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ORIGINAL RESEARCH

Core Muscle Strengthening's Improvement of Balance Performance in Community-Dwelling Older Adults: A Pilot Study

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To determine the effect of core muscle strengthening on balance in community-dwelling older adults, 24 healthy men and women between 65 and 85 years old were randomized to either exercise (EX; $n = 12$) or control (CON; $n = 12$) groups. The exercise group performed a core strengthening home exercise program thrice weekly for 6 wk. Core muscle (curl-up test), functional reach (FR) and Star Excursion Balance Test (SEBT) were assessed at baseline and follow-up. There were no group differences at baseline. At follow-up, EX exhibited significantly greater improvements in curl-up (Cohen's $d = 4.4$), FR (1.3), and SEBT (>1.9 for all directions) than CON. The change in curl-up was significantly correlated with the change in FR ($r = .44$, $p = .03$) and SEBT ($r > .61$, $p \leq .002$). These results suggest that core strengthening should be part of a comprehensive balance-training program for older adults.

Keywords*:* aging, resistance training, torso

The ability to maintain balance requires the complex interaction of neuromuscular, proprioceptive, vestibular, and visual systems. The performance of many of these systems declines with aging, resulting in diminished balance and increased risk of falls in older adults (Berg, 1989). Indeed, falls among older adults are a significant public health problem, and substantial resources have been devoted to developing interventions to prevent falls in the older population.

Various exercise-based rehabilitation strategies have been proposed to improve balance and prevent falls in older adults. Because it has been shown that older adults with a history of falls have diminished lower extremity strength compared with older adults with no history of falls (Daubney & Culham, 1999; Orr, 2010), lower extremity strengthening has been a key component of many of these interventions. However, the effects of limb muscle strengthening as a stand-alone intervention on balance have been inconsistent (Orr, 2010; Orr, Raymond, & Fiatarone Singh, 2008). Furthermore, as noted by Orr (2010) and by Orr et al. (2008), few studies have shown that improvements in balance performance are associated with improvements in leg strength, suggesting that factors other than leg strength are responsible for the improved balance. These results suggest that interventions designed to improve balance must address multiple impairments that contribute to poor balance. Therefore, the identification of additional impairments that can be modified through rehabilitation interventions remains a high priority.

Although leg strength clearly plays an important role in maintaining postural stability, the importance of the abdominal and paraspinal muscles, which stabilize the trunk to allow limb movement for functional tasks (Crisco & Panjabi, 1991; Panjabi, 1992), has received considerably less attention. However, several recent studies suggest that these muscles play a critical role in maintaining balance and functional mobility in older adults. Epidemiological and laboratory-based studies have demonstrated associations between diminished trunk muscle strength (Pfeifer et al., 2001; Suri, Kiely, Leveille, Frontera, & Bean, 2009), endurance (Suri et al., 2009), muscle quality (Hicks et al., 2005a, 2005b), and poor balance and mobility in older adults, even after controlling for limb muscle size (Hicks et al., 2005a, 2005b) or strength (Suri et al., 2009). Furthermore, a recent secondary analysis of a 16-week supervised training study suggested that improvements in trunk extension endurance, but not leg muscle strength or power, was associated with clinically meaningful improvements in balance (Suri, Kiely, Leveille, Frontera, & Bean, 2011). These studies suggest that diminished core muscle performance is an impairment that contributes to diminished balance in older adults and that core muscle training should be a part of balance and mobility training interventions for older adults. However, we are unaware of any study that has directly examined the impact of core strengthening exercises on balance performance in older adults.

The purpose of this randomized controlled trial was to determine the effects of a core muscle strengthening

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home exercise program on balance in community-dwelling older adults. Participants in the exercise group performed the 6-week exercise program designed to improve core muscle strength and endurance independently at home. Core muscle performance was assessed using the curl-up test (Powers & Dodd, 2009), a common field test of abdominal muscle strength and endurance. Balance performance was assessed using two scales that investigate different aspects of balance performance: the Functional Reach Test (FR; Duncan, Studenski, Chandler, & Prescott, 1992; Duncan, Weiner, Chandler, & Studenski, 1990), which requires participants to reach with the upper extremity on a stable base of support, and the Star Excursion Balance Test (SEBT; Gribble, Hertel, & Denegar, 2007), which requires participants to maintain stability on one limb while reaching with the other. We hypothesized that improvements in both curl-up and balance performance would be larger in the exercise group than in the control group and that the improvement in core muscle performance would be associated with the improvement in balance. The results of this study advance our understanding of the role of the core muscles in balance in older adults and suggest a new target for interventions aimed at improving balance and reducing the risk of falls in this population.

