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A Home-based Exercise Program for the Foot and Ankle to Improve Balance, Muscle Performance and Flexibility in Community Dwelling Older Adults: A Pilot Study

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A Home-based Exercise Program for the Foot and Ankle to Improve Balance, Muscle Performance and Flexibility in Community Dwelling Older Adults: A Pilot Study

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Abstract

Background and purpose: Strength and range of motion of the foot and ankle have been shown to be related to measures of balance and fall risk in older adults. The primary purpose of this pilot investigation was to evaluate the feasibility of a 6-week home-based exercise program focusing on the foot and ankle and any associated changes in balance, muscle performance and range of motion in older adults.

Methods: This single-group repeated measures study involved a convenience sample of 21 healthy community-dwelling older adults age 60-90. Nineteen participants completed all phases of the testing and training. The intervention was a 6-week home-based exercise program focusing on ankle musculature performed 3 times per week. Outcome measures were assessed on three separate occasions: baseline, pre-intervention, and post-intervention. Outcome measures included the Mini-Balance Evaluation Systems Test (Mini-BESTest), gait speed, Timed Up and Go (TUG), Activities Specific Balance Confidence Scale (ABC), gastrocnemius muscle strength and ankle dorsiflexion range of motion.

Results: Following the intervention, there were significant improvements in the Mini-BESTest, gait speed, TUG, gastrocnemius strength and ankle dorsiflexion range of motion. There was also significant positive relationship between improvements in the Mini-BESTest and gastrocnemius strength. There were no unanticipated adverse events and compliance was high.

Conclusions: A simple but progressive home-based exercise program for the foot and ankle appears to be feasible for older individuals and may lead to meaningful improvements in measures of balance and mobility. Further research of this targeted intervention may be warranted.

Keywords: Older adult; Balance; Exercise; Home; Strength; Flexibility; Foot; Ankle

Background and Purpose

Maintenance of balance involves a complex interaction between the somatosensory, visual, vestibular and musculoskeletal systems. There is growing body of evidence that suggests certain characteristics of the foot and ankle may play a particularly important role in balance and postural control. More specifically, strength of the dorsiflexors and plantar flexors have been correlated with measures of postural sway [1], walking speed [2], stair climbing [3], sit to stand performance [4] and other functional movements [5]. Additionally, older adults with a loss of muscle power around the ankle are more likely to demonstrate a conservative gait pattern characterized by reduced speed, cadence, and increased variability of step duration and length [6]. Ankle range of motion (ROM) has also been shown to be an important contributor to balance and gait performance, with a decrease in ankle dorsiflexion ROM being an independent predictor of falls [7].

A variety of exercises programs for older adults have been investigated for improving balance and function with generally positive results [8,9]. The practice of doing resistance training on a regular basis has been suggested as one method for preventing the decline in muscle function that occurs with aging process and may be an important contributor to balance impairments [10-12]. Resistance training that improves lower extremity muscle strength and power has been shown to improve functional performance and self-perceived quality of life [13]. In addition to the positive effects of resistance training, stretching exercises have been shown to effectively increase ankle ROM in older adults. Gastrocnemius stretching in particular has been shown to improve ROM for individuals with limited ankle dorsiflexion [14,15]. It has been previously documented that a combination of both resistance and stretching exercises maybe an effective intervention for improving ankle mobility and postural stability in older adults [16].

Despite the relatively large body of evidence regarding the benefits of exercise for improving balance and function in older adults, there is no specific exercise protocol that has been determined to provide optimal benefits. However, given the fact that any exercise program must be performed on an ongoing basis to be effective, a critical factor in determining the potential usefulness of any exercise program is the likely hood of long-term compliance as well as safety. If an exercise program is perceived as too difficult, requires special equipment, or is too costly, long-term compliance may be impacted [17-20]. Additionally, the risks of performing any exercise program should not outweigh the potential benefits.

