Journal of
Gerontology & Geriatric Research

Maritzet al., J Gerontol Geriat Res 2013, 2:3
DOI: 10.4172/2167-7182.1000126

Research Article Open Access

Comparison of Functional Walking Training Using Concentric-Eccentric Resistance on Hip Muscle Strength, Balance, and Functional Mobility in Working and Retired Older Adults

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Abstract

Background: Age-related lower extremity weakness leads to difficulty with stair negotiation, gait, and balance. The purpose of this study was to evaluate and compare the impact of functional walking training on hip strength, balance, and functional mobility among community-dwelling working and retired older adults.

Methods: 12 healthy working adults (10 females and 2 males; mean age 66 years) were recruited from the campus community and 15 retired community-dwelling adults (13 females and 2 males; mean age 75 years) were recruited from a church. Subjects completed pre-post-test measurements: hip strength (flexion, abduction, and extension) were tested using hand held dynamometer; Timed Up and Go test, 30-Second Chair Rise test, and static and dynamic balance tested using the Zeno Walkway System. Subjects completed 8 sessions of functional walking using the BTE TM Primus RS. Subjects were connected to the Primus using cable attachment and waist belt. Primus was set in concentric-eccentric mode and resistance was applied. Subjects walked seven feet in four directions: forward; backward; sideways both directions a total of five times each. Resistance was increased each session. Results: The working group had significant improvements (p= 0.02-0.0003) in Timed Up and Go, 30-Second Chair Rise test, and hip strength following the intervention. The retired group had significant (p=0.01-0.0002) improvements in Timed Up and Go, 30-Second Chair Rise, hip strength, and dynamic balance. Neither group showed statistically significant changes in static balance. Only the Timed Up and Go was significantly different in the amount of change between groups.

Conclusion: A resisted functional walking program resulted in significant improvements in function and strength in both working and retired older adults. Functional walking with resistance allows older adults to benefit without having them assume difficult exercise positions. This exercise protocol can be easily modified for the clinical setting and be used in falls prevention programs.

Keywords: Falls; Balance; Exercise; Functional mobility

Introduction

Every year, one in every three adults over 65 years of age will experience one or more falls [1,2]. After sustaining a fall, the risk of experiencing a recurring fall increases by roughly 50% and the consequences from such a fall can often be devastating [3]. In the elderly population, falls represent the leading cause of injury, fractures and death [4].

Due to the increased risk of falling as a person's age increases, the importance of understanding the contributing risk factors and causes of falls is extremely critical in prevention and treatment for this population [5]. The risk of falling is assessed with the consideration of multiple contributing factors, both extrinsic and intrinsic. Extrinsic factors include environmental factors such as lighting, poor walking surfaces and household clutter. Intrinsic factors include proximal muscle weakness, decreased stance balance, postural control and mobility [5,6].

Many falls occur while older adults are performing mobility tasks such as walking or moving from sit to stand [7]. Research comparing hip strength and hip velocity in younger versus older adults, found older adults demonstrated 16% slower velocity with hip flexion and extension [7]. They concluded both maximum strength and velocity are necessary to move the leg and aid in fall recovery [6]. Lower extremity muscle weakness, particularly hip flexors and knee extensors, increase a patient's likelihood of requiring multiple steps to recover from a forward loss of balance [8]. Furthermore age-related lower extremity weakness has been associated with difficulty with stair negotiation, sit-to-stand, gait, and overall balance [9,10]. It is also well known that balance decreases with age resulting in reduced postural control and increased likelihood of falls [11].

In 2011, the American Geriatric Society (AGS) and British Geriatric Society (BGS) updated their guidelines for treatment to reduce the risk of falls [11,12]. While a multi-factorial fall risk assessment is a key to the identification of the individual risk factors for falling, exercise was viewed to be an essential component to a fall reduction program. The panel recommended that resistance strength training along with balance, gait, and coordination training should be part of each multifactorial intervention. Exercise programs were shown to have significant impact on reducing rate of falls, improving balance and gait, and a decrease in fear of falling [1,10,12-15]. However, it is essential that balance training occur during walking, as this is when most older adults typically fall [11,16].

