Exercise Leads to Faster Postural Reflexes, Improved Balance and Mobility, and Fewer Falls in Older Persons with Chronic Stroke

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OBJECTIVES: To determine the effect of two different community-based group exercise programs on functional balance, mobility, postural reflexes, and falls in older adults with chronic stroke.

DESIGN: A randomized, clinical trial.

SETTING: Community center.

PARTICIPANTS: Sixty-one community-dwelling older adults with chronic stroke.

INTERVENTION: Participants were randomly assigned to an agility (n = 30) or stretching/weight-shifting (n = 31) exercise group. Both groups exercised three times a week for 10 weeks.

MEASUREMENTS: Participants were assessed before, immediately after, and 1 month after the intervention for Berg Balance, Timed Up and Go, step reaction time, Activities-specific Balance Confidence, and Nottingham Health Profile. Testing of standing postural reflexes and induced falls evoked by a translating platform was also performed. In addition, falls in the community were tracked for 1 year from the start of the interventions.

RESULTS: Although exercise led to improvements in all clinical outcome measures for both groups, the agility group demonstrated greater improvement in step reaction time and paretic rectus femoris postural reflex onset latency than the stretching/weight-shifting group. In addition, the agility group experienced fewer induced falls on the platform.

CONCLUSION: Group exercise programs that include agility or stretching/weight shifting exercises improve postural reflexes, functional balance, and mobility and may lead to a reduction of falls in older adults with stroke. **J Am Geriatr Soc 53:416–423, 2005.**

Key words: rehabilitation; cerebrovascular accident; posture; physical fitness; clinical trial

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About 30% of community-dwelling adults aged 65 and older fall at least once each year, and falls and fall-related injuries have been shown to be independent determinants of functional decline.[1,2] Stroke is considered to be one of the greatest risk factors for falls in older adults.[3] Twenty-three percent to 73% of community-dwelling older adults with chronic stroke have been reported to fall over a 4- to 6-month period, with approximately half falling repeatedly,[3,4] and this population has more than seven times the risk of experiencing a fracture.[5] Stroke-related impairments such as muscle weakness, impaired cognition, sensorimotor dysfunction, and balance and mobility problems presumably contribute to the large number of falls. One potential way of improving balance and mobility and reducing falls is through exercise interventions.

Recent studies have demonstrated that exercise can improve mobility[6–8] and functional balance[9,10] in older adults with chronic stroke, but it is unclear what the advantages of different types of exercise programs are and the mechanisms that underlie their improvements. Although falls and fall-related injuries in older adults with stroke are an enormous burden on the individual and the healthcare system, no studies have investigated the effect of an exercise intervention on falls reduction in this population.

Postural reflexes, in the form of coordinated muscle activity, are the first line of defense against an unexpected destabilizing force applied to the body (e.g., collision, slip, and trip) or from self-induced movements (e.g., reaching, transferring). Older adults with stroke have delayed paretic limb postural reflex muscle onset latencies compared with healthy older adults,[11] and it is unknown whether exercise can alter these latencies, which could lead to improved postural control and a reduction in falls. Such a concept would support an emerging idea of neural plasticity with exercise, particularly after brain injury in animal models.[12]

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In addition to slow postural reflexes, older adults with stroke demonstrate a slow rate of force production,[13,14] which may contribute to unsuccessful recovery from an unexpected destabilizing force to the body. In addition, integration of multisensory information (i.e., visual, vestibular, and somatosensory) is impaired after a stroke.[15] Thus, an agility program that involved fast-paced, dynamic movements and a multisensory integration component was designed. The purpose of this study was to determine the effect of two different community-based group exercise programs (agility vs stretching/weight-shifting program) on functional balance, mobility, standing postural reflexes, and falls in older adults with chronic stroke. The stretching/weight-shifting program used weight shifting because this would increase use of the paretic limb, which may improve motor function and reduce the risk of falling.[16,17]

METHODS

Participants

Participants living in the community were recruited from hospital databases, stroke groups, and advertisements. Inclusion criteria were aged 50 and older; single stroke, at least 12 months from onset; ability to walk, with or without an assistive device, for a minimum of 10 m; and an activity tolerance of 60 minutes with rest intervals. Exclusion criteria were not medically stable, neurological conditions not related to stroke (e.g., Parkinson's disease) or severe musculoskeletal conditions (e.g., recent joint replacement surgery, amputation), a score less than 22 on the Mini-Mental State Examination (MMSE),[18] and a Berg Balance score greater than 52 of 56 (minimal balance deficit). After university and hospital ethics approval, participants provided written informed consent before participation. The participant's physician confirmed the presence of stroke and the inclusion/exclusion criteria. In addition, type, location, and onset of stroke were collected through medical records and physician information where available.

