Does Fall Arrest Strategy Training Added to a Fall Prevention Programme Improve Balance, Strength, and Agility in Older Women? A Pilot Study

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ABSTRACT

Purpose: The purpose of this study was to determine the effect of a unique exercise programme (Fall Arrest Strategy Training, or FAST) on upper body strength, range of motion (ROM), and fall risk in older women. FAST was designed to improve upper body capacity to prevent injury when a fall cannot be avoided. **Method:** A quasi-randomized site design included 71 older women (aged 67–95 y, mean age 83 years), who participated either in a standard fall prevention programme (Staying on Your Feet, or SOYF; $n = 29$) or in SOYF combined with FAST ($n = 42$). The women were measured three times—at baseline, after the 12-week intervention, and again 12 weeks later—for upper body strength, ROM, and fall risk factors (fall risk questionnaire, balance, mobility, and leg strength). **Results:** No significant differences were found in age, physical activity, or cognitive or functional status between the SOYF–standard and the SOYF–FAST groups. Both groups improved their fall risk status after the intervention, with no significant differences between them; however, the SOYF–FAST group showed greater improvements in upper extremity strength and ROM ($p = 0.007$). **Conclusion:** FAST can feasibly be integrated into fall prevention programming, with additional gains in upper body strength and ROM in older women.

Key Words: falls, accidental; exercise; muscle strength; postural balance; risk factors.

RÉSUMÉ

Objectif : déterminer l'effet d'un programme d'exercices unique (*Fall Arrest Strategy Training*, ou formation sur la stratégie d'arrêt des chutes, FAST) sur la force du haut du corps, l'amplitude de mouvements (AdM) et le risque de chute chez les femmes âgées. Le programme FAST vise à améliorer la capacité du haut du corps à prévenir les blessures lorsqu'il est impossible d'éviter une chute. **Méthodologie :** l'étude quasi aléatoire dans le milieu incluait 71 femmes âgées (de 67 à 95 ans, âge moyen de 83 ans), qui ont participé soit à un programme de prévention des chutes standard (*Staying on Your Feet*, ou rester sur ses pieds, SOYF), soit aux programmes SOYF et FAST combinés ($n = 29$ et $n = 42$, respectivement). Les femmes ont été mesurées trois fois (au début, après l'intervention de 12 semaines, puis de nouveau 12 semaines plus tard), afin d'évaluer la force du haut de leur corps, leur AdM et les facteurs de risque de chute (questionnaire sur le risque de chute, équilibre, mobilité et force des jambes). **Résultats :** il n'y avait pas de différence significative en matière d'âge, d'activité physique ou d'état cognitif ou fonctionnel entre le groupe SOYF standard et le groupe SOYF–FAST. Les deux groupes avaient réduit leur risque de chute après l'intervention, sans différence significative entre les deux. Cependant, le groupe SOYF–FAST avait amélioré davantage la force du haut du corps et l'AdM ($p = 0,007$). **Conclusion :** le programme FAST peut être intégré à un programme de prévention des chutes et être également bénéfique pour la force du haut du corps et l'AdM chez les femmes âgées.

Falls are the primary reason for hospital admissions because of injury for Canadian older adults, resulting in an average length of post-injury stay of 22 days, double the length of hospital stays for any other cause.¹ Falls are responsible for more than 95% of hip fractures² and 60% of hospital admissions for traumatic head injury.^{3–5} Another common injury, particularly for women, is wrist

fracture, and the associated health care costs amount to \$240 million per year.⁶ A wrist fracture, although rarely resulting in hospitalization, is a strong indicator of a subsequent fragility fracture.⁷

It is likely that the risk of injury depends on both the severity of a fall and musculoskeletal capacity, such as the bone and muscle strength of the affected body part.⁸

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A total of 60% of all falls in community-dwelling older adults occur in a forward direction, and women younger than age 65 years are twice as likely to fall forward as men.^{8,9} Forward falls are typically combined with hand contact as a protective response to prevent head, hip, or torso injury.^{8,10} Aging is associated with persistence in the existence, but a decrease in the effectiveness, of these protective strategies.¹¹ Evidence has suggested that forward-fall arrest strategies can be modified to improve safe landing and reduce the force of impact in younger adults,^{12–15} but whether this applies to older adults, particularly older women at high risk for injury, is not known.