Therefore, the primary purpose of this pilot study was to evaluate the feasibility and potential benefits of a 6-week targeted exercise program for the foot and ankle that was simple, required minimal time and equipment, and could be done safely in a home setting.

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Methods

Participants

A convenience sample of 21 individuals age 60-90 was recruited from the community using flyers distributed at two local senior centers and a primary care physician office. Participants initiated contact with the primary investigator using the information provided in the recruitment flyer. During phone screening, one participant was excluded who did not meet the inclusion criteria. Specific characteristics and demographics for the 19 participants who completed the study can be found in table 1. Each participant met the following inclusion criteria: be a community dwelling adult 60-90 years of age, able to ambulate a minimum of 10 meters unassisted, currently not participating in a regular resistance training program and have a minimum score of 24 on the Mini-Mental Status Exam. Exclusion criteria included any condition that would make participation in a moderate intensity resistance training program unsafe including but not limited to a history of severe or unstable cardiorespiratory disease, recent surgery, presence of any neurological conditions, and the presence of any significant musculoskeletal pain or inflammation that would prevent participation in the exercise program. Participants were also excluded if their resting blood pressure during the baseline testing was ≥ 180/100 and/or resting heart rate was greater than 100. Subjects with insulin dependent diabetes or any foot wounds were also excluded.

During the initial visit, subjects rested quietly for several minutes and heart rate and blood pressure values were recorded. Additionally, height and weight measurements were taken to determine body mass index (BMI) (Table 1). Prior to any data collection each participant signed an informed consent that had been approved by the University of Dayton's Institutional Review Board.

Outcome measures

Outcome measures were selected to represent different aspects of balance, mobility and ankle function and include all of the following: Mini-Balance Evaluation Systems Test (Mini-BESTest), comfortable gait speed, fast gait speed, Timed Up & Go (TUG), Activities Specific Balance Confidence scale (ABC), gastrocnemius muscle performance and ankle dorsiflexion ROM. The primary outcomes of interest were the Mini-BESTest and gait speed and secondary outcomes were TUG, ABC, strength, and ROM.

The Mini-BESTest consists of 14 tasks that are designed to assess four subsystems of dynamic balance including; anticipatory control, reactive control, sensory orientation and dynamic gait [21]. Each task is rated on a 3-point scale from 0-2 with a perfect score of 32. While the Mini-BESTest has not been previously used in community dwelling older adults, it has been shown to have high test-retest reliability in older adults with Parkinson's disease (ICC=0.92) [22].

Walking speed was calculated for both habitual and fast-paced walking using a 10 meter walk test. Participants walked a straight path of 14 meters; timing was started at the 2 meter mark and stopped at the 12 meter mark, allowing for acceleration and deceleration [23].

Subject Characteristic	
Age (yr)	66.5 ± 6.8 (60 - 85)
Male/female	9/10
BMI score	28.0 ± 6.0 (19 - 43.2)

Values expressed as mean ± SD, (range) except for sex
BMI = Body Mass Index

Table 1: Subject characteristics (n=19).

Two trials at each pace were recorded and averaged. Comfortable and fast gait speeds have been show to have good test-retest reliability in healthy older adults (ICC=0.98) [24].

The TUG involves recording the time required for the participant to stand from a standard arm chair, walk 3 meters around a cone and sit back down in the chair. In community-dwelling older adults, the TUG has shown good test-retest reliability (ICC=0.99) [25].

Perceived balance confidence was evaluated using the ABC scale. This measure assesses the participant's perceived level of confidence while performing 16 different activities of daily living. The level of confidence for performing each task is assigned a percentage between 0% and 100% with 100% being completely confident and 0% having no confidence in their ability to perform the activity. The ABC scale has been shown to have established test-retest reliability (ICC=0.92) [26].

Strength of the gastrocnemius was assessed using muscle testing as described by Hislop and Montgomery [27]. Participants received a grade of 0-5 for strength based on the amount of single leg heel raises completed through full plantar flexion ROM. A muscle grade of '5' requires a minimum of 20 repetitions, grade '4'=10-19 repetitions, grade '3'=1-9 repetitions and grade '2'=partial ROM for 1 repetition.

