JACOBS PUBLISHERS

OPEN ACCESS

Jacobs Journal of Sports Medicine

Research Article

High Intensity Exercise Program Using a New Exercise Device Improves Muscle Strength in Women Over 70 years of Age

Dmitry Verniba[1*], William H Gage[1]

[1] *School of Kinesiology & Health Science, York University, Toronto, ON, Canada.*

**Corresponding author: Dmitry Verniba, Orthopaedic Neuromechanics Laboratory, 2020 Sherman Health Science Research Centre, York University, 4700 Keele Street, Toronto, ON, Canada M3J 1P3, Tel: +1(416)736-2100 ext 22042; Fax: +1(416)736-5772; Email: verniba@yorku.ca*

Received: 01-05-2015

Accepted: 01-26-2015

Published: 02-02-2015

Abstract

Falls are a major cause of pain, disability, and early mortality in older adults. Reduction in muscle strength and muscle power generation capacity with age is among the reasons why older adults are at a greater risk of falling than younger people. Despite the recent evidence that high-intensity exercise has been shown to be effective in reducing risk of falling for older adults there is reticence for older adults to engage in high-intensity exercise. Additionally, a limiting factor within institutional living for engaging older adults in meaningful exercise can be lack of space and lack of equipment. The purpose of the current study was to test the feasibility of training older adults at high intensity with a new lightweight and portable exercise stepper device. Female volunteers (n=11, age 84.4±7.9yrs) participated in the study. Participants received an 8-week long high intensity progressive overload exercise program using the stepper exercise device. Pre- and post-intervention assessments included: maximum forward and sideways reach test, 6-Minute Walked Distance test (6MWD), the Timed Up-and-Go (TUG) and the 30 Second Chair Stand (30SCS) test, maximal voluntary left and right knee extensor, knee flexor, and hip abductor isometric strength. Though not statistically significant, participants demonstrated a 26.3±15.9% (mean±SE) and 56.5±38.7% improvements in the forward and side reach, respectively, 2.2±3.8% improvement on the 6MWD test, 10.8±4.2% improvement on the TUG test, and 43.3±26.3% improvement on 30SCS test. Knee extensor, knee flexor, and hip abductor strength improved significantly by 21.7±3.8% ($p<0.01$), 14.8±4.3% ($p=0.02$), and 36.8±10.4% ($p=0.02$), respectively. Participants demonstrated significant improvements in muscle strength and some improvements, though not significant, in functional mobility. The new stepper exercise device was an effective tool for use with this sample population, and received positive feedback from the study participants.

Keywords: Older Adults; Aging; Physical Activity; Falls; Stepper Exercise Device

Introduction

Approximately one-third of people over the age of 65 years will fall each year. About 40% of people over the age of 75 fall each year, and this percentage increases to 50% for people living in long-term care, and to 75% for people who have fallen in the past [1]. Falls are a major cause of pain, disability, and early mortality for persons over 65 years of age [2]. The reasons why older adults are at a greater risk of falling, compared with younger people, are many, and thought to include: reduced balance control associated with changes in peripheral sensory information, changes in vision, and changes in central integration of sensory information with motor planning [3]; reduction in muscle strength and muscle power generation capacity [4,5], and psychosocial factors such as fear of falling [6]; among others. Recent evidence demonstrates that both stand-alone exercise programs and multi-factorial interventions that may include multiple forms of exercise (e.g. strengthening, flexibility, endurance, and balance-specific exercises) as well as individualized fall risk assessments are effective in both reducing fall rate and reducing risk of falling for community-dwelling older adults [7,8]. Multi-factorial fall risk reduction interventions that include exercise have been shown to reduce fall risk and fall rate for older adults living in long-term care [7]. Clearly, exercise can lead to greater muscle strength and endurance for older adults, but exercise can also lead to improvements in mood and balance confidence, important fall risk factors for older adults [9].

Despite evidence to demonstrate effectiveness of exercise for improvements in function and quality of life for older adults, there may still be a reticence among some who provide care to older adults for these individuals to engage in exercise. There may be greater reticence for older adults to engage in high-intensity exercise, perhaps due to safety concerns and perhaps due to lack of general understanding of the benefits of this activity. However, recent literature has demonstrated that high-intensity exercise is effective both for patient groups and older adults. A case report, involving a 70-year-old woman with a history of falling, showed that a high-intensity multi-factorial training program, which included isokinetic knee extensor exercises, resulted in improvements in both balance (evaluated using the Berg Balance Scale) and functional performance, evaluated using the Timed Up-and-Go (TUG) [10]. A review of physical exercise for older adults suggested that exercise intensity should be moderate to high for muscle strengthening activities, assessed on a 0-10 scale where moderate-intensity effort score is 5 or 6 and high-intensity score is 7 or 8 [11].

