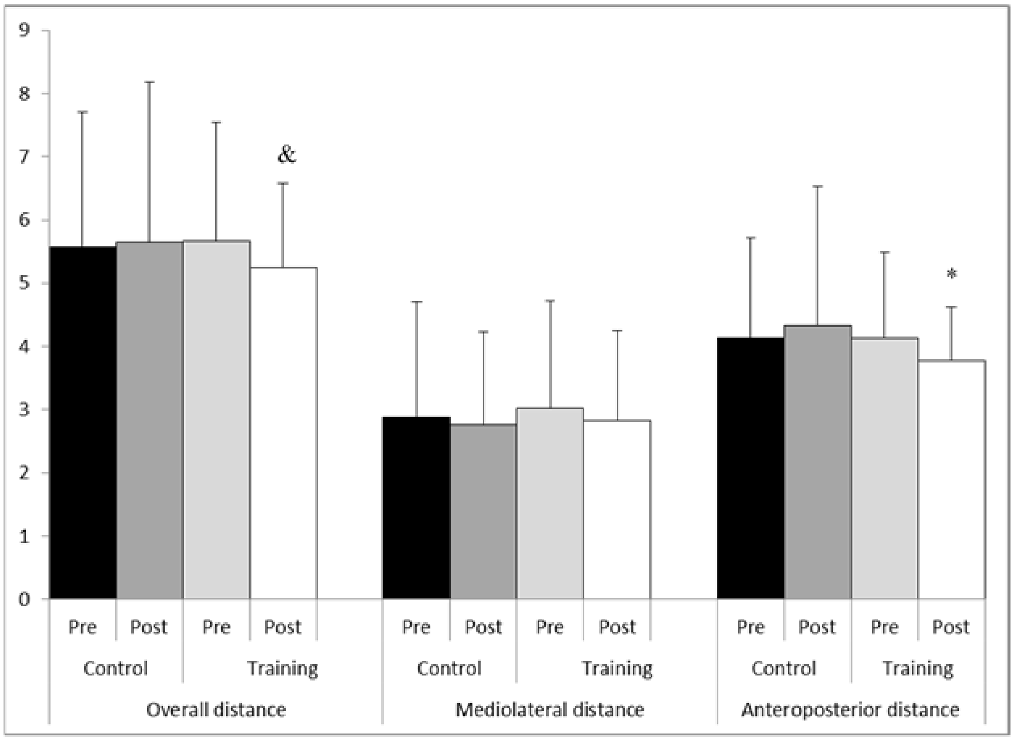
Statistical analysis

Data were analysed using SPSS v25 software (SPSS Inc. Chicago, IL). To determine if the two groups were equivalent prior to the training, independent t-tests were used to compare the two group's age, body mass and pre-test values for the Timed Up and Go, postural sway and leg strength tests. To directly determine if the training exercises decreased fall risk, paired one-tailed t-tests were run with the pre- and post-testing values for the Timed Up and Go, postural sway measures and leg strength for the Training group. To determine the consistency of these measures over time, the pre- and post-testing values for the Control group were compared using paired two-tailed t-tests. The decision to use t-tests and not repeated measures ANOVA was due to the one-tailed nature of the research question and the desire to focus on each group separately. For the survey data, a one-way ANOVA was run for each group to compare participant ratings for their balance, mobility, leg strength and fall concern over time. For any dependent variable that was found to have a main effect, the effect size was determined and post hoc testing was performed to determine which time pairs differed from one another. Additionally, pre-study survey values were compared between the two groups using an independent t-test to determine any differences between the groups prior to the training program. Significance for all statistical tests was reported at $p < .05$.

RESULTS

Seventeen of the nineteen participants in the Training Group completed the study while eighteen of the nineteen participants in the Control Group completed the study. Two female participants dropped out because they were unable to return for post-testing due to vacation plans and one female participant dropped out because of a voluntary (non-emergency) surgery. There remained no significant difference in the ages or masses between the Control and Training Groups.

Figure 1 depicts the average postural sway distance values from the mean centre of pressure (COP) overall, in the mediolateral direction and in the anteroposterior direction for the two testing sessions for each group. There were no significant differences between any of the three mean distance values between the two groups in the initial testing session. The Training Group showed a trend towards a decrease in the overall distance before and after training ($p = .051$) and the average anteroposterior distance after the training decreased significantly from the value prior to training ($p = .042$). The Control Group had no significant differences between any of their three distance values collected six weeks apart.