Ankle dorsiflexion ROM was tested with the participant in a standing lunge position with the knee of the leg to be tested in extension. Participants were instructed to step back with the test leg as far as possible keeping the knee in extension, and heel of the test leg on the ground and the toes pointing directly forward. The participant then leaned forward flexing the hip of the non-test leg until reaching maximal ankle dorsiflexion of the test leg. The maximal position was the point before the heel of the test leg began to rise off the floor. A digital inclinometer was used to measure the angle of the lower leg by placing it on the front of the tibia of the test leg [28-30]. The weight bearing technique for measurement of ankle joint dorsiflexion with the knee extended has been shown to have good test-retest reliability (ICC=0.92-0.95) [30].

Study design

This was a single group, repeated measures study that involved three outcome measure testing sessions and two phases (Figure 1). After phone screening to determine eligibility, participants performed an initial baseline test (Base) that was followed by a 2-week 'control' phase during which they resumed normal activity but received no intervention. Following the control phase, a pre-intervention test (Pre) was conducted, followed by a 6-week 'intervention' phase of ankle strengthening, stretching, and postural control exercises. A final post-intervention test (Post) was administered within one week of completing the exercise program. All of the outcome measures were administered by the primary investigator at each of the testing sessions. Additionally, participant training for the intervention as described below was conducted by the primary investigator.

Intervention

All participants followed the same exercise protocol during the study but the initial level of difficulty and progression was customized to each participant. The entire training program took place at the participant's home. The training program consisted of 3 non-consecutive training sessions per week with each session lasting approximately 15 minutes. Training sessions were separated by 24-48 hours to minimize possible muscle soreness. Participants received weekly phone calls to answer questions about the program and to advise them on proper exercise

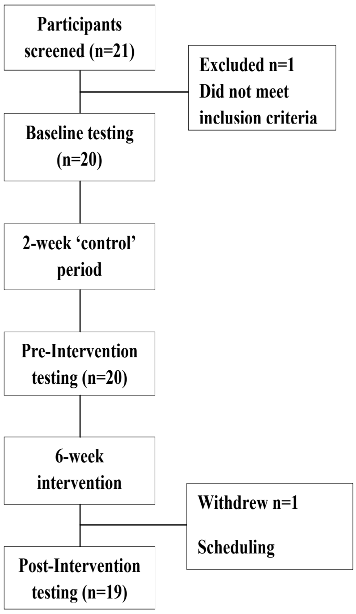

Figure 1: Study design flow chart.

progression. Table 2 provides an overview of the exercise program including dosage, progression and rationale.

After finishing the pre-intervention testing, participants were shown a video demonstrating how to properly perform each exercise. Participants were then personally instructed in each exercise and were able to practice until they were safe and independent. Participants were given an informational packet to take home that included; pictures of each exercise, an explanation of the training program with the specified repetitions and sets for each exercise. Each participant was also given a portable 10 cm wooden step to take home which was used in the training program.

The program consisted of four different exercises (Table 2). Participants were instructed to complete all exercises standing in a corner of their home with a chair in front of them to ensure safety. There were four different hand positions used for each exercise; bilateral hand support, single hand support, finger tip support and no hands. Participants were instructed to use the hand support for each exercise that they felt most comfortable with. As the participant became more confident with each exercise they would progress their hand position until they were able to complete the exercise with no upper extremity support if possible.

The first two exercises focused on muscular strength and power of the plantar flexors and dorsiflexors and included a heel raise and toe raise. Difficulty level and progression of the exercise was determined by altering the following aspects of the exercise; 1) performance on flat ground or over the edge of a 10 cm step, 2) use of both legs or a single leg, 3) amount of upper extremity support, and 4) speed of movement. For both the heel and toe raises, initial difficulty was adjusted so the participant could complete 2 sets of 10-15 repetitions. In order to progress the level of difficulty participants had to complete two consecutive training sessions in which they were able to perform 2 sets of 15 or more repetitions.