Considering the relationship between lower extremity strength and function among older adults [17], this study was designed to assess the benefits of a functional walking program, which used a more dynamic progressive resistance strengthening protocol with older adults. There were two purposes of this study: 1) to determine the impact of functional

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Received June 27, 2013; **Accepted** August 12, 2013; **Published** August 14, 2013

Citation: Maritz CA, McCray S, Bell J (2013) Comparison of Functional Walking Training Using Concentric-Eccentric Resistance on Hip Muscle Strength, Balance, and Functional Mobility in Working and Retired Older Adults. J Gerontol Geriat Res 2: 126. doi:10.4172/2167-7182.1000126

walking training using concentric-eccentric resistance on hip muscle strength, balance, and functional mobility among community-dwelling working and retired older adults and 2) to compare if there were any differences in the outcome between the two groups.

Materials and Methods

Study sample

Twenty-seven subjects were recruited for this study. Twelve healthy working adults (10 females and 2 males) with a mean age of 66 years (SD 5.7) were recruited from the University of the Sciences campus. Fifteen retired community-dwelling adults (13 females and 2 males) with a mean age of 75 years (SD 8.5) were recruited from a local church. Written informed consent was obtained from subjects in accordance with procedures approved by the University of the Sciences Institutional Review Board.

Inclusion criteria for both groups were: ≥ 60 years old and independent with ambulation without an assistive device. All subjects in the working group were employed by the university, while the retired group was comprised of older adults who were no longer working. Subjects were excluded if they were unable to follow directions.

Procedures

After informed consent was obtained, subjects from the working group completed the Physical Activity Readiness Questionnaire (PAR-Q) [18] to screen eligibility and safety for the study. The PAR-Q was designed as a quick screen to determine if a person is able to participate in physical activity. It consists of seven "yes or no" questions relating to a person's feelings of readiness to participate in physical activity. It also functions to quickly screen their medical history to detect any red flags signaling the need for physician consent before continuing with the study. The questionnaire prompts people to answer all questions honestly. If one or more of the questions receive an answer of "Yes" then that person must follow up with their doctor in order to be cleared for participation. Answering "No" to all questions signifies readiness to begin physical activity. Based on the completion of the PAR-Q, all subjects from the working group were eligible to participate in the study. All subjects from the retired group received medical clearance from their physician before participating in the exercise program.

Prior to beginning the eight sessions of functional walking training using the BTE™ Primus RS, all subjects completed pre-testing measurements that assessed hip muscle strength, functional mobility, and balance. The same measures were completed at the end of the eight training sessions.

Hip strength assessment

Hip muscle strength (hip flexion, hip abduction, and hip extension with isolation of gluteus maximus) was tested in the standard manual muscle testing positions using the Lafayette Hand Held Dynamometer (Hanover, MD) [19]. The hand held dynamometer is used to assist clinicians in attaining a more accurate and quantitative value of a muscle's ability to generate force. Using a hand held dynamometer to assess hip strength has been shown to be valid and reliable [20]. Similar to standard manual muscle testing, the device is positioned in the same location as if it were the clinician's hand. The patient is instructed to gradually increase their resistance to the device and hold the resistance for five seconds before relaxing. The device measures the amount of force generated by the patient in kilograms. This test was performed 3 times after which the average of the three trials (in kg) was calculated and used for analysis.

Timed Up and Go test (TUG)

The Timed Up and Go test (TUG) is a standardized outcome measure used to assess mobility in older adults [21]. The test involves timing participants while they stand from being seated in a chair, stand up, walk 3 meters, turn around, walk back 3 meters and sit down. This test was performed 3 times after which the average of the three trials (in seconds) was calculated and used for analysis. Older adults who require > 14 seconds to complete the TUG are said to be at a very high risk for falls [22]. The TUG was originally developed as a clinical measure to assess balance in the elderly and it has shown to have excellent inter and intra-rater reliability [22].The intra-class correlation coefficient (ICC) has been reported to be > 0.95 [7].