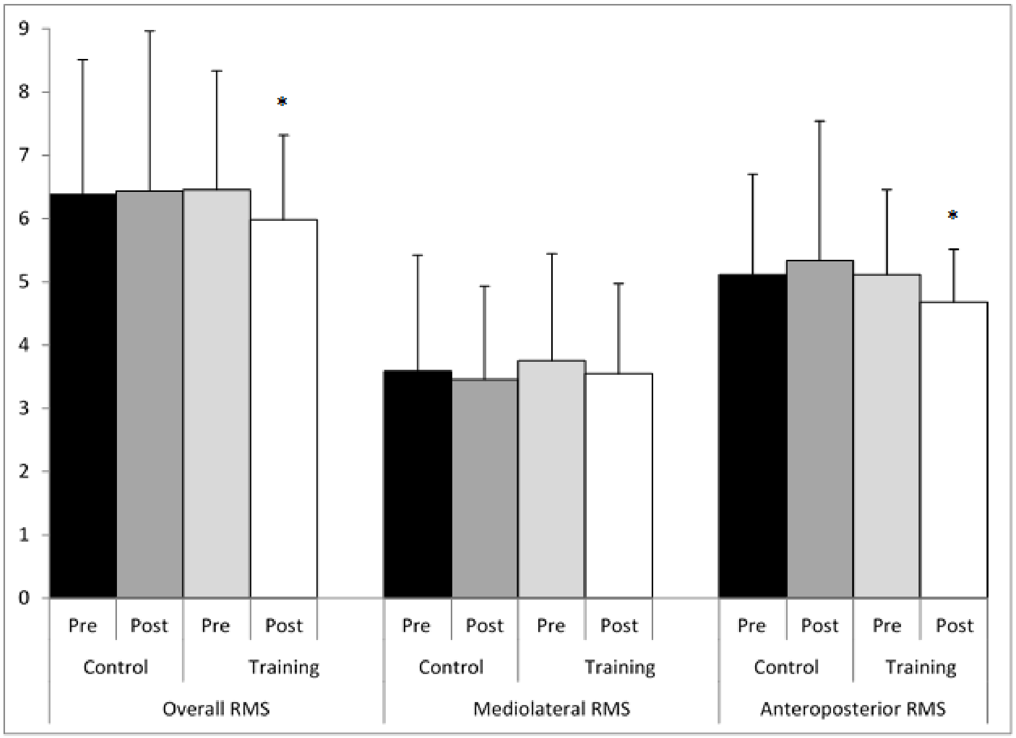


*Note: Error bars indicate the standard deviation for each data set. * denotes Post value is significantly smaller than the Pre value (p < .05) & denotes a trend towards a significant decrease in value (p < .10).*

Figure 1. Centre of pressure mean distance from the average centre of pressure data. Mean values for the Control Group and Training Group from the initial testing session (Pre) and the final testing session (Post) for the overall distance from the average centre of pressure, the mediolateral distance from the average centre of pressure and the anteroposterior distance from the average centre of pressure (in mm).

Figure 2 depicts the postural sway root mean square (RMS) from the mean COP values overall, in the mediolateral direction, and in the anteroposterior direction for the two groups for the two testing sessions. There were no significant differences between the two groups' overall, mediolateral or anteroposterior RMS values in the initial testing sessions. The average overall RMS and anteroposterior RMS values decreased after the training ($p = .046$ and $p = .038$, respectively). The Control Group had no significant differences in their overall, mediolateral or anteroposterior RMS values collected six weeks apart.

The range of the COP values in the mediolateral direction for the Training Group were not significantly different pre-training and post-training (18.2 ± 8.0 mm vs. 17.6 ± 7.0 mm, respectively), but the range of the COP values in the anteroposterior direction were different after training (24.4 ± 5.6 mm vs. 22.4 ± 3.9 mm pre-training and post-training, respectively; $p = .026$). The Control group did not have a significant difference in their mediolateral range of COP between the two sessions (18.0 ± 8.2 mm vs. 16.9 ± 7.1 mm initial and final testing, respectively), nor between their anteroposterior range of COP (25.2 ± 7.7 mm vs. 25.4 ± 9.5 mm initial and final testing, respectively). The two group's range values did not differ from one another in the mediolateral or anteroposterior directions in the initial testing sessions.



*Note: Error bars indicate the standard deviation for each data set. * denotes Post value significantly smaller than the Pre value ($p < .05$).*

Figure 2. Centre of pressure average root mean square from the average centre of pressure data. Mean values for the Control Group and Training Group from the initial testing session (Pre) and the final testing session (Post) for the overall root mean square (Overall RMS) from the average centre of pressure, the RMS in the mediolateral direction (Mediolateral RMS) and the RMS in the anteroposterior direction (Anteroposterior RMS), all given in mm.

Table 2 provides the Timed Up and Go (TUG) and leg strength results for both groups before and after the six weeks. There was no significant difference in the two groups' initial testing values for either test. The Training group significantly improved their Timed Up and Go times and leg strength ($p = .008$ and $p = .022$, respectively), whereas no significant change was found for either of these measures for the Control Group.