The magnitude and direction of the force applied to the palm during a fall is determined primarily by pre-impact neuromuscular factors, such as muscle strength and the kinematic placement of the upper extremity (UE).¹⁴ DeGoede and Ashton-Miller¹³ and DeGoede and associates¹⁴ reported two factors that could significantly diminish the force of hand impact: the initial angle of elbow flexion and the velocity of impact. A training programme that focuses on avoiding accelerating the hand to hit the ground and hitting the ground with a slightly flexed elbow does decrease the forces of impact in younger adults.¹² It is not known why older women have a diminished ability to absorb the energy of a forward descent through the UE compared with younger women,¹⁶ but it may be due to weaker elbow extensor strength.¹³ Reduced wrist extension mobility and greater elbow extension angle at impact also decrease the ability to absorb the energy of hitting one's hand.^{17,18} Aging causes declines in wrist extension range of motion (ROM) of 10°–15° on average;¹⁹ older women lose approximately 0.5° per year.²⁰ Other declines in ROM, such as shoulder extension, may also limit the ability to control the descent of the body post-impact.

Older adults can achieve positive effects in functional performance from both upper and lower extremity strength-training programmes.^{21,22} Exercises for fall prevention focus on balance and lower extremity strengthening, guided by research that has identified these as primary factors for decreasing fall risk.^{23–25} A Saskatoon Health Region fall prevention programme, Staying on Your Feet (SOYF), has demonstrated effectiveness in improving balance, balance confidence, and self-reported fall rates.²⁶ However, the effects of a training programme designed specifically to decrease the risk of upper body injury in the event that a person cannot maintain her or his balance and is about to fall remain unknown.

In summary, current evidence has suggested that, in addition to balance and strength training to decrease fall risk in older women, Fall Arrest Strategy Training (FAST), which focuses on increasing the strength of the shoulder girdle, elbow, and trunk postural-control muscles, in combination with ensuring optimal ROM

and learning how to facilitate a soft landing, may further reduce the risk of injury resulting from a fall.

The primary objective of this research project was to determine the combined effect of FAST and SOYF on improving fall risk, UE muscle strength, and mobility. The principal research questions were as follows:

1. Does the addition of FAST to the SOYF programme lead to improvements in UE strength and ROM compared with SOYF alone (SOYF–standard)?
2. Does FAST combined with SOYF produce similar gains in fall risk factors (fall risk questionnaire, balance, sit to stand, and timed up and go [TUG] test)?
3. Is there a difference in programme adherence when FAST is added?
4. Are any gains in fall risk, UE strength, and ROM maintained 12 weeks after the intervention is completed?

The hypotheses were that SOYF–FAST would result in greater improvements in UE strength and ROM than SOYF–standard and that participants in both programmes would demonstrate similar adherence and similar gains in fall risk factors, which would be maintained at 12-week follow-up.

METHODS

This was a quasi-randomized, site-controlled, longitudinal study evaluating the efficacy of FAST in older women participating in SOYF. Potential sites (including both independent living and assisted living), with women of similar age ranges and programme opportunities, were identified by the SOYF programme coordinator. An individual not directly involved with SOYF or the study randomized the sites as either SOYF–FAST or SOYF–standard (see Figure 1). This resulted in three cohorts at six sites spanning 10 months. In the final cohort, both sites were assigned as FAST sites because of concerns regarding sample size disparity.