The 30-Second Chair Rise test (CRT)

This test provides insight into a person's lower body strength and endurance [9]. It relates strength findings to the ability to perform everyday tasks such as climbing stairs, getting in and out of a vehicle or a bathtub [5]. To perform this test, subjects were seated in a chair without arm rests. The height of the seat was 17 inches from the floor. They were asked to stand up and sit down as many times as they could in 30 seconds. The number of times that they could stand up was then recorded. This test has been shown to have excellent reliability with an ICC of 0.84 for males and 0.92 for females [9].

Balance Assessment using the Zeno Walkway System

This system developed by Protokinetics (Havertown, PA, formerly GaitRite M_sq®)[23] consists of 4'x 4' mat with eight pressure sensors designed to assess static and dynamic balance using temporal and spatial parameters such as velocity and center of pressure. This system has been shown to have strong concurrent validity and test-retest reliability [24]. The pre-test assessments performed on the Zeno Walkway consisted of three balance activities: 1) static standing with eyes open in normal stance for 30 seconds, 2) static standing eyes closed in normal stance for 30 seconds, and 3) performance of the Four Square Step Test. The Four Square Step test (FSST), a clinical test of dynamic standing balance, has been shown to be effective in predicting falls in community dwelling older adults [25]. It assesses a person's balance and limits of stability when changing directions horizontally. FSST has shown to have excellent interrater (ICC ≥ .99) and test-retest reliability (ICC=.98) [25]. Subjects performed one trial of the FSST following a demonstration by the tester.

Interventions

The BTE™ Primus RS (Hanover, MD) is a piece of exercise and testing equipment used by therapists for both evaluating and treating patients. It can be used in the following modes: isometric, isotonic, isokinetic, or continuous passive motion settings. One of the most useful functions of the BTE™ Primus RS is the ability to replicate any functional activity through the various attachments provided [26].

For this training, the waist belt attachment was placed on the subjects and connected to the BTE™ Primus RS using the cable attachment (Figure 1). Once the Primus was set in the concentric-eccentric mode and resistance was applied using pre-test strength measurements as a guide. For example, subjects who demonstrated lower output during muscle testing were started at a lighter resistance than those who achieved higher output. Subjects were instructed to walk seven feet (the maximum distance allowed by the machine) in four directions: (1) forward, (2) backward, (3) side stepping to the left, and (4) side stepping to the right (Figure 1). The resistance was concentric as they moved away from the machine and eccentric as they moved

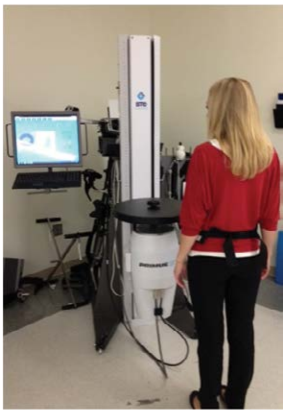

Figure 1: BTE Set up.

towards it. Participants completed 5 repetitions in each of the four walking directions. They attended two sessions a week over a four week period of time. A one to two pound incremental increase in resistance was applied during each of the following seven sessions provided they were still able to demonstrate correct form. Resistance ranged from 10-47 pounds. The most common compensatory movements noted were hip external rotation and lateral trunk bending.

Data analysis

Statistical analysis was performed using SAS v 9.3 (SAS Institute, Cary, NY) and Microsoft Office Excel (2007). Results are presented as mean ± SD. Paired t-tests were used to test for a significant change in mean scores between pre- and post-test for the TUG, 30-Second Chair rise and hip muscle strength, since they followed a normal distribution. The independent *t* test was used to compare the two groups. The Mann Whitney U test was used to test for a significant change in static balance scores pre and post because the data lacked normality. A value of $p<0.05$ was considered statistically significant.

Results

Subjects

The subjects from the working group were significantly (p=0.01) younger than the subjects in the retired group. The retired group, while nearly an average of ten years older than the working group was also active in a group-based exercise class two days a week. There were no significant differences in the baseline data between the groups except for in FSST scores (p=0.002). The working group was significantly faster in their performance of the FSST.