A limiting factor within institutional living for engaging older adults in meaningful exercise can be lack of space and lack of equipment. Lightweight and portable exercise devices may provide a solution to the issue of space. Lower-cost devices may provide opportunity to increase availability of exercise devices for people residing in long-term care. The capacity to move the exercise equipment easily can allow a space purposed for non-exercise activities (such as dining) to quickly become an exercise facility, and then return to the original purpose with little effort from participants or staff. A portable stepping exercise device (Better Motion Group, Aurora, Ontario, Canada) characterized as easily moveable, having castors to roll on the floor, and easy to use, may provide an opportunity for uses to remain in their regular seating while performing the physical activity. The stepper device can be easily attached (detached after use) to standard four-legged chairs as well as wheelchairs (Figure 1). Our research group partnered with a community long-term care and residential living facility (Unionville Home Society, Unionville, Ontario, Canada) to test the use and effectiveness of the new stepper device with a group of women over the age of 70.

Figure 1. The exercise stepper device docked to a chair (the docking option used in the current study) and an example of the stepper device docked to a wheelchair (not used in the current study, demonstration purposes only) (Verniba, 2014).

The objectives of the current study included: 1) to explore the effectiveness of high intensity exercise with a new stepper device for women over the age of 70, and 2) to examine the effects of exercise on a) measures of functional balance and mobility, b) muscle strength, and c) measures of fear of falling and balance confidence. We were also interested in feedback from participants concerning the use of the stepper device.

Methods

Participants

A convenience sample of female participants ((n = 13, age 81.9 ± 8.6yrs; mean ± SD), agreed to participate in this study. Each participant provided written informed consent prior to their participation. All of the participants resided at the same assisted living community; wherein 7 participants used ambulatory aids. All participants reported low levels of physical activity prior to the study. Participants received clearance from their physician prior to participation in this study. The local institutional research ethics board provided ethical approval of the methods used in this study.

Exercise Program

Participants completed a 10-week study protocol; wherein the 1st and last weeks were dedicated to pre- and post-testing and screening, and the middle 8-week period consisted of a high-intensity exercise intervention with a frequency of 30-minutes, 3 times per week. "High intensity" was defined as exercise intensity producing a heart rate of 70% to 85% of heart rate reserve (HRR); HRR is the difference between predicted maximum heart rate (220 – age) and resting heart rate [12]. Each participant wore a heart rate monitor throughout the exercise (OxyWatch Fingertip Pulse Oximeter, Avida Healthwear Inc., Mississauga, Ontario, Canada).

The lead author attended the residence to deliver the exercise program. Participants exercised in a group setting. Due to limited availability of the stepper devices, participants were placed randomly in 2 exercise groups with 5 and 6 participants per group. Each exercise session consisted of: warm up – continuous bilateral stepping using the stepper (50-60% HRR; 5 minutes), a progressive overload stepping exercise program (15 minutes) using the stepper, a cool-down using the stepper (50-60% HRR; 5 minutes), and light stretching of large muscle groups while sitting down in the chair (5 minutes). The training program used a periodized training design in which the 8 weeks were sub-divided into 3 periods. In the 1st period (first 2 weeks) participants were acquainted with the stepper and engaged in initial conditioning at 60-65% HRR. Participants performed bilateral, reciprocal stepping movements in 30-60 second intervals. In the 2nd period (middle 3 weeks) participants engaged in stepping exercises consisting of 20-45 second intervals at 70-80% HRR. In the 3rd period (final 3 weeks) participants engaged in stepping exercises consisting of 20-45 second intervals at 80-85% HRR. A 1.5-minute rest period was given between each exercise interval, in each phase. Exercise intervals were increased by 5-10 seconds each session, to each individual's tolerance; individual participants increased the intensity of the exercise to their own tolerance by adjusting the resistance on the stepper. Participants were encouraged to work at their own comfortable pace.