Once potential sites were determined, women aged 65 years and older were recruited using poster advertisements at the site. An information session was also advertised and conducted on site for interested participants to receive more information about the study and SOYF. A screening questionnaire was administered in person to determine whether the following exclusion criteria were present: (1) recent upper body injury or painful joint problem that limited day-to-day activities or resulted in daily pain, (2) wrist fracture in the past 2 years, (3) any fracture in the past year or multiple fractures of the wrist or forearm, (4) a history of neurological problems involving the UE, (5) cardiovascular problems that would contradict an UE strength-training programme, and (6) inability to safely ambulate independently (with or without a walking aid). Cognitive status was assessed at baseline using the Mini-Cognitive Assessment Instrument for

Dementia (Mini-Cog)²⁷ as well as the cognitive screen section of the Falls Risk for Older People—Community setting (FROP-Com) screen.^{28,29} Participants were excluded if they showed signs of severe cognitive impairment (as determined by scores of <3 on the Mini-Cog and <7 on the FROP-Com).^{27–29}

Ethics approval was obtained from the University of Saskatchewan's Biomedical Ethics Review Board and operational approval from the Saskatoon Health Region. All participants completed informed consent forms before we performed baseline testing.

Intervention

The class size at each site ranged from 12 to a maximum of 30 participants. Because SOYF is a regular programme offered through the Saskatoon Health Region, there was a mix of study participants and non-study participants exercising together. The classes were held in the senior residence buildings, except for one SOYF-FAST group in cohort 3 ($n = 10$), for which class was held in a community church.

Both SOYF-FAST and SOYF-standard participants met for 12 weeks for 30 minutes of education once per week and 30–45 minutes of exercise twice per week. Exercises for SOYF-FAST, developed on the basis of our lab studies evaluating fall descent^{30,31} and in consultation with SOYF leaders, were added as a modification to the original SOYF-standard programme. The additional goals of SOYF-FAST include (1) increasing UE strength (shoulder girdle and arm); (2) improving muscular control of the trunk and neck, focusing on stabilization and balance reactions; and (3) learning a soft-fall arrest-strategy landing. The progression of UE strength training was based on individual needs, which were identified by the instructors using guidelines for progressive resistance exercise for older adults.^{32,33} We targeted intensities whereby participants could complete 5–10 repetitions, maintaining good form, with some muscle fatigue but no discomfort or pain, with the goal of reaching two sets of 10 repetitions (see the online Appendix).

To accommodate the extra time for FAST, some components of the general mobility and balance exercises were condensed and modified but still retained key elements of balance and functional practice. SOYF-standard included the same balance, gait, and lower extremity strengthening exercises without the FAST intervention. An experienced licensed physical therapist and an athletic therapist-graduate student supervised all exercise programmes. Participants were encouraged to perform the same exercises at home at least 2 other days of the week. After the 12-week intervention, a research assistant contacted participants once every 2 weeks to answer questions and encourage them to continue doing the exercises at home.

Outcome measures

The following outcome measures were administered at each of three testing time points (baseline, 12 wk, and 24 wk) by one researcher and two research assistants, blinded to site allocation. The participants performed all measurements, with the exception of the TUG test, at home. The TUG test was administered by the leaders before and after completion of the programme because of space requirements and to maintain the consistency of the environment. The outcome measures in this initial pilot study addressed three of the primary goals of FAST: UE strength, balance and agility, and UE ROM.

Muscle strength handheld dynamometry

A handheld dynamometer (HHD; Lafayette Instrument Company, Lafayette, IN) was used to measure isometric shoulder abduction and flexion as well as elbow extension. A standardized protocol was applied, as documented in previous literature.^{34–36} All tests were performed in supine to optimize stabilization of the trunk, with standardized positioning of the HHD using anatomical landmarks. Shoulder abduction was tested at 45°, and shoulder flexion and elbow flexion were tested at 90°. Three trials for each test were given using a “make” test, in which the participants were asked to gradually increase their maximal force over the course of 5 seconds while the tester met their maximal contraction to sustain an isometric contraction.³⁴ Validity and reliability of this technique have been confirmed for a variety of UE muscles in previous studies.^{34,36–38} The mean peak force of three trials was determined for each side, and then a composite strength score, which added the peak force means of left and right for each muscle group tested, was used for analysis.

Grip strength

Isometric grip strength was assessed using a calibrated Baseline Hydraulic Hand Dynamometer (Fabrication Enterprises, White Plains, NY) and a standard protocol³⁹ while the participant sat with her back supported, shoulder adducted, elbow flexed at 90°, wrist in neutral, and palm facing medially. A standard distance for the handgrip position (second grip) was used for all participants. Three trials were given, alternating between hands to allow a rest period of 30 seconds between contractions. A composite grip-strength score of the means of all trials for left and right hands was used for analysis.