Method

Design Overview

This study employed a randomized, controlled, parallel group design to evaluate the effects of a core muscle strengthening program on balance performance. The exercise group was instructed to perform a series of core strengthening exercises at home for 6 weeks, but to otherwise maintain their current activity level. The program was progressive, and the intensity was matched to the subject's ability. Participants in the control group were instructed not to change their activity level. Balance (FR, SEBT) and trunk muscle (curl-up test) performance was assessed at baseline and after the 6 week intervention. All data were collected in the Muscle Function Laboratory at the University of Toledo. Participants provided written informed consent, and all procedures were approved by the University of Toledo Biomedical Institutional Review Board.

Participants

Volunteers were recruited from the local community by flyers that were posted in area senior centers and mailed to potential participants through a database maintained by the Center for Successful Aging at the University of Toledo. Volunteers were eligible if they were between the ages of 65 and 85 years old, were able to walk around the block without the use of a cane or walker, had not had a lower extremity injury or surgery in the past 6 months, had not had a major neurological or cardiovascular event (i.e., neurological disease or injury, stroke, heart attack, chest pain, or heart surgery) in the past year, were free from signs of activity intolerance (i.e., dizziness, chest pain, or "lightheadedness" with activity), and were willing to participate in the study. The sample size was estimated based on a prior study of core muscle training in young adults (Kahle & Gribble, 2009), but a formal analysis to determine sample size was not performed for this preliminary study.

Randomization and Intervention

Participants were randomly assigned to either and exercise or control group in a 1–1 ratio. The randomization scheme was generated using the Web site Randomization.com. Allocation was concealed; assignments were placed in sealed, opaque, numbered envelopes by an individual who had no contact with the study participants. A single assessor performed all assessments. The assessor was not blinded, but standardized scripts and protocols were followed to minimize bias.

Participants in the exercise group performed a progressive program consisting of eight exercises designed to increase the strength and endurance of the muscles of the core, including the rectus abdominis, transverse abdominis, multifidus, internal and external obliques, and the segmental stabilizers of the spine. The exercise program was based on one that has been shown to improve dynamic balance in healthy young adults (Kahle & Gribble, 2009). The exercises were modified for older adults by decreasing the duration and/or repetitions to account for the known decrease in muscle strength with advancing age and selecting exercises that could be performed in a supine or seated position to decrease the risk of injury and allow the exercises to be performed at home without special equipment. Each subject received individual instruction on the exercise program, which consisted of demonstrating and explaining the exercises, providing written instructions and figures for each exercise, and practicing the exercises with feedback from the research assistant.

The exercises, as described in Table 1, incorporated isometric and dynamic contractions of the core muscles and all were performed in a slow, controlled manner (5–25 s per repetition, depending on the exercise), and participants rested 1–2 min between sets. Several of the exercises emphasized maintaining strong contractions while resistance, in the form of limb or trunk weight, was added. Slow, prolonged contractions were emphasized in an effort to improve strength and endurance, as previous studies have shown that core muscle endurance is associated with balance performance (Suri et al., 2009, 2011). Participants were instructed to perform each exercise three times per week for 6 weeks. The initial intensity (duration of hold number of repetitions) was prescribed based on their baseline performance on the curl-up test; participants who scored "good" started with the number of repetitions listed in Table 1, which were determined based on our clinical experience with this population. Intensity was progressed every 2 weeks