Table 2. Timed Up and Go (TUG) and Leg Strength Test Results. Mean (standard deviation) test values from the initial (Pre) and final (Post) testing sessions for Timed Up and Go (TUG) and leg strength are provided below.

Group	Pre TUG (s)	Post TUG (s)	Pre Leg Strength (Nm)	Post Leg Strength (Nm)
Control	10.69 (5.24)	10.30 (3.98)	115.7 (44.9)	114.7 (37.8)
Training	10.55 (3.26)	9.60 (3.59)*	113.8 (45.8)	124.4 (40.9)*

*Note: * indicates a statistically significant improvement from Pre value to Post value ($p < .05$).*

The participant's perceptions of their balance, mobility, leg strength and fear of falling are provided in Table 3. There was no difference between the two group's values at the initial testing session for any of the four items. There was no main effect of time on any of the four perception values for the Control Group. However, the Training Group did show a main effect for all four perception values. There was a main effect of time on balance ($p < .001$, $\eta^2 = .454$) with both the post-testing and reception perception values differing from the pre-testing values ($p = .009$ and $p = .001$, respectively). There was a main effect of time on mobility ($p < .001$, $\eta^2 = .537$) with both the post-testing and reception perception values differing from the pre-testing values ($p = .006$ and $p < .001$, respectively). There was a main effect of time on leg strength ($p < .001$, $\eta^2 = .515$) with both the post-testing and reception perception values differing from the pre-testing values ($p = .008$ and $p = .001$, respectively). There was a main effect of time on fear of falling ($p = .021$, $\eta^2 = .276$) with both the post-testing and reception perception values differing from the pre-testing values ($p = .016$ and $p = .040$, respectively).

Table 3. Subject Perception Values. Mean (standard deviation) perception values for both groups before the first testing session (Pre), after the second testing session (Post), and at approximately nine weeks after the second testing session (Reception). For balance, mobility and leg strength, lower values indicate a worse rating and for fear of falling lower values indicate a greater fear. All scales are from 1 (worst) to 10 (best).

	Control			**Training**		
	Pre	**Post**	**Reception**	**Pre**	**Post**	**Reception**
Balance	5.8 (2.0)	6.3 (2.2)	6.1 (1.8)	5.5 (2.0)	7.3 (1.8)*	7.6 (2.2)*
Mobility	6.3 (1.8)	6.6 (2.2)	6.2 (1.9)	5.9 (2.1)	7.4 (1.9)*	7.8 (1.9)*
Leg strength	6.2 (1.9)	6.6 (2.1)	6.1 (1.8)	5.5 (1.9)	7.1 (1.8)*	7.6 (2.1)*
Fear of falling	5.8 (2.4)	6.5 (2.4)	6.3 (2.7)	6.3 (2.8)	7.4 (2.3)*	7.2 (2.6)*

*Note: * denotes that the value is significantly greater from the Pre-test perception value ($p < .05$).*

DISCUSSION

The training program was effective at improving participants' mobility, strength and postural sway and led to greater confidence in the participants' physical abilities and less fear of falling. Many previous studies have used the TUG test to measure mobility and determine the effectiveness of a variety of training programs. The majority of the programs that have been effective have been longer in duration than the current study and/or have met more frequently. There have been a few programs shorter than 8 weeks that have been able to evoke improved mobility, as determined by faster TUG times. A six week balance enhancing training program which met four times a week, on average, with more rigorous components such as quarter turn jumps was conducted with a younger population (Hafström et al., 2016). They reported TUG and balance improvements but did not include a control group. Nagy et al. (2007) conducted an eight-week long training program which focused on strength, flexibility and balance. Their participants showed improved mobility, but their postural control results were mixed. An eight-week long Pilates-inspired training program with younger and more mobile participants reported increased mobility and some postural sway improvements but did not include a control group (Kaesler et al., 2007). None of these shorter programs investigated leg strength and so their overall effectiveness at decreasing fall risk is unknown. Additionally, they did not include an assessment on the fear of falling of the participants. The current study provides a fast and efficient way to improve mobility by lowering TUG times for this population.

The increase in leg strength experienced by the Training Group likely indicates a decrease in their fall risk due to the strong relationship between fall risk and muscle strength (Rubenstein & Josephson, 2002). Several previous studies lasting 12 weeks or longer have determined that training programs can lead to lower extremity strength increases in older adults. Patil et al. (2015) used step boards and various modes of weights in a two-year training program. Leg extensor strength was increased by 14% over the control group, but there was no difference in TUG times and balance measures were not performed. The current study found a 9.3% increase in strength over the six weeks of training. A 16-week long training program focused on strengthening the knee and ankle musculature increased peak knee extension strength by a similar amount to the current study (11%) but their sample size was very small (n = 4 for training, n = 5 for control) and neither mobility nor balance were measured (Pijnappels et al., 2008). Another strength training focused study was performed for 14 weeks with a similar population and also reported strength increases and TUG improvements, but no balance measurements were collected in their study (Sousa & Sampaio, 2005). A balance training study conducted for 12 weeks reported knee extensor strength increases and dynamic balance improvements, but did not investigate mobility (Gusi et al., 2012). None of the programs effective in increasing leg strength have also increased both stability and mobility. The current study is unique in creating greater leg strength without special equipment or professional instruction and also providing mobility and stability benefits, along with a decrease in the fear of falling.