The American Heart Association Stroke Functional Classification was collected to provide an indication of the level of function of the participants. This scale[19] consists of five levels and measures residual impairment and disability of stroke in the areas of basic activities of daily living (BADLs) and instrumental activities of daily living (IADLs). Level 1 indicates independence in BADLs and IADLs, and Level 5 indicates complete dependence.

Study Design

Participants were screened for a 6-month fall history, balance (Berg Balance), and dementia (MMSE) and then randomly assigned alphanumeric codes through a random number generator. After this procedure, participants were stratified[20] for functional balance (Berg Balance) and falls (recalled over the previous 6 months) to generate four subgroups: Berg Balance less than 40 and fewer than two falls ($n = 12$), Berg Balance less than 40 and two or more falls ($n = 9$), Berg Balance 40 or greater and fewer than two falls ($n = 25$), and Berg Balance 40 or greater and two or more falls ($n = 15$). Subsequently, a person independent of the study (i.e., concealed allocation) randomly assigned participants (using their codes) from each subgroup such that there were similar numbers of participants placed into the two exercise groups. Participants knew they were in one of two exercise groups but were unaware of the differences between them. Exercise instructors were not aware of the outcome measures of the study. All assessors were blinded to the group assignment, study design, and purpose.

Intervention

The two exercise programs consisted of 1-hour sessions, three times a week for 10 weeks held at a local community center supervised by three instructors (physical therapist, kinesiologist, and recreation therapist). There were six classes (three for each exercise program) with a 1:3 instructor:participant ratio.

Each of the exercise programs began with a 5-minute warm-up consisting of walking and light stretching and ended with a 5-minute cool-down of light stretching. The agility exercise program challenged dynamic balance, and the tasks progressively increased in difficulty based on set criteria and dependent on an individual's ability. This program emphasized agility and a multisensory approach. Tasks included standing in various postures (e.g., tandem or feet apart, one-foot stance, and weight-shifting) and walking with various challenges (e.g., different step lengths and speeds, tandem walking, figure-eight walking, stepping up and over low risers, side stepping, crossover stepping, and stepping over obstacles). Additional exercises included sit-to-stand movements, rapid knee raise while standing, and standing perturbations (i.e., instructor pushing participant in a controlled manner or participant pushing instructor to destabilize balance and elicit postural reflexes). Eyes-closed conditions and foam surfaces were incorporated for many of the tasks.

The stretching/weight-shifting exercise program focussed on slow, low-impact movements consisting of stretching and weight shifting. Weight-shifting exercises incorporated tai chi–like movements and reaching tasks, which encouraged increased force to be taken through the paretic lower limb. Stretching of major muscle groups was performed while standing and on mats on the floor. The act of getting down on and up from the floor was considered an exercise in itself and was practiced with the aid of the instructors.

Outcome Measures

Participants were evaluated three times: before the intervention (baseline), after the intervention (postintervention), and 1 month after the intervention (retention). For each of these periods, participants were assessed on two occasions separated by 2 days to minimize fatigue.

The Berg Balance Scale[21] was used to assess functional balance, and the Timed Up and Go (TUG) test[22] was used to assess functional mobility. Balance confidence and health-related quality of life were measured using the Activities-specific Balance Confidence (ABC) Scale[23] and Nottingham Health Profile (NHP)[24], respectively. Higher scores on the ABC reflect better perceived balance confidence, and lower scores on the NHP reflect better perceived health-related quality of life.