Change over time within groups

Working Group: Eleven of the 12 subjects recruited completed the study. One subject opted not to continue in the study due to family concerns. This group had significant (p=0.02-0.0003) improvements in TUG scores, 30-second CRT, and hip muscle strength (Tables 1-2) following the exercise intervention. There were no statistically significant differences found among the variables tested for static and dynamic balance (Table 3).

Retired group: Twelve of the 15 subjects recruited completed the study. One subject opted not to continue due to complaints of vertigo and the other two were lost to attrition. This group had significant (p=0.01-0.0002) improvements in TUG scores, 30-second CRT, hip muscle strength, and dynamic balance using the FSST (Tables 1-3). There were no statistically significant differences found among the variables tested for static balance (Table 3).

Comparison between the groups: When comparing the groups, there were no significant (p=0.99-0.12) differences in the amount of change, between the pre- and post-test, between the groups in all of the variables except for the TUG (p=0.03) (Table 4).

Discussion

This study examined the effects of resisted walking exercises on hip strength, mobility, and balance in a group of working and a group of retired older adults ≥ 60 years of age. This protocol was designed in keeping with the work of Bean et al., [27] to provide progressively increasing resistance to challenge the subjects during each training session. Additionally, the training focused on the importance of weight bearing in multiple planes as a means of improving both strength and balance [17]. The results of this study support the supposition that resisted walking can improve hip strength, and functional mobility. Both the working and retired groups demonstrated significant improvements in hip muscle strength TUG scores, 30-second CRT after completing this program. The retired group also had significant improvements in dynamic balance.

LaStayo et al., [28] investigated the impact of eccentric training on older adults. They found that while traditional lower extremity resistance training can improve muscle structure and function, greater increases in strength were seen in those who performed the eccentric training. These changes translated to improvements in overall function. Although the older adults in this study had difficulty controlling the eccentric force initially, once learned, they were able to demonstrate good motor control and adaptation to the increasing resistance. Considering the large eccentric component to this training, it is not surprising that both groups showed improvements in the TUG and CRT.

Although these researchers did not measure core strength of the participants, eliminating the use of upper extremity support while training may have promoted core strengthening. Granacher et al., [29] found that core strengthening improves dynamic balance and functional mobility in older adults. In fact, the improvements on both the TUG and CRT (working group p= 0.011; retired group p=0.0078) suggest that this functional walking program may also have resulted in better overall core stability.

Timed Up and Go Test	Pre	Post	Change	p-Value (one-tailed
TUG Scores (sec) Working Group Mean ± SD	7.89 ± 0.99	7.31 ± 0.57	-0.58 ± 0.90	0.03*
TUG Scores (sec) Retired Group Mean ± SD	8.58 ± 1.16	7.33± 0.95	-1.25 ± 0.66	<0.001*
Functional Lower Extremity Strength				
30-Second CRT Working Group Mean ± SD	12.73 ± 1.85	14.27 ± 2.76	1.55 ± 1.92	0.01*
30-Second CRT **Retired Group** Mean ± SD	14± 2.30	15.08± 1.88	1.08± 1.08	0.01*

*Significant: p<.05

Table 1: Mobility and functional lower extremity strength: working and retired group

	Working Group				Retired Group			
MMT(kg) Mean ± SD	Pre	Post	Change	p-value (one- tailed)	Pre	Post	Change	p-value (one- tailed)
Hip Flexion Right	12.19 ± 2.06	14.93 ± 2.52	2.74 ± 1.89	<0.001*	17.48 ± 4.72	20.71 ± 3.11	3.23 ± 2.57	<0.001*
Hip Flexion Left	13.76 ± 2.21	16.21 ± 2.52	2.45 ± 1.7	<0.001*	17.39 ± 3.47	20.41 ± 3.11	3.02 ± 2.54	<0.001*
Hip Abduction Right	13.05 ± 1.35	15.12 ± 2.13	2.07 ± 1.54	<0.001*	18.59 ± 3.08	19.90 ± 3.95	1.31 ± 1.98	0.02*
Hip Abduction Left	13.23 ± 2.05	15.54 ± 2.85	2.31 ± 1.97	<0.001*	17.88 ± 4.44	20.81 ± 2.38	2.93 ± 3.11	<0.001*
Hip Extension Right	12.34 ± 2.74	14.55 ± 2.2	2.21 +/= 1.67	<0.001*	13.55 ± 6.34	18.37 ± 3.95	4.82 ± 2.57	<0.001*
Hip Extension Left	12.85 ± 2.68	15.04 ± 2.74	2.18 ± 1.68	<0.001*	13.23 ± 5.58	17.91 ± 3.30	4.68 ± 4.98	<0.001*