The initial postural sway values for both groups, in both the anteroposterior and mediolateral directions, compared well to previous studies that reported the same measures for similar populations (Fukusaki et al., 2016; Kim et al., 2010; Maki et al., 1994; Prieto, et al., 1996; Swanenburg et al., 2009). The results of other exercise training programs that measure postural sway values with a force plate have reported various outcomes. A recent meta-analysis performed on exercise interventions intended to improve postural control concluded that balance exercise interventions are effective for decreasing total and AP sway length and velocity measures with eyes open in double stance (Low et al., 2017). However, they concluded that programs that focused on resistance training or that were multicomponent did not affect any sway measure. Their analysis did not consider the effectiveness of any program to improve mobility or leg strength.

Several individual studies have determined that exercise training can improve postural sway values. Four different training regiments have determined sway improvements, but in different directions. A six-month long training program emphasizing swimming decreased sway path lengths and areas for both the intervention group and the control group (Kawasaki et al., 2011). Three varieties of gymnastics-based training for 12 weeks were effective at decreasing sway area and both mediolateral and anteroposterior sway velocity (de Oliveira et al., 2014) and a 24 weeklong Tai Chi program found similar results (Yu & Yang, 2012). Rogers et al. (2001) reported that a 10-week long training program involving stretching, strengthening and balance training altered sway in the mediolateral direction, but not the anteroposterior direction. It should be noted that none of the four aforementioned studies considered mobility or leg strength, both important elements of fall risk.

Some studies have investigated both postural sway and mobility for this population. Nagy et al. (2007) reported unusual results of participants having improved mobility and no difference in the anteroposterior sway direction but increasing their mediolateral sway path after 8 weeks of aerobic, balance and resistance training. Their low sampling rate (16 Hz) may have contributed to their unexpected sway results. Six weeks of interactive videogames has been found to decrease sway area and velocity as well as TUG times (Lai et al., 2013). Another shorter (5 weeks) training program involving obstacle courses did not result in postural sway changes, however their control participants increased their AP velocity (Weerdesteyn et al., 2006). No strength or mobility was determined for their study. A longer training program (6 months) compared a strength and balance exercise program to a flexibility and balance exercise program and determined no change in double stance static balance for either group (Judge et al., 1993). The strength and balance group did increase their knee extension strength while the flexibility and balance group did not. Mobility was not measured. Finally, Paquette et al. (2015) investigated 8 weeks of stationary bike or agility/reaction time training and found neither decreased postural sway measures.

Previous research has identified that individuals classified as fallers have larger postural sway values overall, in the mediolateral, and/or anteroposterior directions when compared to non-fallers (Maki, et al., 1994; Melzer, et al., 2010; Pajala et al., 2008; Stel et al., 2003; Swanenburg et al., 2009). Thus, the decreases exhibited by the Training Group members in the current study suggests that they may have decreased their fall risk through their participation in the training program.

Fear of falling has been reported to be predictive of future falls (Delbaere et al., 2004; Stel et al., 2003). Many other training programs have measured fear of falling and have determined that it can be decreased by various types of exercise. However, most of these programs were 12 or more weeks in duration (Banez et al., 2008; Gusi et al., 2012; Delbaere et al., 2006; Liu-Ambrose et al., 2004; Nicholson et al., 2014;). There have also been long programs that have not found any differences in fear of falling (Nicholson, et al., 2014; Paquette, et al., 2015; Shigematsu et al., 2008).

Three shorter programs that have created a decrease in the fear of falling but none of them investigated leg strength. A six-week training program similar to the current study's but with more challenging components such as rotational jumps reported a decreased fear of falling, faster TUG times, but no similar changes in postural sway (Hafström et al., 2016). They intended on their training to be performed daily but reported that it was performed four times a week, on average. Lai et al. (2013) used an interactive videogame-based training program for 6 weeks with training 3 times per week. Participants lowered their fear of falling, their TUG times, and postural sway. Weerdesteyn et al. (2006) performed a shorter training program (5 weeks) using an obstacle course twice a week for 90 minutes a session. Training participants decreased their fear of falling but showed no change in postural sway and their mobility was not tested. The current study is unique in measuring fear of falling not only before and immediately after a training program, but also determining the long-term effects of the training on fear of falling.