Wrist and shoulder range of motion

Passive wrist extension and shoulder extension (active motion with passive overpressure at end range) were measured in one trial. Both wrist and shoulder extension were tested in sitting. For wrist extension, the forearm was supported on a towel roll placed on a table top or firm surface. For shoulder extension, the participant sat

in a chair without arm rests, maintaining trunk posture with the back supported by the chair during the test motion. A standard and reliable protocol was followed for positioning, anatomical landmarks, and limb support.^{40,41} A composite wrist and shoulder extension score of left and right extremities was used for the analysis.

Balance

Two standing balance measures, one-leg standing (OLS)⁴² and the tandem standing test (TST),⁴³ were used to measure balance. For the TST, participants first performed a 10-second TST with support and then a 30-second TST without support.⁴³ The 10-second TST with support starts with participants holding a support surface (i.e., kitchen counter) with one hand and placing their foot of choice forward in a tandem stance. Once they feel stable, they are asked to remove their hand from the support and hold the position for 10 seconds. The 10-second TST is considered successful if participants can hold the position without moving out of the tandem position or contacting the external surface for a full 10 seconds. If the participants are able to successfully perform the 10-second TST, they attempt a 30-second TST without support in which they are asked to move into the same TST and hold it for 30 seconds without the use of any support during the task.

The TST (10 s and 30 s) was categorized on the basis of previous research⁴³ as (1) unsuccessful 10-second TST, not stable enough to begin timing once hand support was removed; (2) unsuccessful 10-second TST but stable enough to begin timing, holding the position for less than 10 seconds; (3) a successful 10-second TST with a 30-second TST of less than 10 seconds; (4) a successful 10-second TST with a 30-second TST between 10 and 29 seconds; and (5) a successful 10-second TST with a full 30-second TST. Participants were given two attempts for OLS on both legs, and the best time (≤ 60 s) was used for analysis. Both OLS and the TST are associated with fall risk and are valid and reliable tests of standing balance.⁴⁴

Sit to stand (lower extremity strength, balance, and agility)

The 30-second chair sit-to-stand (STS) measures the number of full STS repetitions that can be performed in 30 seconds without using the UE. STS is primarily a measure of lower extremity strength, and although it is associated with fall risk, a specific cutoff score for higher fall risk has not been verified.⁴⁵

Fall risk assessment

The FROP-Com²⁸ is a valid and reliable measure of fall risk status, with a 71% sensitivity for predicting high fall risk at a score of 19 out of 60 or higher.⁴⁶ This interviewer-administered, in-home assessment evaluates a range of fall risk factors, including fall history, functional ability, gait, and lifestyle factors.

Balance confidence

The Activities-specific Balance Confidence Scale (ABC)⁴⁷ was used to monitor changes in fear of falls and balance

confidence; it is a reliable and valid instrument commonly used with community-dwelling older adult populations.

Timed up-and-go (fall risk, balance, and agility)

The TUG test, a reliable and valid outcome tool for measuring fall risk status, with a 90% prediction rate at a cutoff of 13.5 seconds,⁴⁸ was applied according to a standardized protocol.⁴⁹ The TUG determines a participant's functional ability to stand up, walk 3 metres, turn, and return to sitting.

Demographic and medical history, activity, medications, and adherence log

A medical history and demographic questionnaire and the Physical Activity Scale for the Elderly (PASE)⁵⁰ were administered at baseline, 12 weeks, and 24 weeks. The medical history questionnaire was designed to first identify any conditions that might jeopardize safety or any exclusion criteria, and subsequent administration tracked any changes in medication, health conditions, or injuries. A calendar was given to each participant to record details about any significant changes in activity level or medical status and to record falls or any other injuries. Attendance in the programme was recorded by the leaders.