The third exercise, which emphasized postural control and stability of the lower extremity, was a single leg stand. Participants were instructed to use the same progression of hand positions as used with the heel and toe raises. Participants were instructed to perform the single leg stand for 30 seconds to 1 minute for 2 repetitions on each leg. Once participants were able to complete two consecutive training sessions of the single leg stand for a minimum of 30 seconds with no upper extremity support, they were instructed to move onto the next progression of the exercise. The next progression was to complete the single leg stand while performing rhythmic head movements; up, down, left and right. The final progression for the single leg stand was to complete the same progression with eyes closed.

The last exercise was a gastrocnemius stretch. Participants would place the ball of their foot onto the edge of the 10 cm step while simultaneously dropping the heel and leaning forward until they felt a comfortable stretch in their gastrocnemius. Participants were instructed to perform the stretch on each leg individually holding the stretch for 30 seconds to 1 minute and repeat 2 times during each training session.

Data analysis

Data analyses were performed using SPSS version 18.0 (SPSS Inc, Chicago, Illinois, USA). Descriptive and inferential statistics were used to assess the differences in performance between baseline, pre-intervention and post-intervention testing. Data was tested for normality using the Shapiro-Wilk test and the box-plots were used to identify outliers. Non-normally distributed data (Mini-BESTest, ABC) was analyzed using non-parametric Friedman's analysis of variance and the Wilcoxon Signed Rank test (2-tailed) for post hoc comparisons. Normally distributed data was analyzed using a repeated measures general linear model (GLM) with paired samples t-test for post-hoc analysis. The magnitude of change between the pre and post-intervention values was determined by calculating effect sizes using Cohen's *d*. Because of multiple comparisons, and the risk of inflating the possibility of a Type I error, a Bonferroni correction was applied so that a p value of ≤ 0.02 was considered significant. The relationship between changes in the impairment measures (strength and ROM) and the balance and gait measures was explored using Pearson correlations.

Results

Of the 21 participants initially recruited, 19 completed the home exercise program and all phases of testing. One participant was excluded for not meeting the inclusion criteria and one participant dropped out because of outside factors and time constraints. No unanticipated adverse events were experienced during training.

The mean Base, Pre, and Post test values for each of the outcome measures are summarized in table 3. Based on Freidman's ANOVA, there was a statistically significant effect for testing session (Base, Pre, and Post), for Mini-BESTest ($p<0.0001$) and ABC ($p<0.0001$). Based on the GLM there was a statistically significant effect for testing session (Base, Pre, and Post) for ROM ($p<0.0001$), TUG ($p<0.001$), fast gait speed ($p<0.0001$), habitual gait speed ($p<0.0001$), and strength ($p<0.0001$).

Post hoc analysis demonstrated significant differences between most of the Pre and Post test values with medium to large effect sizes (Table 3). The only measure that did not show a significant change was the ABC. As expected, there were no significant differences between any of the Base and Pre test values.

Correlational analysis revealed a significant positive relationship between changes in gastocnemius strength and changes in the Mini-

Exercise	Dosage	Progression	Rationale
Heel Raises	2 sets of 10-15 repetitions	Bilaterally on flat ground progressing to over edge of block then single leg with increasing speed as tolerated. Reduce upper extremity support as able.	Improve plantar flexor strength and power
Toe Raises	2 sets of 10-15 repetitions	Bilaterally on flat ground progressing to over edge of block then single leg with increased speed as tolerated. Reduce upper extremity support as able.	Improve dorsiflexor strength and power
Single Leg Stand	30 sec - 1 min on each leg	Add horizontal and vertical head movements with eyes open progressing to eyes closed and increased speed. Reduce upper extremity support as able.	Improve balance and postural control in single leg stance
Wedge Stretch	30 sec - 1 min 2 repetitions	Increase stretch as tolerated	Improve ankle dorsiflexion range

[a]All exercises performed 3 times a week for 6 weeks

Table 2: Description of specific exercises[a].