Pre-and Post-testing

Testing was conducted in the same way both pre- and post-exercise program intervention. Functional balance was evaluated using maximum forward and side reach distances. A meter stick, affixed to the wall at the chest level, was used to measure the reach distance. During the forward reach participants were asked to stand next to the wall with their arms flexed at the shoulder and extended forward in front of them. The initial position of the participants' finger tips with respect to the meter stick was recorded by the researcher. Participants were then asked to reach forward as far as they could without taking a step or lifting their feet off the floor. The final position of participants' finger tips with respect to the meter stick was recorded. Maximal displacement (measured in centimeters) was used as the measure of reach distance. During the side reach test participants faced the wall and maintained their arms abducted at the shoulder height. Similarly to the instructions in the forward reach test, participants were asked to reach to the side as far as they could without taking a step or lifting their feet off the floor. There were two trials performed for the forward and both side (left and right) reaches.

Functional mobility was assessed using the 6-Minute Walked Distance test (6MWD) [13], where participants were asked to walk up and down the hallway alongside the affixed 20-meter-long measuring tape. The ends of the measuring tape were marked by masking tape. As participants crossed the markings they turned around and walked back. The Timed Up-and-Go (TUG) test, in which participants were asked to stand up from a seated position, walk a measured 3-meter distance at their own comfortable pace, return, and sit back into the chair [13]; and the 30-Second Chair Stand (30SCS) test, in which participants were asked to stand up from fully seated position and return to seated position as many times as possible in the 30 second time period [13]. Distance walked during the 6MWD test (measured in meters), time to complete the TUG test (measured in seconds), and number of completed repetitions for the 30SCS test, were recorded.

Left and right maximal voluntary knee extensor, knee flexor, and hip abductor isometric strength was measured using a portable uniaxial load cell (A-Tech Instruments Ltd., Scarborough, Ontario, Canada). The load cell was attached to station-

ary object at one end, and to the participant's ankle, at the other end, via an inelastic strap. The load cell was factory calibrated and zeroed prior to testing of each participant. Knee extensor and knee flexor strength were measured in a seated position with the knee at 90° flexion; and hip abductor strength was measured in a standing posture with the knee and hip fully extended (participants placed a hand on a chair or table to ensure standing balance during the hip abductor testing). Each strength test was performed 3 times, and the maximum peak value was recorded.

Balance confidence and fear of falling were measured using the Activities-specific Balance Confidence (ABC) questionnaire, and the Modified Falls Efficacy Scale (MFES), respectively. The ABC and MFES questionnaires were administered on two occasions, during the pre- and post- testing. The participants' perceptions regarding the use of the stepper were evaluated during post-testing using an adaptation of Davis' "Perceived Usefulness" and "Perceived Ease of Use" questions.

Data Reduction and Statistical Analyses

Individual percent change from pre- to post-testing was calculated for each measure. One-sample t test with Bonferroni correction for multiple comparisons was used to test for a significant change; significance level was set at $p < 0.05$. The effect size was reported using Cohen's d.

Results

Participants

Two participants were unable to complete the study. The 1st participant terminated involvement in the study during the 1st week of training due to participant's lack of availability. The 2nd participant became unavailable during the 4th week of training following a scheduled surgery, which was unrelated to the study. Thus, a total of 11 participants (age 84.4 ± 7.9yrs) completed the study.

Functional Balance and Mobility

Though not statistically significant, participants demonstrated improvement in the forward reach ($t(10) = 1.65$, $p = 0.68$, $d = 0.50$) and improvement in side reach ($t(10) = 1.45$, $p = 0.17$, $d = 0.44$); improvement on the 6MWD test ($t(10) = 0.56$, $p = 0.59$, $d = 0.36$); improvement on the TUG test ($t(10) = 2.61$, $p = 0.12$, $d = 0.78$); and improvement on 30SCS test ($t(10) = 1.65$, $p = 0.52$, $d = 0.50$) (Table 1).

Table 1. Descriptive statistics for the measures obtained in the current study.

Measure	Pre-testing		Post-testing		Change (%)		
	Mean	±SE	Mean	±SE	Mean	±SE	*P*-value
Functional Balance and Mobility							
Forward reach test (cm)	22.1	7.5	25.3	5.3	26.6	15.9	0.68
Side reach test (cm)	21.0	8.2	25.7	7.8	56.5	38.7	0.17
6MWD test (m)	343.7	18.3	344.5	27.5	2.2	3.8	0.36
TUG test (s)	14.0	4.6	12.3	3.7	10.8	4.2	0.12
30SCS test (rep)	6.9	4.1	9.0	5.2	43.3	26.3	0.52
Muscle Strength							
Knee extensor (N)	144.5	45.5	174.4	56.7	21.7	3.8	< 0.01
Knee flexor (N)	98.8	30.5	111.4	30.5	14.8	4.3	0.02
Hip abductor (N)	78.2	39.7	107.8	67.7	36.8	10.4	0.02
Fear of Falling and Balance Confidence							
ABC	69.1	21.0	74.1	17.3	13.2	7.5	0.22
MFES	8.1	2.0	8.5	1.7	11.0	10.6	0.64