To assess standing postural reflexes, 20 platform translations (8 cm displacement, 30 cm/s velocity, and 300 cm/s^2 acceleration), separated by 15- to 30-second intervals, were induced while participants stood on two force plates (Bertec

Corp., Columbus, OH) embedded in the platform. Participants wore a harness attached to the ceiling, and at least one spotter was present. Participants were told that the platform could move at any time, but the onset and direction of the translation were unexpected in nature. The direction was counterbalanced across participants so that 10 consecutive backward translations followed 10 forward translations or vice versa. The first trial from each direction was discarded from the analysis, because the first trial to a perturbation is much more variable than subsequent ones.[25]

Force plate data and surface electromyography (Bortec Biomedical Ltd, Calgary, Alberta, Canada) from bilateral tibialis anterior (TA), medial head of gastrocnemius (MG), rectus femoris (RF), and biceps femoris (BF) were recorded at 600 Hz for 2 seconds before platform movement and 4 seconds after. The TA and RF muscles were analyzed for the forward translations and MG and BF for the backward translations because of their roles in the primary recovery response to those translation directions.[26] Electromyography was band-passed (10–1000 Hz), full-wave rectified, and low-pass filtered at 100 Hz (second-order, zero-lag, Butterworth algorithm). Muscle onset latency, representing a postural reflex, was defined as an increase in muscle activity that exceeded +2 standard deviations (beyond mean signal 1 second before platform movement) for at least 30 ms and was determined using an interactive computer algorithm.

Test-retest reliability over 2 separate days for 10 older adults with chronic stroke produced intraclass correlation coefficients $\pm$ standard error of measurement (SEM) (ms) for the paretic TA, RF, and MG of 0.92 ± 9.2, 0.87 ± 11.17, 0.79 ± 9.90, respectively, and for the nonparetic TA, RF, and MG of 0.79 ± 4.32, 0.79 ± 14.07, and 0.67 ± 4.40, respectively. No learning effect was observed, as evident from nonsignificant F tests over the 2 days.

Participants were instructed to step forward as fast as possible after an auditory cue to measure step reaction time. The first two and last two trials were with the nonparetic limb, and the middle trial was with the paretic limb to reduce any standing postural bias. Only data from the nonparetic limb were recorded because pilot work found that older adults with stroke tended to step with this limb in response to platform translations. Reaction time, averaged over the four nonparetic limb trials, was defined as the time between the auditory cue and when the vertical force from the force plate reached 0 (foot lift).

Participants kept a self-report monthly falls diary over 1 year from the start of the intervention; phone calls were placed if the monthly diary was not returned. A fall was defined as unintentionally coming to rest on the floor or another lower level not due to seizure, stroke/myocardial infarction, or an overwhelming displacing force (e.g., earthquake).[1] Falls were also determined during the platform translations at baseline, postintervention, and retention assessments and were defined as being unable to recover balance after the perturbation and requiring the use of the harness system (caught by the rope and harness system) or the assistance of the spotter.

Statistical Analysis

Based on a Berg Balance score (primary outcome measure) $\pm$ standard deviation of 45.3 ± 5.7 and desired 5-point change,[10] a sample size of 21 persons per group would have 80% power with alpha of 0.05. Thirty persons per group were sought to account for dropouts. All participants received the agility or stretching/weight-shifting condition as allocated and were included in the analyses if measures of outcomes were available. Baseline descriptive variables were compared between groups using chi-square (sex, affected limb), Mann-Whitney U (age, stroke duration, and MMSE), median (American Heart Association Stroke Functional Classification), or independent t (mass) tests. Outcome measures were tested for normality and, when applicable, log (Berg Balance, TUG, step reaction time) or rank (NHP) transformed for subsequent analysis. Baseline outcome measures between the exercise groups were compared using independent t tests.

Three separate multivariate analyses of variance (MANOVAs) were performed to compare the outcome measures of two exercise groups (group: agility versus stretching/weight-shifting) at three assessment times (time: baseline, postintervention, retention) using a mixed model with group as the between-subjects factor and assessment time as the within-subjects factor.[27] The first MANOVA included the clinical outcome measures: Berg Balance, TUG, step reaction time, ABC, and NHP; the second MANOVA included the paretic limb postural reflex muscle onset latencies for the TA, RF, MG, and BF; and the third MANOVA included the muscles of the nonparetic limb. After a significant MANOVA, a two-way (group by time) analysis of variance (ANOVA) was undertaken and, if applicable, Duncan post hoc tests. A covariate (baseline scores) was included in the ANOVAs when baseline differences were significant for a particular variable.