*Significant: p<.05

Table 2: Muscle testing scores for working and retired groups

	Working Group				Retired Group			
Static Balance (Filtered COP in X and Y Range)	Pre	Post	Change	p Value (two-tailed)	Pre	Post	Change	p Value (two-tailed)
Eyes Open Sway A/P Direction (cm)	2.24 ± 0.60	2.72 ± 1.15	-0.72 ± 0.89	0.10	1.0 ± 0.51	0.86 ± 0.50	0.24 ± 1.03	0.79
Eyes Open Sway M/L Direction (cm)	2.97 ± 1.15	2.39 ± 1.18	-0.66 ± 1.27	0.12	1.4 ± 0.57	1.43 ± 0.50	0.73 ± 1.11	0.22
Eyes Closed Sway A/P Direction (cm)	2.89 ± 1.06	2.74 ± 1.23	0.14 ± 0.96	0.57	1.37 ± 0.47	1.42 ± 0.58	0.57 ± 1.89	0.84
Eyes Closed Sway M/L Direction (cm)	1.77 ± 0.82	2.03 ± 0.62	-0.67 ± 1.58	0.27	1.71 ± 0.48	2.0 ± 0.77	-0.67 ± 2.08	0.48
	Working Group				Retired Group			
Dynamic Balance Duration (sec)	Pre	Post	Change	p value (one- tailed	Pre	Post	Change	p value (one-tailed
Four Square Step Test Duration (sec) Mean ± SD	10.74 ± 1.62	10.75 ± 1.07	-0.01 ± 1.08	0.3021	14.53 ± 2.85	13.27 ± 2.41	1.25 ± 1.61	0.02*

*Significant: p<.05

Table 3: Static and Dynamic Balance for Working and Retired Groups.

This protocol addressed key components of current evidence-based fall prevention guidelines [1,8,13,14]. Exercise that improves hip strength assists older adults with mobility and functional tasks while also allowing them greater responsiveness to alterations in balance [4,10]. Static balance was not significantly affected due in part to the short duration of this training protocol but also because the two samples demonstrated a fairly high level of balance at baseline. Research studies have found that balance training programs require 12 weeks or longer of training in order to see significant changes in balance measurements.

In the retired group, dynamic balance as measured by the FSST showed a significant improvement following the performance of the functional walking program. Research previously found that strength training alone does not enhance standing balance in active community-dwelling older adults [30]. However, the dynamic nature of the resisted functional walking program in this study might explain the positive results on dynamic balance. Since this exercise program was only performed during a relative short duration it would be of interest to see if greater improvement can be achieved with continuing this exercise program for a longer time period. It has also been reported that there is a relationship between hip muscle strength and the ability of older adults to recover from a backward balance loss [31]. Based on that data the researchers suggest that training should include the facilitation of stepping responses. In this present study, concentric and eccentric resistance to backward walking was applied during the training to promote greater stability when moving in a backward direction and this might also be an explanation for the positive findings on balance.

Despite being older than the working group, the retired group was not significantly different in any of the baseline measurements. Instead in some of the variables the retired group had better values then the working group. One explanation for this could be that the retired group participated in a twice-weekly exercise program that involves upper and lower body strengthening and balance training. While the working group was younger they may have been more sedentary due to the nature of their jobs at the university.