While this training program was found to be effective for these participants, it may not be inferable to older adults whose physical status differs greatly from those tested in this study. The participants selected for this study were in good health and involved in no physical activity programs. Even participants with low physical functionality were able to complete the program. For those who dropped out of the training program, it was not due to the program being too difficult, rather it was due to personal situations (e.g. required surgery or extended vacations). Older adults who are more physically active would not likely benefit from this training program as it may not be rigorous enough to stimulate physical or neural changes for them. It is also important to note that the participants who participated in this study are not necessarily typical of this population. Individuals who choose to volunteer for a research study are likely more motivated and outgoing than the typical individual. However, this is a limitation of every research project that involves training. Another limitation of this study was that the training was led by investigators and their oversight may be difficult to duplicate outside of this study. However, because the program requires little equipment or specialty training, it is easier to initiate than most exercise training programs. Future studies should consider whether a single session of training per week might also be effective at creating changes in these three important physical measures and participant perceptions. Additionally, further follow up to determine the long-term efficacy for fall prevention by this training program should be determined.

CONCLUSION

In conclusion, the simple training program was effective in eliciting physical changes that are known to reduce fall risk. Overall, participants who participated in training experienced a decrease in their TUG times, indicating an increase in their mobility. They were able to increase their leg strength significantly which may enable them to recover from a loss of balance more effectively than a weaker individual. Additionally, those study participants who underwent the training experienced changes in various overall and AP postural sway measures indicating greater stability. All three physical measurements taken resulted in favourable and significant changes that are associated with decreased fall risk for this population. This study is unique in reporting changes in all three measures and inducing these changes in such a short amount of time and session frequency and duration.

Those participants who underwent the exercise training program became more confident in their abilities. They ranked their mobility, strength and balance after the six weeks of training and about nine weeks after the training ended as better than they were when the study commenced. They also reported less concern for falling at these two time points when compared to their concern before the study. These perceptions are important in that they influence what activities the older adults will participate in and they are also linked to fall risk with less risk being associated with less fear of falling.

The results of this study provide extremely helpful information for health care providers. Practitioners can bundle elastic bands (including various resistance levels) and the instructions for the exercises together and distribute these bundles to the older adults they oversee. Additionally, they can distribute these bundles to family members that visit the older adults frequently and answer any questions they may have about the program. Residential program directors could create an incentive program to encourage their residents to complete the training twice a week for six weeks or more. Alternatively, residential program directors could conduct a class at their centre if their residents wanted a group setting that would include the social benefits often associated with exercise adherence promotion. Finally, practitioners could consider making a video to guide older adults through the various exercises.

AUTHOR CONTRIBUTIONS

Michele LeBlanc: substantial contributions to the research design, data collection, analysis, drafting of manuscript and revisions, approval of final manuscript. Tiffany Linville: substantial contributions to the research design, conducting subject training, data collection, manuscript revisions, and approval of final manuscript. Michael Calkins: substantial contributions to the research design, conducting subject training, data collection, manuscript revisions, and approval of final manuscript.

SUPPORTING AGENCIES

No funding agencies were reported by the authors.

DISCLOSURE STATEMENT

No potential conflict of interest was reported by the authors.

REFERENCES

Banez, C., Tully, S., Amaral, L., Kwan, D., Kung, A., Mak, K., ... & Alibhai, S. M. (2008). Development, implementation, and evaluation of an interprofessional falls prevention program for older adults. Journal of the American Geriatrics Society, 56(8), 1549-1555. https://doi.org/10.1111/j.1532-5415.2008.01790.x

Barbosa, B. T., Silva, R. L. S. D., Meneses, A. B. C. D., Brindeiro-Neto, W., Bacurau, T. P., Rocha, A. I. S. D. S., ... & Brasileiro-Santos, M. D. S. (2019). Self-related quality of life of elderly submitted to a 12-week aquatic training program. Journal of Human Sport and Exercise, 14(2), 281-291. https://doi.org/10.14198/jhse.2019.142.03

Bergen, G., Stevens, M.R., & Burns, E.R. (2016). Falls and fall injuries among adults aged ≥ 65 years—United States, 2014. MMWR. Morbidity and Mortality Weekly Report, 65. https://doi.org/10.15585/mmwr.mm6537a2

Bird, M. L., & Fell, J. (2014). Positive long-term effects of Pilates exercise on the age-related decline in balance and strength in older, community-dwelling men and women. Journal of Aging and Physical Activity, 22(3), 342-347. https://doi.org/10.1123/japa.2013-0006

Boyd, R., & Stevens, J. A. (2009). Falls and fear of falling: burden, beliefs and behaviours. Age and Ageing, 38(4), 423-428. https://doi.org/10.1093/ageing/afp053

Burns, E., & Kakara, R. (2018). Deaths from falls among persons aged≥ 65 years—United States, 2007–2016. Morbidity and Mortality Weekly Report, 67(18), 509. https://doi.org/10.15585/mmwr.mm6718a1