Table 1 Exercise Descriptions

Exercise	Description
Bridging	Start in hook lying, raise buttocks from floor while tightening stomach muscles and "pulling belly button towards spine." Hold 5 s, then lower and repeat 10 repetitions.
Reclining curl	Sit on floor with knees flexed, arms reaching forward. Curve spine and lean back to approximately 45° while inhaling. Hold 15 s, then return to start.
Curl-up	Start in hook lying, slowly curl-up to raise head and shoulders from floor while inhaling. Hold 5 s, then lower and repeat 10 repetitions.
Seated oblique crunch	Sit on floor with knees flexed, arms on chest. Tighten your stomach, lean back slightly, and rotate trunk to bring 1 elbow to the opposite knee. Hold 5 s, then return to the start position. Repeat 10 repetitions to each side.
Abdominal contraction	In hook lying, tighten stomach by pulling belly down into spine. Hold 5 s while maintaining normal breathing, then relax and repeat 10 repetitions.
Lower trunk rotation	Start in hook lying. Tighten stomach and bring both knees in toward chest. Slowly rotate knees repeatedly from side to side, keeping knees together and feet off floor. Keep stomach tight while breathing normally. Repeat 10 repetitions to each side.
Straight leg raise	Lie on back with one knee bent and one straight. Tighten your stomach while breathing in and raising your straight leg 12 in. off the floor. Hold 5 s, then lower your leg while breathing out. Repeat 10 repetitions with each leg.
Seated marching	Sit in a chair with arms across chest. Tighten stomach by pulling your belly button toward your spine. Slowly raise 1 leg, hold 5 s, then return and raise other leg. Repeat 10 repetitions with each leg while breathing normally.

by adding repetitions (five repetitions) or prolonging the duration of hold (by 5 s). The protocol was designed to take approximately 20 min to perform, although some subjects reported that it took them longer (less than 35 min). Compliance was monitored with an exercise log that participants were instructed to complete after each exercise session. In addition, participants in the exercise group returned to the Muscle Function Laboratory after 3 weeks to allow the research assistant to ensure that the exercises were being performed correctly and to answer any questions.

Outcome Measures

The age, weight, height, and gender were recorded for each subject. Participants also completed the Godin–Shephard Leisure-Time Physical Activity Questionnaire to quantify activity level (Godin & Shephard, 1985). Scores greater than 24 indicate that an individual is active (approximately 14 kcal · kg^{-1} · week^{-1}), 14–23 indicate moderately active (7–13.9 kcal · kg^{-1} · week^{-1}), and less than 14 indicate insufficiently active (less than 7 kcal · kg^{-1} · week^{-1}; Godin, 2011). Participants then performed the dynamic balance and core strength tests in the order of FR, SEBT, and curl-up test.

FR Test. The FR requires the participant to reach as far forward as possible without taking a step or losing balance. Test–retest and intrarater reliability are high (ICC = .86–.88 and .96–.97, respectively) in the older adult population, and the predictive validity of the scale for identifying risk for falls in community-dwelling older adults has been established (Duncan et al., 1992; Muir, Berg, Chesworth, Klar, & Speechley, 2010). Briefly, participants stood shoeless, with their feet shoulder-width apart, next to a yardstick positioned at shoulder height. Participants reached forward with one hand as far as possible while maintaining their balance, then returned to upright standing. The distance they reached was measured. Participants were given four practice trials and then performed three test trials after a 2-min rest. If the participants lost their balance or took a step during the reach, the trial was discarded and the reach was performed again. The mean of the three trials was used for analysis.

SEBT. The SEBT requires the participant to stand on one leg while reaching in one of three directions (anterior, posterolaterally, and posteromedially) with the other leg, and is therefore the lower extremity analog to the FR. Inter- and intratester reliability is high (ICC = .78–.96 and .81–.93, respectively) in young (Hertel, Miller, & Denegar, 2000) and middle-age adults (intertester ICC = .72–.96; Bouillon & Baker, 2011). Reliability of this test has not been established in older adults, but the test is sensitive to age-related declines in balance performance (Bouillon & Baker, 2011; Stockert, 2009). Briefly, participants stood shoeless in the center of a grid marked on the floor. The grid was in the form of a three-pointed star reaching directly in front (anterior), and behind and to either side of the subject (posterolateral and posteromedial). While keeping their hands on their hips, the participants were instructed to reach in one of the three directions, gently tap the grid with their toe, and then bring their feet together without losing their balance.