Muscle Strength

Knee extensor ($t(10) = 5.69$, $p < 0.01$, $d = 1.72$) and flexor ($t(10) = 3.48$, $p = 0.02$, $d = 1.04$) strength improved significantly. Hip abductor isometric strength improved significantly ($t(10) = 3.53$, $p = 0.02$, $d = 1.07$) (Table 1).

Fear of Falling, and Balance Confidence

Participants demonstrated improvements in both fear of falling, and balance confidence measures. ABC scores ($t(10) = 1.76$, $p = 0.22$, $d = 0.53$) and MFES scores ($t(10) = 1.04$, $p = 0.64$, $d = 0.31$) increased, though these differences were not statistically significant (Table 1).

Perceived Usefulness and Ease of Use

Results of the "Perceived Usefulness" and "Perceived Ease of Use" questions, such as "I would find the stepper easy to use", and "Using the stepper is useful for doing exercise" (rated between "extremely likely" and "extremely unlikely"), were considered positive. The average of scores in response to these questions was in the "slightly likely" category.

Discussion

The objectives of the current study included: 1) to explore the effectiveness of high intensity exercise with a new stepper device for women over the age of 70, and 2) to examine the effects of exercise on a) measures of functional balance and mobility, b) muscle strength, and c) measures of fear of falling and balance confidence. The results showed that the high intensity exercise approach was effective for women over 70 years of age, resulting in significant improvements in muscle strength, and also in substantial, though not statistically significant, improvements on functional performance measures such as the timed-up-and-go and chair-stand tests.

Previous research has demonstrated that patient groups and

older adults are able to engage in high intensity exercise. Weening-Dijksterhuis, et al. [11] recommended that moderate to high intensity exercise is appropriate, 3 times per week for a period of 10 weeks or more. Globas, et al. [14] reported that a high intensity aerobic treadmill exercise program resulted in significant improvements both in cardiovascular fitness and functional gait performance for older patients with chronic stroke. It was clear that all participants in the current study were able to engage in the high intensity exercise intervention. Monitoring of the heart rate response during exercise bouts confirmed that participants were working within the intended range, at the intended level of intensity. The stepper exercise device, which allowed participants to remain seated throughout the exercise sessions, may have facilitated the participants' ability to reach the desired level of intensity by facilitating engagement in the exercise by removing fear of loss of balance or falling. During rest intervals between exercise bouts, participants remained seated, which may have been physiologically more restful (as opposed to standing continuously, or having to sit and stand between exercise bouts). By remaining seated between exercise bouts, perhaps participants were able to relax and rest more completely than if they had been required to remain standing, or been able to sit and then stand between exercise bouts.

Functional balance and mobility measures showed substantial, but not significant, improvements in the current study, following the muscle strengthening intervention, which is not particularly surprising. The exercise intervention was focused on muscle strengthening and did not include any components of balance or walking. The seated nature of the exercise precluded any balance component of the exercise. The most successful fall prevention programs have included balance and walking as integral to the intervention [15]. However, it is worth considering that an exercise program that focuses on muscle strengthening, and which likely improves cardiovascular fitness (though not measured in the current study) perhaps creates a foundation of capacity for individuals to engage in meaningful balance and walking interventions. This might be particularly true for frail elderly individuals who initially may not have the capacity to engage in moderate to intense walking exercises.

Finally, complexity in use of an exercise device might be considered a barrier to exercising and reduce the enjoyment of exercising. It appears that the participants in the current study found the stepper both useful and easy to use. Enjoyment of exercise can be a critical element in adherence to an exercise program. Exercising in a group environment, as in the current study, can increase enjoyment and satisfaction. The use of "Perceived Usefulness" and "Perceived Ease of Use" questions to evaluate the participants' perceptions of the stepper device showed that participants rated the exercise device as "slightly likely" in response to questions such as "I would find the stepper easy to use", and "Using the stepper is useful for doing exercise".

One limitation of this study is that all participants were female. As a result, the findings of this study cannot be generalized to males over the age of 70. Furthermore, we investigated a group of self-selected participants who were generally self-motivated to engage in an 8-week-long training program, which may have biased the findings of the current study.