Analysis and sample size

Sample size estimates used conservative estimates of effect sizes, for a 10% mean difference in change in shoulder and elbow muscle strength. We based this estimate on previous HHD studies; however, there is no decisive minimal detectable change (MDC) that can be applied to these muscle groups in this population.^{34–38,51} Using G*Power version 3.1.5 (Heinrich-Heine-Universität Düsseldorf, Germany),⁵² a repeated-measures multivariate analysis of variance (MANOVA) comparing within and between groups (two groups $\times$ three time points), an α of 0.05 at 90% power, and an effect size of 0.30, the total estimated sample size was $n = 22$ per group.

An intention-to-treat analysis was conducted using all participants, who were randomly assigned to SOYF-FAST or SOYF-standard. Missing values were replaced using a last-observation-carried-forward approach or group mean replacement if missing at baseline for all outcome measures. Demographics, fall status, and baseline outcome measures were compared between the groups using independent t tests. Two repeated-measures MANOVAs, comparing within and between groups (two groups $\times$ three time points), were used to examine the effects of the intervention on (1) fall risk (FROP-Com, STS, TST, OLS, and ABC) and (2) UE strength and mobility (composite shoulder abduction, shoulder flexion, and elbow extension strength), hand grip, and wrist and shoulder ROM. If there were significant multivariate effects, post hoc analysis was conducted using a separate repeated-measures MANOVA and subsequent univariate testing for each group independently. TUG was analyzed separately with a one-way repeated-measures analysis of

Figure 1 Flowchart of participants.

UE = upper extremity; SOYF = Staying on Your Feet; FAST = Fall Arrest Strategy Training.

Table 1 Demographic Data for 42 SOYF-FAST and 29 SOYF-Standard Participants

Measure	Baseline		Post-intervention		Follow-up	
	SOYF-FAST	SOYF-standard	SOYF-FAST	SOYF-standard	SOYF-FAST	SOYF-standard
Age, mean (SD)	82.5 (5.9)	82.5 (5.9)	—	—	—	—
Mini-Cog /3, mean (SD)	2.0 (0.99)	1.9 (0.99)	—	—	—	—
No. (%) reporting falls*	19† (48)	7 (26)	7	3	5	3
PASE, mean (SD)	69.0 (36.6)	73.4 (51.6)	77.6 (50.4)	73.5 (47.1)	76.8 (43.9)	76.6 (56.4)

* At baseline, reported in past year; at post-intervention and follow-up, reported since previous assessment (3 mo).

† Significant difference between groups, Pearson χ^2 , $p = 0.038$; missing data, $n = 4$.

SOYF = Staying on Your Feet; FAST = Fall Arrest Strategy Training; Mini-Cog = Mini-Cognitive Assessment Instrument for Dementia; PASE = Physical Activity Scale for the Elderly.

variance (ANOVA) because it was measured at only two time points: baseline and post-intervention. Significance was set at $p < 0.05$ for omnibus tests using Pillai's trace for multivariate tests.

RESULTS

A total of 78 women aged older than 65 years were screened for participation, and 71 were eligible to participate (see Figure 1). No significant differences were found between SOYF-FAST ($n = 42$) and SOYF-standard ($n = 29$) for intervention attendance (adherence) rates, number of dropouts, number of falls, age, physical activity level, cognitive status, or baseline fall-risk status (see Table 1). Attendance in the 12-week programme was excellent for both groups: Participants attended an average of 88% of the classes. There were more dropouts in SOYF-FAST than in SOYF-standard ($n = 9$ vs, $n = 3$, non-significant difference, $p = 0.336$; however, only one re-

ported reason related to the exercise programme. There were no noted changes in medical condition or medication that warranted further attention, other than the reported dropouts. There were no significant changes in PASE scores across three time points in both groups ($p = 0.519$, but there was a significant difference in the number of participants reporting falls in the previous year in SOYF-FAST versus SOYF-standard ($p = 0.038$; see Table 2).