Participants were instructed that they could bend at the trunk, hip, knee, or ankle, but must keep their stationary foot planted and their heel on the floor. Participants were given four practice trials in each direction before performing three test trials in each direction with each leg after a brief rest. The order of limb and direction of reach were randomized, but all three reaches in one direction were completed before moving on to the next direction, and all reaches with one leg were completed before moving onto the next leg. The average of the three distances for each direction was used in the analysis.

Curl-Up Test. The curl-up test, performed as described by Powers and Dodd (2009), was used to quantify core muscle performance and establish a baseline for the exercise program for each subject in the exercise group. Briefly, the participant lie supine with knees bent and feet flat on a plinth with arms placed at the sides of the body and palms facing down. A strip of tape was placed at the subject's fingertips of each hand, and another strip was placed 10 cm away. The subject was instructed to reach for the far tape mark by using the abdominal muscles to perform a curl-up and then return to the supine position at a pace of 25 curls/min. The subject performed the exercise until one of the following end points was reached: The subject became fatigued and was unable to continue, the fingertips of either hand failed to reach the second tape, or the subject performed 25 curl-ups. The number completed was then compared with published age- and gender-adjusted normative data (Powers & Dodd, 2009). If the subject was assigned to the exercise group, the fitness level was used to establish baseline core strength and determine the exercise protocol and progression to use (based on fair, good, very good, or excellent core strength according to the normative tables).

Statistical Analysis

All participants were analyzed in the group to which they were assigned (intention-to-treat). The assumption of normality was assessed using the Shapiro-Wilk test. When the assumption was satisfied, two-tailed, independent-samples *t* tests were used to compare the groups with respect to demographics (age, height, weight, and BMI), baseline performance, and the change in performance. When the assumption of equal variance was not met based on Levene's test (e.g., age, baseline curl-up, the change in SEBT anterior reach distance on the right and left), the analysis was adjusted so that equal variance was not assumed. When the assumption of normality was not satisfied (change in curl-up, FR, and SEBT posteromedial reach distance for the right and left, and posterolateral reach distance for the right), the Mann-Whitney *U* test was used, and the confidence interval on the difference between the medians was determined. Mean differences between the groups for both the baseline score and the change from baseline were calculated as (exercise – control). Between-group standardized effect sizes (Cohen's *d*) were calculated from the change scores. Spearman's rho correlation was used to explore the association between the change in performance in the curl-up test and the change in performance on FR and the SEBT. SPSS 17.0 (SPSS, Inc., Chicago, IL) was used for all statistical analyses, and the significance level set a priori at $p < .025$ for group comparisons of performance on pre- and posttesting (to control for the increased risk of type I error with this analysis), and $p < .05$ for group comparisons of demographics and correlations.

Results

As shown in Figure 1, 55 people were screened for eligibility between January and August of 2011. Twenty-six volunteers met the inclusion criteria and were enrolled in the study. After randomization, 1 subject from each group withdrew from the study for personal reasons. As a result, data from the 24 participants (12 in each group) who completed the study were included in all analyses.

Participant demographics are depicted in Table 2. The study sample was predominantly female, with each group having 8 women and 4 men, and overweight, according their mean BMI. Scores on the Godin–Shephard Leisure-Time Physical Activity Questionnaire indicate that, on average, the subjects were moderately active, expending approximately 7–13.9 kcal · kg^{-1} · week^{-1} in leisure time activity (Godin, 2011), but not meeting general minimum activity recommendations of approximately 14 kcal · kg^{-1} · week^{-1} (1,000 kcal/week for 70 kg individual; Nelson et al., 2007). There were no significant differences between the control and exercise group for any baseline characteristic.

Performance on the outcome measures is shown in Table 3. The exercise and control groups were not different from one another with respect to baseline performance on the curl-up test, FR, or SEBT. FR distance for 6 participants—3 in each group—was less than 25.4 cm, indicating that they were at moderate risk for falls. The exercise logs completed by the participants in the exercise group indicated that they completed 99.5% of the exercise sessions, and there were no adverse events.