The number of falls occurring over 1 year in the community for each participant was normalized to the number of months over which information was collected. Subsequently, the number of falls per month over the course of 1 year from the start of the intervention (excluding falls during the classes) for each group was compared using a Mann-Whitney U test. Additionally, the total number of fallers (individuals who fell ≥ 1 times) and a subset of the fallers (individuals who fell ≥ 2 times, i.e., repeat fallers) over the 1-year period were compared between the two groups using chi-square tests.

Finally, the total number of falls during the platform translations was rank transformed and entered in a two-way ANOVA to compare the two exercise groups across three assessment times (group as the between-subjects factor and assessment time as the within-subjects factor).

An alpha level of 0.05 was selected for all statistical analyses (SAS 8.2, SAS Institute, Inc., Cary, NC).

RESULTS

Participant Characteristics

One hundred nine potential participants were identified over 3 months. Forty-eight participants were excluded; 35 did not meet inclusion criteria, 11 could not obtain physician approval, make the exercise class times, or were planning a conflicting extended vacation, and two refused to participate. Thus, 61 persons underwent random assignment: 31 into the stretching/weight-shifting and 30 into the agility program. Two individuals discontinued the study before baseline assessment because of time commitments.

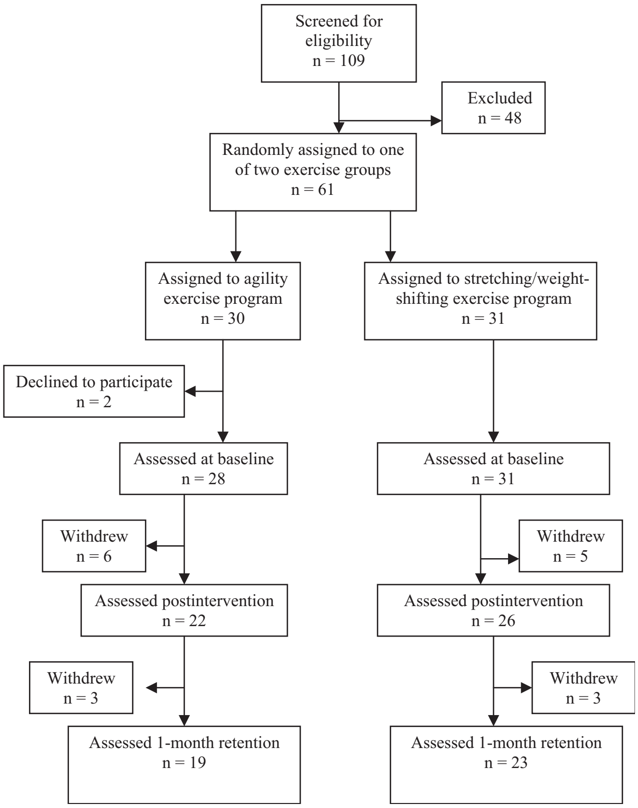

Figure 1. Trial profile.

Eleven individuals discontinued the intervention because of time commitments (n = 2), hip fracture (n = 1, during exercise in the agility program on a nonchallenging task that was included in both programs), illness (e.g., severe flu, hospitalization) (n = 5), and personal reasons (n = 3). Six participants were lost at retention testing because of illness (n = 2), vacation (n = 3), or personal reasons (n = 1) (Figure 1). The mean percentage of exercise classes attended for the stretching/weight-shifting and agility groups were 94.4% ± 5.5% and 92.6% ± 10.4%, respectively. Table 1 describes participant characteristics. There were no differences between exercise groups for baseline descriptive variables ($P > .20$).

Clinical Outcome Measures

There were no differences in the baseline clinical outcome measures (P-value range = .09–1.0) except for step reaction time ($P = .01$), which was entered as a covariate. The MANOVA for the clinical outcome measures demonstrated an overall group-by-time interaction (Wilk's $\lambda = 0.75$, $P = .04$), time main effect (Wilk's $\lambda = 0.33$, $P < .001$), but no group main effect (Wilk's $\lambda = 0.83$, $P = .18$). Step reaction time decreased more in the agility exercise group than in the stretching/weight-shifting group after the intervention (Table 2). There was also a trend ($P = .08$) for group-by-time effect for the TUG test (Table 2). All clinical measures showed improvements after the intervention, which with the exception of step reaction time, were retained at follow-up (Table 2).