Outcome Measure[b]	Baseline	Pre-Intervention	Post-Intervention	Mean Difference Pre-Post (95% CI)	*P* [c]	Effect Size[f]
Mini-BESTest (max=32 pts)	25.2 (4.3)	25.1 (4.3)	30.0 (2.3)	4.9 (3.5–6.4)	<0.0001[d]	1.42
Comfortable Gait Speed (m/s)	0.9 (0.18)	0.9 (0.16)	1.1 (0.18)	0.16 (0.10-0.21)	<0.0001[e]	1.2
Fast Gait Speed (m/s)	1.2 (0.27)	1.2 (0.27)	1.3 (0.28)	0.16 (0.10-0.21)	<0.0001[e]	0.36
Timed Up & Go (seconds)	9.9 (1.9)	10.0 (2.1)	8.0 (1.7)	1.9 (2.6-1.3)	<0.0001[e]	1.0
Strength (0-5 rating scale)	3.5 (0.90)	3.7 (0.91)	4.4 (0.50)	0.8 (0.50-1.1)	<0.0001[e]	0.95
Ankle ROM (degrees)	32.8 (8.9)	33.4 (8.5)	40.1 (10.2)	6.7 (3.3-10.0)	0.001[e]	0.71
ABC Scale (max=100%)	85.8 (18.2)	85.9 (18.2)	88.2 (16.2)	2.3 (1.9-6.5)	00.04	0.13

Mini-BESTest = Mini Balance Evaluation Systems Test, ABC = activities specific balance confidence scale, ROM = range of motion
[a] Values expressed as mean (± standard deviation) unless otherwise indicated
[b]All measures demonstrated a significant (p<0.05) effect for time (Baseline, Pre, Post) using repeated measures GLM or Freidman's ANOVA (Mini-BESTest, ABC)
[c] *P* value for pair-wise comparison of Pre-Intervention and Post-intervention means
[d] Significant difference between Pre-intervention and Post-intervention (p ≤ 0.02) for Wilcoxon-Signed Rank Test
[e] Significant difference between Pre and Post-intervention (p ≤ 0.02) for paired *t*- test
[f] Cohen's *d* for change between Pre and Post intervention measures

Table 3: Outcome measure values for baseline, pre-intervention and post-intervention testing[a].

BESTest (r=0.54, p=0.018). No other significant relationships were identified.

Discussion

Gait and balance outcomes

Following the intervention, the largest improvement (20%) was seen for our primary outcome measure, the Mini-BESTest. We chose the Mini-BESTest as our primary outcome measure for several reasons. First, it assesses higher level dynamic balance activities such as fast reactive stepping, gait with dual tasking and walking with head turns and pivot turns that may be more important for assessing fall risk. Second, the Mini-BESTest is less susceptible to the ceiling effects commonly seen with other balance measures such as the Berg Balance Scale [31]. The Mini-BESTest has been also been shown to be a good predictor of falls and postural control deficits in older adults with Parkinson's disease [32]. In a recent study by Godi et al. [33] it was estimated that the minimal detectable change (MDC) and minimal clinically important difference (MDIC) values for the Mini-BESTest were 3.5 and 4.0 points respectively. Given the fact that our subjects improved by an average of 4.9 points, it likely that they experienced a clinically meaningful change in their dynamic balance performance that could lead to a reduction in fall risk.

Following training we saw a significant increase in both comfortable (18%) and fast (14%) gait speeds. The mean difference from pre-post test for both comfortable and fast gait was 0.16 m/s. In a study by Perera and colleagues, they estimate that a 0.13 m/s improvement in gait speed indicated a meaningful change in a group of community-dwelling older adults [34]. Another study of community-dwelling older adults by Chui et al. [35] found a MDC value of 0.07 m/s. Across several other studies there is agreement that a meaningful change in walking speed is approximately 0.1 m/s [34-36]. A change in walking speed of 0.1m/s has also been shown to be associated with an improvement in morbidity and mortality in older adults [34-36]. Therefore, the improvements in gait speed that were elicited by our training program would likely indicate a clinically meaningful improvement.