At the posttest, participants in the exercise group demonstrated significantly greater improvement in performance on all outcome measures than those in the control group, as shown in Table 3. Curl-up test performance improved by 44% in the exercise group, while no change was observed in the control group, resulting in a large between-group effect (Cohen's $d = 4.45$). As shown in Figure 2, FR distance improved by 16% in the exercise group, which was also consistent with a large effect of the intervention (between-group Cohen's $d = 1.30$). In addition, all 3 participants in the experimental group who were at moderate risk of falls improved and were no longer considered to be at elevated risk at the posttest. SEBT reach distance significantly improved in all directions, and the effect was large (Cohen's $d = 1.93–3.1$). No changes in any variable were observed in the control group.

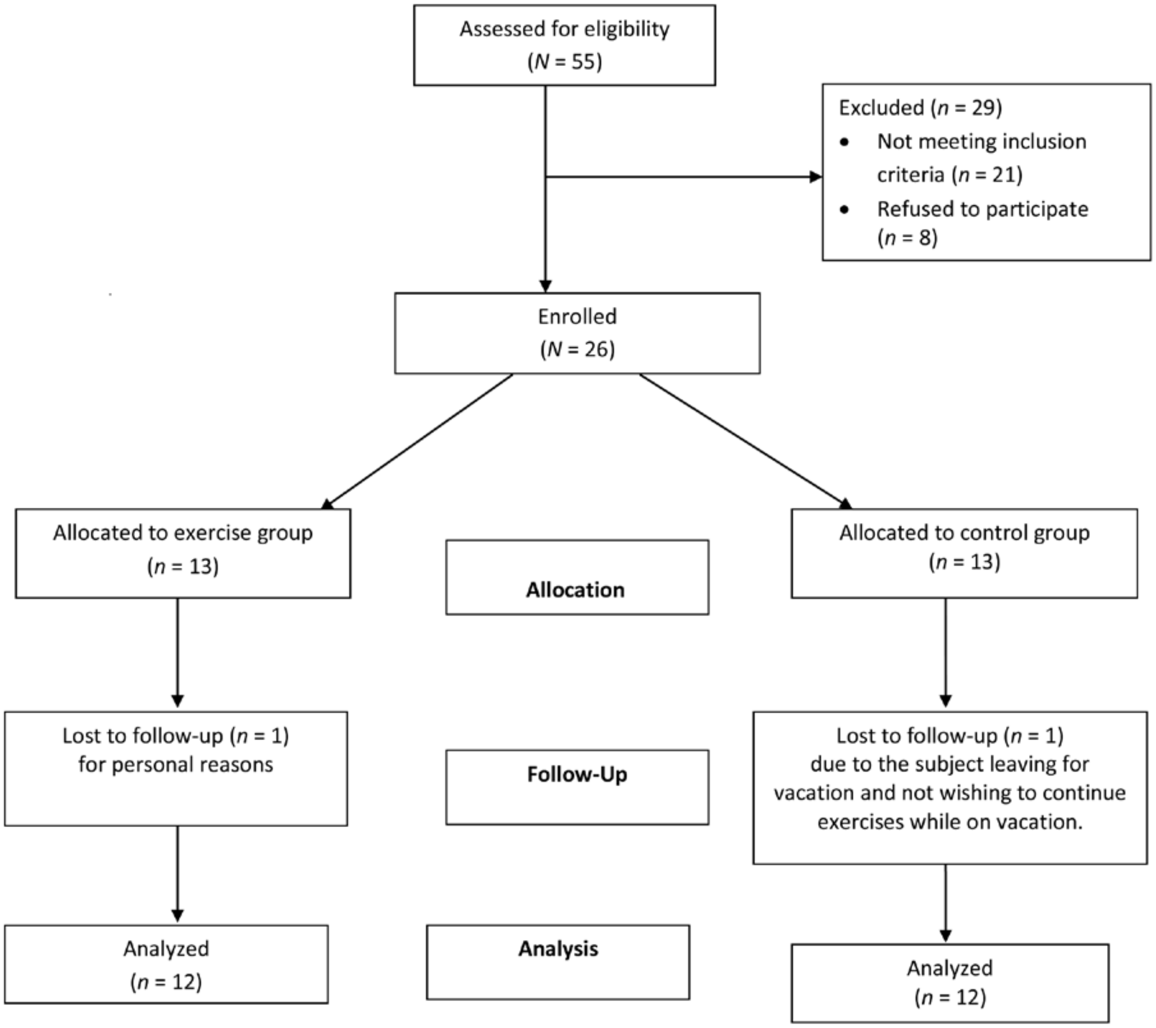

Figure 1 — Prospective participant and subject participant flow diagram.