Muscle Onset Latencies

Muscle baseline measures were not different between groups (P-value range = .08–.87) except for the paretic RF and nonparetic MG ($P = .03$ and .04, respectively), which were entered as a covariate for their respective analyses. The MANOVA for the paretic limb onset latencies demonstrated an overall group-by-time interaction (Wilk's $\lambda = 0.68$, $P = .05$) and time main effect (Wilk's $\lambda = 0.50$, $P < .001$) but no group main effect (Wilk's $\lambda = 0.87$, $P = .31$). The paretic RF onset latency was significantly faster, by 27.5 ms, after the agility exercise program, compared with 11 ms faster after the stretching/weight-shifting program. Onset latencies improved in all paretic muscles between 4.7 ms and 27.5 ms (Table 2) and were not due to different recovery strategies, because muscle sequencing was similar in all test sessions. Figure 2 shows typical postural reflexes for the paretic muscles at baseline and postintervention assessments.

The MANOVA for the nonparetic limb did not show a group-by-time interaction (Wilk's $\lambda = 0.84$, $P = .21$) or group main effect (Wilk's $\lambda = 0.86$, $P = .20$) but did show a time main effect (Wilk's $\lambda = 0.64$, $P < .001$). Of the nonparetic musculature, only the RF showed faster onset latency between the retention assessment and the baseline and postintervention assessments (Table 2).

Falls During Platform Translations

The number of falls that occurred during the baseline assessment in response to platform translations was entered in the ANOVA as a covariate. There was a significant group-by-time interaction ($P = .009$) but no group or time main effects ($P = .43$ and $P = .39$, respectively) for the total number of falls experienced during the platform translations. The number of falls on the platform decreased for the agility exercise group, whereas they increased for the stretching/weight-shifting exercise group after the interventions (Table 2).

Prospective Community-Based Falls

Twenty-one and 19 participants for the stretching/weigh-shifting and agility exercise groups, respectively, completed all 12 months of the fall diary. There were 75 falls in the stretching/weight-shifting group (0.26 falls/month per person) and 25 falls in the agility group (0.10 falls/month per person), but this did not reach significance ($P = .20$). There were 16 fallers that contributed to these values for the stretching/weight-shifting group and 11 fallers in the agility group ($P = .42$). In addition, there were 11 repeat fallers in the stretching/weight-shifting group and seven in the agility group ($P = .45$).

A subanalysis of those who had a history of falls (15 per group with at least one fall before starting the intervention) revealed that fewer participants continued to fall in the agility group (8/15) than in the Stretching/weight-shifting group (13/15) ($P = .05$).

DISCUSSION

Exercise Leads to Improvements in Physical Function and Psychosocial Measures

Older adults may have poorer functional balance and impaired mobility,[28] slower step reaction time,[29] and delayed postural reflex muscle onset latencies in response to perturbations of balance[30] that is further exacerbated in