There were also consistent improvements in the TUG. TUG performance is highly dependent on gait speed, and showed a comparable improvement of 19%. The mean difference between pre-post testing for TUG was 1.9 sec. The MDC and MCID has not been reported specifically for community-dwelling older individuals but ranges from 13% - 23% for individuals with stroke who have had mild to moderate hemi paresis [37]. A MCID has been determined in persons with osteoarthritis for the TUG and was estimated to range between a 0.8 and 1.2 sec. reduction in TUG time [38]. Our subjects mean improvement was similar or greater than these published values indicating that our subjects likely experienced a clinically meaningful improvement.

Balance confidence

Following training the ABC scale showed a non- significant improvement of 3% pre to post testing. The MDC or MCID for the ABC scale have not been determined for community-dwelling older individuals. A MDC of a 13% change has been established for individuals with Parkinson disease [39]. One possible explanation for the minimal change in ABC scores is that our subjects reported high levels of overall balance confidence (86%) prior to the intervention and therefore were unlikely to experience further improvement in confidence levels.

Muscle performance and flexibility

Following training there was a 22% increase in strength and 20% increase in ankle ROM. Correlational analysis revealed that the improvements in our subject's strength were positively correlated with their improvements on the Mini-BESTest. These findings are consistent

with a study by Spink et al. [40] who found a significant association between foot and ankle strength and ROM and performance in balance and functional tests in older adults. We did not identify any significant relationship between improvements in ROM and any of our gait and balance measures. This finding is different from Menz et al. [1] who investigated 176 retirement village residents and compared balance and functional ability to a range of foot and ankle characteristics also reported ankle dorsiflexion ROM and strength to be significant independent predictor of balance and functional ability. This discrepancy could be attributed in part to the fact that we had a much smaller sample of relatively younger community dwelling subjects, making any direct comparisons difficult.

Limitations

When interpreting the findings of this investigation, it is important to be aware of its limitations. This was a small nonrandomized investigation using highly motivated volunteers mostly at the lower end of the age requirement. Testing was performed by a non-blinded evaluator introducing the possibility of evaluator bias. There was also no long-term follow up to assess carry-over effects of the program or prospective changes in fall-risk. An additional limitation was the inclusion of only healthy older adults who had no other significant co-morbidities. Therefore, the clinical meaningfulness of our findings should be interpreted cautiously.

Feasibility and Practical Implications

Despite the considerable limitations of this pilot study there were several practical implications for clinicians and researchers to consider. First, the subjects in this study tolerated the progressive nature of the exercise program well with only minor complaints of muscle soreness and no adverse events reported. Additionally, the exercise program was simple and took most participants only 10 minutes to complete. Anecdotally, participants reported that these factors made the program feasible and improved compliance. Another factor that likely improved compliance and retention was the weekly phone calls that participants received to update the exercise program and answer questions. This type of follow-up may be harder to accomplish in a clinical setting but should be considered as a potentially important element of the study. The fact that our participants experienced no adverse events and made clinically important improvements in several outcomes measures, provides support for a larger randomized controlled trial of this targeted exercise intervention.

Conclusion

The primary purpose of this study was to evaluate the feasibility of a 6-week home exercise program on the foot and ankle and any associated changes in muscle performance, flexibility, and balance in older adults. With proper screening and precautions, we found this home exercise program to be safe and feasible in the home setting. Following training, participants demonstrated statistically and clinically significant improvements in most of the outcome measures. This study provides evidence that simple but progressive home exercise program focusing on the foot and ankle may positively influence multiple domains of balance and mobility in healthy community dwelling older adults and warrants further investigation.

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