Cadore, E. L., Rodríguez-Mañas, L., Sinclair, A., & Izquierdo, M. (2013). Effects of different exercise interventions on risk of falls, gait ability, and balance in physically frail older adults: a systematic review. Rejuvenation Research, 16(2), 105-114. https://doi.org/10.1089/rej.2012.1397

Cancela Carral, J. M., Pallin, E., Orbegozo, A., & Ayan Perez, C. (2017). Effects of three different chair-based exercise programs on people older than 80 years. Rejuvenation Research, 20(5), 411-419. https://doi.org/10.1089/rej.2017.1924

Chang, H. T., Chen, H. C., & Chou, P. (2016). Factors associated with fear of falling among community-dwelling older adults in the Shih-Pai study in Taiwan. PloS One, 11(3), e0150612. https://doi.org/10.1371/journal.pone.0150612

Choi, N. G., Bruce, M. L., Dinitto, D. M., Marti, C. N., & Kunik, M. E. (2019). Fall worry restricts social engagement in older adults. Journal of Aging and Health, 0898264319825586. https://doi.org/10.1177/0898264319825586

de Oliveira, M. R., da Silva, R. A., Dascal, J. B., & Teixeira, D. C. (2014). Effect of different types of exercise on postural balance in elderly women: a randomized controlled trial. Archives of Gerontology and Geriatrics, 59(3), 506-514. https://doi.org/10.1016/j.archger.2014.08.009

Delbaere, K., Bourgois, J., Van Den Noortgate, N., Vanderstraeten, G., Willems, T., & Cambier, D. (2006). A home-based multidimensional exercise program reduced physical impairment and fear of falling. Acta Clinica Belgica, 61(6), 340-350. https://doi.org/10.1179/acb.2006.054

Delbaere, K., Crombez, G., Vanderstraeten, G., Willems, T., & Cambier, D. (2004). Fear-related avoidance of activities, falls and physical frailty. A prospective community-based cohort study. Age and Ageing, 33(4), 368-373. https://doi.org/10.1093/ageing/afh106

Fisher, N. M., Dolan, D. M., Brenner, C., & Pendergast, D. R. (2004). Quantitative effects of a water exercise program on functional and physiological capacity in subjects with knee osteoarthritis: A pilot study. Sport Sciences for Health, 1(1), 17-24. https://doi.org/10.1007/s11332-004-0004-x

Franco, M. R., Howard, K., Sherrington, C., Ferreira, P. H., Rose, J., Gomes, J. L., & Ferreira, M. L. (2015). Eliciting older people's preferences for exercise programs: a best-worst scaling choice experiment. Journal of Physiotherapy, 61(1), 34-41. https://doi.org/10.1016/j.jphys.2014.11.001

Fukusaki, C., Masani, K., Miyasaka, M., & Nakazawa, K. (2016). Acute positive effects of exercise on center-of-pressure fluctuations during quiet standing in middle-aged and elderly women. The Journal of Strength & Conditioning Research, 30(1), 208-216. https://doi.org/10.1519/jsc.0000000000001062

Gusi, N., Adsuar, J. C., Corzo, H., del Pozo-Cruz, B., Olivares, P. R., & Parraca, J. A. (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. https://doi.org/10.1016/s1836-9553(12)70089-9

Hafström, A., Malmström, E. M., Terdèn, J., Fransson, P. A., & Magnusson, M. (2016). Improved balance confidence and stability for elderly after 6 weeks of a multimodal self-administered balance-enhancing exercise program: a randomized single arm crossover study. Gerontology and Geriatric Medicine, 2. https://doi.org/10.1177/2333721416644149

Judge, J. O., Lindsey, C., Underwood, M., & Winsemius, D. (1993). Balance improvements in older women: effects of exercise training. Physical Therapy, 73(4), 254-262. https://doi.org/10.1093/ptj/73.4.254

Justine, M., Hamid, T. A., Mohan, V., & Jagannathan, M. (2011). Effects of multicomponent exercise training on physical functioning among institutionalized elderly. ISRN Rehabilitation, 2012. https://doi.org/10.5402/2012/124916

Kaesler, D. S., Mellifont, R. B., Kelly, P. S., & Taaffe, D. R. (2007). A novel balance exercise program for postural stability in older adults: a pilot study. Journal of Bodywork and Movement Therapies, 11(1), 37-43. https://doi.org/10.1016/j.jbmt.2006.05.003

Kamide, N., Shiba, Y., & Shibata, H. (2009). Effects on balance, falls, and bone mineral density of a home-based exercise program without home visits in community-dwelling elderly women: a randomized controlled trial. Journal of Physiological Anthropology, 28(3), 115-122. https://doi.org/10.2114/jpa2.28.115