Table 1. Participant Characteristics

Variable	Stretching/Weight-Shifting (n = 26)	Agility (n = 22)	Dropouts (n = 11)
Male/female, n (%)	18 (69)/8 (31)	17 (77)/5 (23)	6 (55)/5 (45)
Age, mean ± SD	67.5 ± 7.2	68.1 ± 9.0	69.6 ± 10.8
Mass, kg, mean ± SD	78.4 ± 15.9	83.5 ± 17.7	76.3 ± 16.3
Years since stroke, mean ± SD	3.8 ± 2.4	3.6 ± 1.8	4.1 ± 5.7
Affected side, right/left /not applicable, n (%)	8 (31)/18 (69)/0 (0)	10 (45)/11 (50)/1 (5)	3 (27)/7 (64)/1 (9)
American Heart Association Stroke Functional Classification, median (IQR) (possible range 1–5)	2.5 (2.0–3.0)	2.0 (1.0–3.0)	3.0 (2.5–3.0)
Mini-Mental State Examination, median (IQR) (possible range 1–30)	26 (24–28)	28 (27–28)	27 (26–28)
Number of fallers, n (%)*	15 (58)	15 (68)	6 (55)
Stroke location, n (%)			
Cortical	10 (39)	4 (18)	2 (18)
Subcortical	8 (31)	7 (32)	2 (18)
Brainstem/cerebellum	4 (15)	6 (27)	3 (27)
Cortical-subcortical	0	0	1 (9)
Unknown	4 (15)	5 (23)	3 (27)
Comorbidities, n (%)			
Arthritis	3 (12)	5 (23)	2 (18)
Diabetes mellitus	9 (35)	4 (18)	2 (18)
Depression	9 (35)	4 (18)	3 (27)
Hypertension	20 (77)	22 (100)	11 (100)
Obesity (body mass index > 30)	9 (35)	6 (27)	1 (11)
Hyperlipidemia	8 (31)	12 (55)	4 (36)
Assistive devices, n (%)†			
Ankle-foot orthosis	2 (8)	4 (18)	3 (27)
Wheelchair	3 (12)	2 (9)	2 (18)
Four-wheel walker	3 (12)	3 (14)	2 (18)
Quad cane	2 (8)	3 (14)	2 (18)
Regular cane	9 (35)	5 (23)	5 (45)

* ≥1 falls within 6 months before the study.
† Some participants used multiple assistive devices.
SD = standard deviation; IQR = interquartile range.

older adults who have had a stroke. For both types of exercise programs, exercise training improved functional balance and mobility, led to faster standing paretic limb postural reflexes and step reaction time, and resulted in greater balance confidence and health-related quality of life in older adults with chronic stroke. The 1-month retention of the effects is particularly important, given that mobility has been shown to deteriorate over a 3-month period in older adults with chronic stroke.[31]

The group aspect of the programs enhanced social contact, which is important, considering that approximately 20% of this population suffers from depression.[3] Both exercise programs led to improvements in perceived health-related quality of life. This may explain, in part, the good adherence to the interventions.

Differences Between the Exercise Interventions

The agility exercise group demonstrated greater improvements in step reaction time and paretic RF postural reflex onset latency, as well as a trend toward greater improvement in the TUG test (representative of functional mobility). The importance of these outcome measures is reflected in the literature in that reaction time and the TUG test have been shown to discriminate between older adult fallers and nonfallers.[32,33] The task-specific nature of the agility exercise program may have contributed to the greater improvements in step reaction time, because task-specific training is thought to drive neural plasticity.[34] Task-specific interventions may be particularly important in stroke, in which altered motor coordination is present. For example, in stroke, muscle strengthening protocols may require complementary task-specific practice to transfer the strength gains to functional tasks.[35] Specifically, the use of the RF muscle to step forward during the rapid stepping tasks in the agility exercise classes may have facilitated the change in step reaction time.

This is the first time lower extremity postural reflex muscle onset latency has been shown to change with exercise in any population. One study[36] reported faster neck muscle reflex onset latency in response to platform translations after a multisensory exercise program in older adults. Appropriately timed postural reflexes in response to a destabilizing event presumably help prevent the occurrence