This study had a number of limitations including that it used a sample of convenience instead of having a control group. The sample size was small but it did not seem to impact the ability to see a difference in function with treatment but might have been too small to detect differences between the groups. However the main purpose of the study was to evaluate if there were any changes over time in different populations and not to show that the treatment was superior in any group. The short treatment duration of eight sessions may also have been too short to determine the effect of this protocol on static balance and we recommend future studies with a longer duration of the training. Despite these limitations we were able to detect significant improvements over time, which indicates that this type of exercise program might be of great benefit to this older population.

Lower extremity weakness, particularly in the hip region, can be a problem in older adults due in part to sedentary life styles and age-related changes in muscle strength. For many older adults traditional hip extension strengthening exercises are difficult to perform due to their lack of ability to lay prone. Standing leg lifts are an alternative but the ease of muscle substitution in the form of compensatory movements makes them less desirable. Functional walking with resistance, such as this functional walking program, allows older adults to benefit from a hip strengthening activity while walking without having them assume positions that are either difficult or uncomfortable. To date, no studies appear to have examined the effects of resisted functional walking on hip strength, mobility and balance in both working and retired community-dwelling older adults. The use of the BTE™ Primus

Functional Measurements	Working Change	Retired Change	p-Value (two-tailed)
TUG Scores (sec) Mean ± SD	0.58 ± 0.90	1.39 ± 0.69	0.03*
Chair Rise Test Mean ± SD	1.72 ± 1.74	1.18 ± 1.08	0.29

*Significant: p<.05

Table 4: Comparison between groups mobility and functional lower extremity strength

MMT (kg)	Working Change	Retired Change	p-Value (two-tailed)
Hip Flexion Right	2.74 ± 1.89	3.24 ± 2.57	0.60
Hip Flexion Left	2.44 ± 1.70	3.03 ± 2.54	1.13
Hip Abduction Right	2.07 ± 1.54	1.42 ± 1.98	0.39
Hip Abduction Left	2.31 ± 1.97	2.94 ± 3.11	0.57
Hip Extension Right	2.56 ± 2.26	4.49 ± 4.49	0.21
Hip Extension Left	2.40 ± 1.68	2.51 ± 3.09	0.91

Table 5: Comparison between groups in strength

Static Balance (Filtered COP in X and Y Range)	Working Change	Retired Change	p-Value (Two-tailed)
Eyes Open Sway A/P Direction (cm)	-0.72 ± 0.89	0.24 ± 1.03	0.06
Eyes Open Sway M/L Direction (cm)	-0.66 ± 1.27	-0.73 ± 1.12	0.92
Eyes Closed Sway A/P Direction (cm)	0.14 ± 0.96	0.57 ± 1.89	0.54
Eyes Closed Sway M/L Direction (cm)	-0.67 ± 1.58	-0.67 ± 2.08	0.99
Dynamic Balance Duration (sec)	**Working Change**	**Retired Change**	**p-Value (Two-tailed)**
Four Square Step test (FSST) Duration (sec) Mean ± SD	-0.01 ± 1.80	1.26 ± 1.61	0.12

Table 6: Comparison between Groups in Static and Dynamic Balance.

RS provided a highly motivating way for older adults to exercise. This program was very well received and in fact subjects expressed a desire to continue as they reported functional benefits such as increased ease climbing steps and better posture when walking. This resistive functional walking training can impact falls prevention through improvements in hip muscle strength and functional mobility and can be easily modified to allow for use in the clinical setting.

Conclusion

The use of the BTE™ Primus RS for resisted walking exercises positively impacted hip muscle strength and functional mobility in both these groups of community-dwelling older adults aged ≥ 60 years of age. In regards to the TUG, the retired group started out slower but improved more than the working group. In the 30-second chair rise test the retired group started out better than the working group but had less of a change following the training. Regarding muscle strength, all muscle groups tested showed improvements in both groups, but the retired group showed the most change. The retired group started stronger and ended stronger in all muscle groups except for right hip abduction.

Acknowledgement

The authors would like to thank BTE for their generous donation of the BTE equipment to our University of the Sciences BTE Advanced Evaluation and Rehab Laboratory. We would also to thank Citizens Bank for funding this study.

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