Table 2 Participant Characteristics

	Total	Control	Experimental	*p*	Diff [95% CI]
Age (years)	76.0 (5.4)	75.6 (3.6)	76.5 (6.9)	.69	0.9 [–3.8, 5.6]
Height (m)	1.60 (0.12)	1.62 (0.12)	1.57 (0.13)	.34	–0.05 [–0.15, 0.05]
Weight (kg)	70.0 (11.6)	70.0 (10.1)	70.0 (13.5)	.99	0.0 [10.1, –10.1]
Body-mass index (kg/m^2)	27.5 (5.3)	26.8 (5.1)	28.4 (5.8)	.48	1.6 [–3.0, 6.3]
Activity	21.0 (15.7)	23.5 (20.7)	18.5 (9.8)	.45	–5.0 [–18.7, 8.7]
Gender	16 F, 8 M	8 F, 4 M	8 F, 4 M		

Note. Diff [95%CI] = mean difference between the groups [95% confidence interval]. Data in first 3 columns presented as mean (*SD*), except gender (frequency counts).

Table 3 Curl-up and Balance: Baseline and Change From Baseline

	Baseline				Change From Baseline			
	Control	**Exercise**	***p***	**Diff [95% CI]**	**Control**	**Exercise**	***p***	**Diff [95% CI]**
Curl-up	17.6 (5.4)	16.5 (2.3)	.532	–1.1 [–4.7, 2.5]	0.0 (2)*	7.5 (2)*	<.001	7.0 [6.0, 8.0]
FR (cm)	29.0 (6.2)	28.4 (5.2)	.758	–0.7 [–5.5, 4.1]	0.43 (3.6)*	4.6 (6.7)*	.006	5.3 [1.5, 8.2]
SEBT (cm)								
ant L	54.4 (10.8)	55.2 (11.5)	.856	0.8 [–8.6, 10.3]	0.05 (1.7)	15.0 (6.9)	<.001	15.0 [10.5, 19.4]
ant R	60.5 (11.2)	55.3 (13.6)	.320	–5.1 [–15.7, 5.4]	0.30 (1.2)	14.4 (9.9)	<.001	14.2 [7.8, 20.5]
PM L	36.8 (9.7)	42.8 (12.1)	.194	6.0 [–3.3, 15.3]	0.15 (1.8)*	11.7 (16.7)*	<.001	10.8 [6.2, 20.1]
PM R	42.3 (12.6)	43.1 (15.0)	.899	0.7 [–11.0, 12.5]	0.37 (2.1)*	20.3 (16.6)*	<.001	20.0 [8.7, 23.8]
PL L	61.1 (8.0)	63.4 (13.9)	.625	2.3 [–7.3, 11.9]	0.16 (2.2)	13.9 (6.2)	<.001	13.8 [9.8, 17.9]
PL R	64.6 (9.7)	65.6 (13.5)	.833	1.0 [–8.9, 11.0]	–0.5 (5.6)*	11.4 (12.7)*	<.001	15.7 [10.5, 22.0]

Note. Diff [95% CI] = difference between the group means or medians [95% confidence interval]; FR = functional reach; SEBT = star excursion balance test; ant = anterior reach; PM = posteromedial reach; PL = posterolateral reach; L = left leg; R = right leg. Control and Exercise presented as mean (*SD*) or, where indicated by *, median (IQR). *p* represents the *p* value for the between-group comparison.