Table 2. Outcome Measures

Measure	Stretching/Weight-Shifting Group			Agility Group			*P*-value	
	Baseline (n = 26)	Postintervention (n = 26)	Retention (n = 23)	Baseline (n = 22)	Postintervention (n = 22)	Retention (n = 19)	Time	Group × Time
	Mean ± Standard Deviation							
Clinical measure								
Berg Balance (maximum = 56)	44.8 ± 7.1	48.1 ± 5.7	47.5 ± 6.0	44.7 ± 6.5	49.1 ± 5.0	49.0 ± 5.4	< .001†	.63
Timed Up and Go, sec	18.4 ± 13.1	17.0 ± 10.7	17.5 ± 11.0	20.2 ± 10.8	16.7 ± 9.6	16.9 ± 10.5	< .001†	.08
Step Reaction Time, ms*	590 ± 171	540 ± 144	659 ± 175	721 ± 170	608 ± 124	633 ± 130	.005‡	.01
Activity-specific Balance Confidence Scale, % (maximum = 100)	58.0 ± 21.2	68.3 ± 19.4	64.8 ± 20.0	68.1 ± 18.6	74.0 ± 18.3	76.0 ± 17.2	< .001†	.39
Nottingham Health Profile (maximum = 600)	155 ± 108	123 ± 133	133 ± 124	116 ± 98	99 ± 102	100 ± 98	< .001†	.36
Postural reflex onset latency, ms								
Paretic TA	115.7 ± 18.8	109.5 ± 15.9	115.9 ± 18.4	122.8 ± 19.5	118.1 ± 19.9	124.7 ± 27.8	.05‡	.94
Paretic RF*	140.3 ± 32.2	129.3 ± 26.6	138.0 ± 28.4	164.7 ± 33.6	137.2 ± 22.5	146.9 ± 23.1	< .001§	.04
Paretic MG	130.0 ± 33.7	117.7 ± 18.0	120.2 ± 18.3	131.6 ± 19.1	126.4 ± 21.1	132.1 ± 31.1	.004‖	.47
Paretic BF	170.9 ± 37.8	164.6 ± 21.5	156.7 ± 33.6	185.7 ± 27.5	167.4 ± 13.4	156.6 ± 24.9	.01¶	.49
Nonparetic TA	107.1 ± 13.0	105.1 ± 11.3	106.5 ± 14.5	109.1 ± 16.8	111.7 ± 20.4	106.7 ± 18.4	.52	.58
Nonparetic RF	139.6 ± 33.0	134.5 ± 26.5	129.0 ± 23.4	148.2 ± 35.5	141.2 ± 24.5	133.1 ± 29.2	.01#	.61
Nonparetic MG*	109.1 ± 15.3	109.2 ± 20.5	107.6 ± 14.0	120.1 ± 20.5	113.2 ± 17.6	113.5 ± 18.3	.15	.22
Nonparetic BF	149.9 ± 30.7	145.7 ± 22.7	152.7 ± 31.5	171.4 ± 22.2	162.6 ± 31.5	153.5 ± 33.8	.09	.68
Falls during platform translations per person, n	0.76 ± 2.11	1.20 ± 2.68	0.86 ± 2.63	1.64 ± 3.05	1.00 ± 2.51	1.06 ± 2.44	.39	.009

Note: The time factor tested whether there was a difference between the baseline, postintervention, and retention testing over the whole sample, whereas the group × time interaction tested whether the agility group responded differently between the three time points than did the stretching/weight-shifting group.

* Group baseline differences, $P < .05$.

† Postintervention and retention different from baseline.

‡ Postintervention different from baseline and retention.

§ Three time periods all different.

‖ Postintervention different from baseline.

¶ Retention different from baseline.

\# Retention different from baseline and postintervention.

TA = tibialis anterior; RF = rectus femoris; MG = medial head of gastrocnemius; BF = biceps femoris.

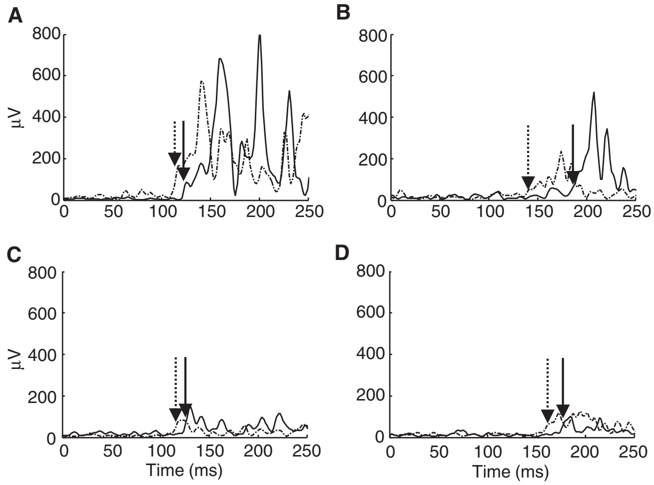

Figure 2. Typical postural reflexes evoked during platform translations at baseline (solid lines) and postintervention (dashed lines) assessments. Sample postural reflexes of a person with stroke during forward platform translations for the (A) paretic TA and (B) paretic RF. Sample postural reflexes of a person with stroke during backward platform translations for the (C) paretic MG and (D) paretic BF. Platform translations triggered at time zero. Arrows (solid for baseline assessment and dashed for postintervention assessment) indicate the onset latency identified by the combination of a computer algorithm and visual inspection.