Kawasaki, T., Sullivan, C. V., Ozoe, N., Higaki, H., & Kawasaki, J. (2011). A long-term, comprehensive exercise program that incorporates a variety of physical activities improved the blood pressure, lipid and glucose metabolism, arterial stiffness, and balance of middle-aged and elderly Japanese. Hypertension Research, 34(9), 1059. https://doi.org/10.1038/hr.2011.81

Kim, J. W., Eom, G. M., Kim, C. S., Kim, D. H., Lee, J. H., Park, B. K., & Hong, J. (2010). Sex differences in the postural sway characteristics of young and elderly subjects during quiet natural standing. Geriatrics & Gerontology International, 10(2), 191-198. https://doi.org/10.1111/j.1447-0594.2009.00582.x

Kyrdalen, I. L., Moen, K., Røysland, A. S., & Helbostad, J. L. (2014). The Otago exercise program performed as group training versus home training in fall-prone older people: a randomized controlled trial. Physiotherapy Research International, 19(2), 108-116. https://doi.org/10.1002/pri.1571

Lai, C. H., Peng, C. W., Chen, Y. L., Huang, C. P., Hsiao, Y. L., & Chen, S. C. (2013). Effects of interactive video-game based system exercise on the balance of the elderly. Gait & Posture, 37(4), 511-515. https://doi.org/10.1016/j.gaitpost.2012.09.003

Liu-Ambrose, T., Khan, K. M., Eng, J. J., Lord, S. R., & McKay, H. A. (2004). Balance confidence improves with resistance or agility training. Gerontology, 50(6), 373-382. https://doi.org/10.1159/000080175

Low, D. C., Walsh, G. S., & Arkesteijn, M. (2017). Effectiveness of exercise interventions to improve postural control in older adults: a systematic review and meta-analyses of centre of pressure measurements. Sports Medicine, 47(1), 101-112. https://doi.org/10.1007/s40279-016-0559-0

Maki, B. E., Holliday, P. J., & Topper, A. K. (1994). A prospective study of postural balance and risk of falling in an ambulatory and independent elderly population. Journal of Gerontology, 49(2), M72-M84. https://doi.org/10.1093/geronj/49.2.m72

Melzer, I., Kurz, I., & Oddsson, L. I. (2010). A retrospective analysis of balance control parameters in elderly fallers and non-fallers. Clinical Biomechanics, 25(10), 984-988. https://doi.org/10.1016/j.clinbiomech.2010.07.007

Nagy, E., Feher-Kiss, A., Barnai, M., Domján-Preszner, A., Angyan, L., & Horvath, G. (2007). Postural control in elderly subjects participating in balance training. European Journal of Applied Physiology, 100(1), 97-104. https://doi.org/10.1007/s00421-007-0407-x

Nicholson, V. P., McKean, M. R., & Burkett, B. J. (2014). Twelve weeks of BodyBalance® training improved balance and functional task performance in middle-aged and older adults. Clinical Interventions in Aging, 9, 1895. https://doi.org/10.2147/cia.s71769

Ortman, J. M., Velkoff, V. A., & Hogan, H. (2014). An aging nation: the older population in the United States (pp. 25-1140). Washington, DC: United States Census Bureau, Economics and Statistics Administration, US Department of Commerce.

Pajala, S., Era, P., Koskenvuo, M., Kaprio, J., Törmäkangas, T., & Rantanen, T. (2008). Force platform balance measures as predictors of indoor and outdoor falls in community-dwelling women aged 63–76 years. The Journals of Gerontology Series A: Biological Sciences and Medical Sciences, 63(2), 171-178. https://doi.org/10.1093/gerona/63.2.171

Park, J., & Yim, J. (2016). A new approach to improve cognition, muscle strength, and postural balance in community-dwelling elderly with a 3-D virtual reality kayak program. The Tohoku Journal of Experimental Medicine, 238(1), 1-8. https://doi.org/10.1620/tjem.238.1

Paquette, M. R., Li, Y., Hoekstra, J., & Bravo, J. (2015). An 8-week reactive balance training program in older healthy adults: A preliminary investigation. Journal of Sport and Health Science, 4(3), 263-269. https://doi.org/10.1016/j.jshs.2014.06.004

Patil, R., Uusi-Rasi, K., Tokola, K., Karinkanta, S., Kannus, P., & Sievänen, H. (2015). Effects of a multimodal exercise program on physical function, falls, and injuries in older women: a 2-year community-based, randomized controlled trial. Journal of the American Geriatrics Society, 63(7), 1306-1313. https://doi.org/10.1111/jgs.13489

Pereira, A., Izquierdo, M., Silva, A. J., Costa, A. M., Bastos, E., González-Badillo, J. J., & Marques, M. C. (2012). Effects of high-speed power training on functional capacity and muscle performance in older women. Experimental Gerontology, 47(3), 250-255. https://doi.org/10.1016/j.exger.2011.12.010