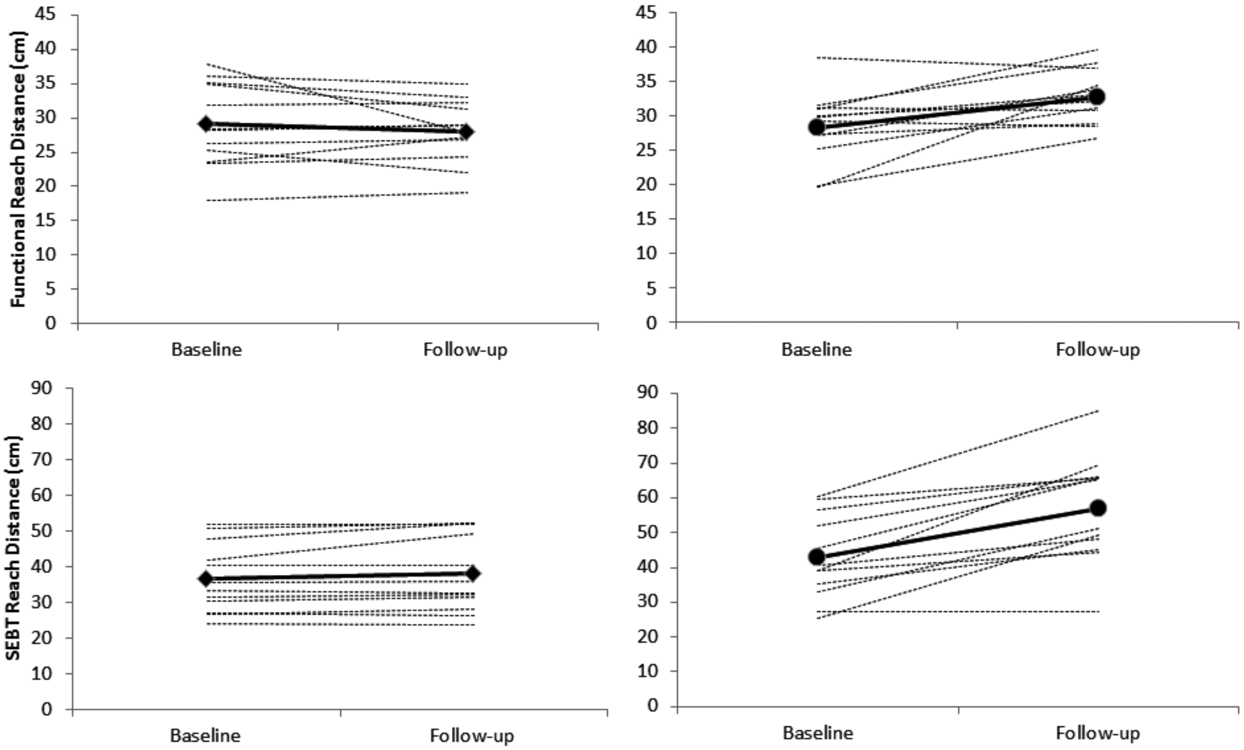

Figure 2 — Reach distance for FR (top panels) and left posterolateral Star Excursion Balance Test (SEBT; lower panels) in control (left panels) and exercise (right panels) groups. Individual (thin broken lines) and group mean (heavy, solid line) are shown. The change in performance on both tests was significantly greater in the exercise group ($p < .01$).

The change in curl-up test performance was significantly correlated with the change in FR (*r* = .44, *p* = .03) and SEBT (*r* = .61–.82, *p* < .001, for all directions except right posteromedial, where *p* = .002). In addition, the change in FR score was significantly correlated with the change in all SEBT reach directions (*r* .41–.65, *p* < .05 for all directions).

Discussion

In this study, participation in a 6-week-long core strengthening home exercise program produced improvements in core muscle strength and endurance that were associated with improvements in performance on two tests of dynamic balance in community-dwelling older adults. The calculated effect size indicated that improvements in all measures in the exercise group were large, compared with those of the control group, for this stand-alone intervention. These results are comparable with those of Suri and colleagues (2011), who showed that, among older adults who completed a 16-week supervised exercise program, clinically meaningful improvements in balance performance were associated with improvements in trunk muscle endurance but not limb muscle strength and power. Our results extend the results of this prior study by demonstrating, using an experimental study design, that a brief (6-week), simple, unsupervised exercise program focusing on core muscle strength and endurance can improve performance on tests of dynamic balance in older adults. Together, these results suggest that diminished core muscle strength and endurance are impairments that contribute to balance deficits in older adults and that core muscle training may have an important role in a comprehensive program aimed at improving balance and preventing falls in older adults.