of a fall, but other factors such as the magnitude of the response might also contribute. Although participants in both the agility and stretching/weight-shifting groups demonstrated improvements in reflex onset latency for several muscle groups, only RF showed a group-by-time effect, with a 27-ms faster paretic RF reflex latency for the agility group. In addition, this change is as long as the monosynaptic stretch reflex and is suggestive of functional significance. The multisensory training in the agility group, which enhances vestibular stimulation, may have contributed to the change in RF onset latency, because the vestibulospinal tract is believed to exert a large influence on proximal leg muscles.[37] Although the improvements in postural control were demonstrated in a standing task, it is likely that these changes would generalize to other dynamic tasks given the functional nature of the exercise program.

The two exercise programs had some similar components, including warm-up and cool-down periods and the fact that both used weight-shifting activities. More importantly, both groups had to attend the program three times a week, which involves substantial activation in itself (e.g., transportation, walking into the center). Despite these similarities, differences between groups were found in step reaction time, RF onset latency, number of falls induced by platform translations, and a trend for the TUG test.

Neuronal circuitry remodeling probably contributed to the neurophysiological and functional changes in this study. Exercise may promote brain plasticity through mechanisms such as increased expression of brain-derived neurotrophic factor.[38] Additionally, exposure to enriched rehabilitative training has demonstrated that increased dendritic arborization accompanies increased motor performance in rats.[39] In humans, forced use of the paretic limb in older adults with chronic stroke has shown cortical reorganization and improved motor performance.[40] In addition, repetitive exercise can alter spinal circuitry, as observed in spinal cats undergoing step training.[41]

The most noteworthy group difference was that the total number of falls experienced during platform translations was reduced more in the agility than the stretching/weight-shifting group after the interventions. Although the stretching/weight-shifting group had three times as many falls registered over the 1-year period from the start of the intervention as the agility group, this did not reach statistical significance. However, the subanalysis showed that the agility exercise program reduced by half the number of fallers in the year after the intervention for individuals who had a prior history of falling in the community. There was a large amount of group variability in the falls in response to the platform translations and the prospective falls recorded over the year. Because of the variability in the fall measures and the small sample size, the results should be interpreted with caution. This study was powered for functional balance measures, not falls. In addition, only 83% of exercising participants completed the 12-month prospective fall diaries. Based on the fall data, a sample size of 292 participants per exercise group would be required to detect differences for the number of fallers between the two interventions.[42]

The study had several limitations. Although the results can be generalized to community-dwelling ambulatory chronic stroke patients, many of whom regain walking ability,[43] the results may not generalize to stroke patients who are not ambulatory or who reside in a nursing home. Overall, the participants were representative of a sample at risk for falls because the mean baseline Berg Balance score of the participants was 45, which has been reported as a threshold value for fall risk.[21] The current study compared individuals randomized to two different types of exercise programs but did not include a nonexercising control group. In addition, because the participants responded to a recruitment advertisement regarding exercise, it is possible that they were more interested and motivated to pursue activities, which may benefit their health, than those who did not respond.

Implications and Conclusions

The results suggest that exercise programs for older adults with chronic stroke should include dynamic balance training, with emphasis on multisensory and agility tasks. Agility exercises have been effective in exercise studies aimed at reducing fall risk and improving balance in older women with osteoporosis.[44] The reduction in falls in the agility exercise program is encouraging, although larger studies are required to confirm these findings. Getting to the floor for mat exercises in the stretching/weight-shifting group was a major challenge, and several people reported that it was the first time they had attempted this task since their injury. Thus, incorporating this task into the agility exercise program would be beneficial. The instructors reported that the stretching/weight-shifting exercise program was easier to administer than the agility program because the latter required closer supervision to ensure that the tasks were appropriately graded to provide a challenge to the participant yet not result in a fall. Future studies could consider the use of hip protectors in conjunction with exercise in this patient population.

The community-based group-exercise interventions were effective in reducing fall risk factors in this older adult group with chronic stroke, including functional balance, mobility, and standing postural reflexes. These programs increase regular physical activity for older adults with chronic conditions and could offset the secondary complications that often occur after sedentary lifestyle.

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