Petridou, E. T., Manti, E. G., Ntinapogias, A. G., Negri, E., & Szczerbińska, K. (2009). What works better for community-dwelling older people at risk to fall? A meta-analysis of multifactorial versus physical exercise-alone interventions. Journal of Aging and Health, 21(5), 713-729. https://doi.org/10.1177/0898264309338298

Pijnappels, M., Reeves, N. D., Maganaris, C. N., & Van Dieen, J. H. (2008). Tripping without falling; lower limb strength, a limitation for balance recovery and a target for training in the elderly. Journal of Electromyography and Kinesiology, 18(2), 188-196. https://doi.org/10.1016/j.jelekin.2007.06.004

Podsiadlo, D., & Richardson, S. (1991). The timed "Up & Go": a test of basic functional mobility for frail elderly persons. Journal of the American Geriatrics Society, 39(2), 142-148. https://doi.org/10.1111/j.1532-5415.1991.tb01616.x

Pondal, M., & del Ser, T. (2008). Normative data and determinants for the timed "up and go" test in a population-based sample of elderly individuals without gait disturbances. Journal of Geriatric Physical Therapy, 31(2), 57-63. https://doi.org/10.1519/00139143-200831020-00004

Prieto, T. E., Myklebust, J. B., Hoffmann, R. G., Lovett, E. G., & Myklebust, B. M. (1996). Measures of postural steadiness: differences between healthy young and elderly adults. IEEE Transactions on Biomedical Engineering, 43(9), 956-966. https://doi.org/10.1109/10.532130

Rogers, M. E., Fernandez, J. E., & Bohlken, R. M. (2001). Training to reduce postural sway and increase functional reach in the elderly. Journal of Occupational Rehabilitation, 11(4), 291-298.

Rubenstein, L. Z. & Josephson K.R. (2002). The epidemiology of falls and syncope. Clinics in Geriatric Medicine, 18, 141-58. https://doi.org/10.1016/s0749-0690(02)00002-2

Shigematsu, R., Okura, T., Sakai, T., & Rantanen, T. (2008). Square-stepping exercise versus strength and balance training for fall risk factors. Aging Clinical and Experimental Research, 20(1), 19-24. https://doi.org/10.1007/bf03324743

Sousa, N., & Sampaio, J. (2005). Effects of progressive strength training on the performance of the Functional Reach Test and the Timed Get-Up-and-Go Test in an elderly population from the rural north of Portugal. American Journal of Human Biology, 17(6), 746-751. https://doi.org/10.1002/ajhb.20446

Stel, V. S., Smit, J. H., Pluijm, S. M., & Lips, P. (2003). Balance and mobility performance as treatable risk factors for recurrent falling in older persons. Journal of Clinical Epidemiology, 56(7), 659-668. https://doi.org/10.1016/s0895-4356(03)00082-9

Swanenburg, J., De Bruin, E. D., Uebelhart, D., & Mulder, T. (2009). Compromising postural balance in the elderly. Gerontology, 55(3), 353. https://doi.org/10.1159/000212757

Vogler, C. M., Sherrington, C., Ogle, S. J., & Lord, S. R. (2009). Reducing risk of falling in older people discharged from hospital: a randomized controlled trial comparing seated exercises, weight-bearing exercises, and social visits. Archives of Physical Medicine and Rehabilitation, 90(8), 1317-1324. https://doi.org/10.1016/j.apmr.2009.01.030

Weerdesteyn, V., Rijken, H., Geurts, A. C., Smits-Engelsman, B. C., Mulder, T., & Duysens, J. (2006). A five-week exercise program can reduce falls and improve obstacle avoidance in the elderly. Gerontology, 52(3), 131-141. https://doi.org/10.1159/000091822

Whitehurst, M. A., Johnson, B. L., Parker, C. M., Brown, L. E., & Ford, A. M. (2005). The benefits of a functional exercise circuit for older adults. Journal of Strength and Conditioning Research, 19(3), 647. https://doi.org/10.1519/00124278-200508000-00027

Wright, R. L., Robinson, P. D., & Peters, D. M. (2012). Lifetime adherence to physical activity recommendations and fall occurrence in community-dwelling older adults: A retrospective cohort study. Journal of Human Sport and Exercise, 7(1), 310-320. https://doi.org/10.4100/jhse.2012.71.09

Yu, D. H., & Yang, H. X. (2012). The effect of Tai Chi intervention on balance in older males. Journal of Sport and Health Science, 1(1), 57-60. https://doi.org/10.1016/j.jshs.2012.03.001

Zijlstra, G. A. R., Van Haastregt, J. C. M., Van Eijk, J. T. M., van Rossum, E., Stalenhoef, P. A., & Kempen, G. I. (2007). Prevalence and correlates of fear of falling, and associated avoidance of activity in the general population of community-living older people. Age and Ageing, 36(3), 304-309. https://doi.org/10.1093/ageing/afm021