Our intervention was designed to improve the strength and endurance of the core muscles that stabilize the trunk. This is consistent with recent studies demonstrating that trunk muscle endurance is associated with balance performance (Suri et al., 2009; 2011), although these studies found that trunk extension was most closely associated with balance. Our intervention focused on the deep stabilizers, rotators, and flexors of the trunk, all of which play a critical role in providing a stable foundation upon which the limb muscles can move (Crisco & Panjabi, 1991; Panjabi, 1992). Although recent studies in limb muscles have suggested that power is more critical to balance performance than strength (Foldvari et al., 2000), it is unclear if this is true for the trunk. Future studies should clarify what aspect of core muscle performance is most critical to balance performance and the most efficient means of training those aspects.

Our sample consisted of healthy community-dwelling older adults aged 65–85 years who were, on average, moderately active. Baseline FR was below previously published norms for 41- to 69-year-olds (37.8 and 35.1 cm for men and women, respectively) and 70- to 87-year-olds (33.5 cm for men and 26.7 cm for women; Duncan et al., 1990), and six of the participants were at moderate risk of falls. The group used for this study is therefore an ideal target population for a home-based preventative balance improvement program. The exercise program consisted of eight simple exercises and required no more than 35 min to complete. No equipment was required, and all participants were able to perform the exercises independently after they were provided with written instructions and a single brief training session. The intervention was well tolerated by the participants, and the exercise logs indicated that compliance with the program was excellent. Anecdotally, several participants in the exercise group reported that they felt stronger after the intervention. One reported that he was better able to "hold himself upright," while another reported feeling steadier when walking over uneven surfaces and that he was "better able to take side-steps along the bed or into the bathroom." Still another reported significant decreases in low back pain, which he attributed to "stronger trunk muscles," which allowed him to return to playing tennis. The improvement in FR reported in this study (4.4 ± 4.6 cm) is comparable to those observed in studies of supervised progressive resistance training (mean for three trials = 3.27 [95% CI = 1.39–5.15] cm; Howe, Rochester, Neil, Skelton, & Ballinger, 2011) and multiple-component exercise trials (mean of two studies = 5.8 [95% CI = 3.37–8.23] cm; Howe, Rochester, Jackson, Banks, & Blair, 2007), but smaller than that observed following a supervised 6-month walking program (11.8 [95% CI = 7.75–15.85] cm; Okumiya et al., 1996). The smaller magnitude of change realized in this study may be partially attributed to the unsupervised nature of the core exercises, the short duration of the study, or the stand-alone nature of the intervention.

There are limitations that must be considered when interpreting this study. The sample size is small, and follow-up was limited to a single posttest session. In addition, resources did not allow for a separate assessor and trainer, so the assessor was not blinded. However, standardized scripts and protocols were used to minimize bias.

While the intervention was successful in inducing large changes in balance performance, the potential impact of this type of training on the risk of falls in older adults is unclear. To our knowledge, the degree of change in FR or SEBT necessary to produce a meaningful reduction in fall risk has not been established; however, it was not our intention to promote core training as a stand-alone intervention to prevent falls. As discussed above, maintaining balance involves the coordinated action of multiple systems, and poor balance performance is but one factor that contributes to falls in the older population. Programs designed to prevent falls in older adults, therefore, must be comprehensive and directed at mitigating the multiple impairments that contribute to poor balance and falls. Our results suggest that core muscle performance is one impairment that can be improved by an exercise intervention, leading to improved balance. Future studies, therefore, should be directed at identifying efficient ways to incorporate core training into a more comprehensive program. While the subjects did not report any difficulty fitting the sessions into their schedule, and self-reported compliance was high, the practicality of adding 20–35 min of core strengthening exercise to a comprehensive balance-training program is questionable. Movements that stress both the limbs and the core, and therefore may provide a training stimulus to both simultaneously, would appear to be a particularly attractive area of further study.

In conclusion, the results of this study indicate that an unsupervised, short duration home exercise program of core strengthening exercises can improve core muscle and dynamic balance as measured by the FR and SEBT. The results highlight the key role of core strength in balance performance in older adults and add to the small-but-growing body of literature suggesting that core muscle training should be a part of a comprehensive balance training program.

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