Conclusions

The current study was a preliminary examination of a) the use of high intensity muscle strengthening exercise using a new exercise stepper device with frail older women, and b) the effect of high intensity muscle strengthening exercise on measures of muscle strength, functional mobility, and gait performance. The current study was limited by the number of people and sex who were willing to participate. Participants demonstrated improvements in muscle strength and some improvements, though not statistically significant, in functional mobility. No changes were observed in measures of fear of falling and balance confidence. The new stepper exercise device was an effective tool for exercise, and was shown to be well regarded by the study participants. A potential advantage for this device, compared with other commercially available devices may be the small, portable form factor, and the ability to attach directly to the participant's wheelchair or standard chair, obviating the need for the participant to stand and/or transfer weight in order to engage in the exercise, and thus reducing the risk of falling.

Acknowledgements

The authors would like to acknowledge Better Motion Group, who provided a stipend to the graduate student and lead author and also supplied the exercise devices at no cost for this study. The authors also acknowledge Unionville Home Society for the generous support in providing space to conduct the study, and assistance in recruiting participants.

References

1. Rubenstein LZ. Falls in older people: epidemiology, risk factors and strategies for prevention. Age Ageing. 2006, 35(Suppl 2):ii37-ii41.

2. Murray CJ, Lopez AD. Global mortality, disability, and the contribution of risk factors: Global Burden of Disease Study. Lancet. 1997, 349(9063): 1436-1442.

3. Lord SR, Ward JA, Williams P, Anstey KJ. Physiological factors associated with falls in older community-dwelling women. J Am Geriatr Soc. 1994, 42(10): 1110-1117.

4. Thelen DG, Wojcik LA, Schultz AB, Ashton-Miller JA, Alexander NB. Age differences in using a rapid step to regain balance during a forward fall. J Gerontol A Biol Sci Med Sci. 1997, 52(1): M8-M13.

5. Wojcik LA, Thelen DG, Schultz AB, Ashton-Miller JA, Alexander NB. Age and gender differences in peak lower extremity joint torques and ranges of motion used during single-step balance recovery from a forward fall. J Biomech. 2001, 34(1): 67-73.

6. Vellas BJ, Wayne SJ, Romero LJ, Baumgartner RN, Garry PJ. Fear of falling and restriction of mobility in elderly fallers. Age Ageing. 1997, 26(3): 189-193.

7. Rose DJ, Hernandez D. The role of exercise in fall prevention for older adults. Clin Geriatr Med. 2010, 26(4): 607-631.

8. Gillespie LD, Robertson MC, Gillespie WJ. Interventions for preventing falls in older people living in the community. Cochrane Database Syst Rev. 2012, 9:CD007146.

9. Arnold CM, Faulkner RA, Gyurcsik NC. The Relationship between Falls Efficacy and Improvement in Fall Risk Factors Following an Exercise Plus Educational Intervention for Older Adults with Hip Osteoarthritis. Physiother Can. 2011, 63(4): 410-420.

10. Beebe JA, Hines RW, McDaniel LT, Shelden BL. An isokinetic training program for reducing falls in a community-dwelling older adult: a case report. J Geriatr Phys Ther. 2013, 36(3): 146-153.

11. Weening-Dijksterhuis E, de Greef MH, Scherder EJ, Slaets JP, van der Schans CP. Frail institutionalized older persons: A comprehensive review on physical exercise, physical fitness, activities of daily living, and quality-of-life. Am J Phys Med Rehabil. 2011, 90(2): 156-168.

12. Heyward VH. Advanced fitness assessment and exercise prescription. 5th ed. Champaign, IL: Human Kinetics, 2006.

13. Bennell K, Dobson F, Hinman R. Measures of physical performance assessments: Self-Paced Walk Test (SPWT), Stair Climb Test (SCT), Six-Minute Walk Test (6MWT), Chair Stand Test (CST), Timed Up & Go (TUG), Sock Test, Lift and Carry Test (LCT), and Car Task. Arthritis Care Res (Hoboken). 2011, 63(Suppl 11): S350-70.

14. Globas C, Becker C, Cerny J. Chronic stroke survivors benefit from high-intensity aerobic treadmill exercise: a randomized control trial. Neurorehabil Neural Repair. 2012, 26(1): 85-95.

15. de Negreiros Cabral K, Perracini MR, Soares AT. Effectiveness of a multifactorial falls prevention program in community-dwelling older people when compared to usual care: study protocol for a randomised controlled trial (Prevquedas Brazil). BMC Geriatr. 2013, 13: 27.