There was a significant improvement in fall risk factors for both SOYF-FAST and SOYF-standard from baseline to posttesting to follow-up, with a significant multivariate time effect ($p < 0.000$, $\eta^2_p = 0.22$), but no significant group $\times$ time interaction ($p = 0.739$). In univariate analysis, significant improvements were seen for both groups in fall risk scores (FROP-Com) from pre- to posttesting ($p < 0.000$) and from pretesting to follow-up ($p < 0.000$), but not from posttesting to follow-up ($p = 0.085$). STS

Table 2 Outcome Variables at Each Testing Point for 42 SOYF-FAST and 29 SOYF-Standard Participants

Measure	Baseline		Post-intervention		Follow-up	
	SOYF-FAST	SOYF-standard	SOYF-FAST	SOYF-standard	SOYF-FAST	SOYF-standard
TUG (sec)	12.5 (4.1)	11.7 (3.1)	11.6 (4.1)	10.9 (3.1)		
FROP-Com/60	13.1 (6.7)	10.7 (4.6)	11.0 (6.6)	8.9 (4.5)	10.0 (6.4)	8.8 (5.3)
ABC/100	73.9 (21.3)	78.9 (18.8)	76.0 (19.4)	79.2 (18.8)	77.1 (21.0)	77.7 (21.7)
TST/5	2.8 (1.5)	2.9 (1.5)	3.1 (1.5)	3.1 (1.5)	3.2 (1.5)	3.2 (1.4)
OLS (sec)	14.7 (19.2)	19.7 (21.6)	15.4 (18.3)	19.7 (21.3)	16.1 (20.0)	19.5 (20.9)
Chair stand (no.)	8.7 (3.7)	9.2 (3.9)	9.7 (3.7)	10.0 (4.1)	10.0 (3.7)	10.7 (5.2)
Shoulder abduction (kg)*	13.1 (5.2)	13.7 (4.9)	14.3 (4.2)	12.6 (4.1)	14.5 (3.9)	14.1 (5.3)
Shoulder flexion (kg)*	11.7 (3.8)	13.3 (6.2)	13.5 (4.0)	11.4 (3.8)	13.2 (4.4)	12.1 (3.8)
Elbow extension (kg)*	13.2 (4.7)	14.8 (5.8)	14.6 (4.1)	13.5 (4.9)	14.3 (4.0)	14.1 (5.1)
Grip (kg)*	36.7 (11.1)	36.1 (9.9)	38.6 (11.3)	36.7 (8.4)	38.7 (9.8)	36.1 (9.1)
Wrist extension (degrees)*	144.6 (20.9)	147.7 (15.6)	155.1 (19.3)	148.0 (16.4)	152.7 (19.5)	146.9 (16.6)
Shoulder extension (degrees)*	109.1 (17.5)	118.9 (17.3)	109.6 (18.6)	118.2 (24.5)	110.9 (19.0)	115.1 (21.5)

* Composite scores

Note: All data reported as mean (SD).

SOYF = Staying on Your Feet; FAST = Fall Arrest Strategy Training; TUG = timed up-and-go; FROP-Com = Falls Risk for Older Persons—Community setting; ABC = Activities-specific Balance Confidence Scale; TST = tandem- standing test; OLS = one-leg standing.

Figure 2 Comparison of SOYF-FAST and SOYF-standard mean composite elbow extensor strength, with SE bars at pretesting, posttesting, and follow-up 12 weeks post-intervention.

* Significant change from pre- to posttesting ($p = 0.03$) for SOYF-FAST. PRE = pretest; POST = posttest; FWUP = follow-up; SOYF = Staying on Your Feet; FAST = Fall Arrest Strategy Training.

significantly improved at all time points ($ps = 0.001$, 0.000 , and 0.015 , respectively; see Table 2). TUG scores were analyzed in a separate one-way repeated-measures ANOVA and showed significant improvement in scores from pre- to posttesting for both groups ($p < 0.000$, $\eta^2_p = 0.26$), but there was no significant group $\times$ time interaction ($p = 0.758$).

There was an overall improvement (time effect; $p = 0.006$, $\eta^2_p = 0.10$) in upper body strength and mobility, with a significant group $\times$ time interaction

Figure 3 Comparison of SOYF-FAST and SOYF-standard mean composite grip strength, with SE bars at pretesting, posttesting, and follow-up 12 weeks post-intervention.

* Significant change from pre- to posttesting ($p = 0.018$) and from pretesting to follow-up ($p = 0.007$) for SOYF-FAST. PRE = pretest; POST = posttest; FWUP = follow-up; SOYF = Staying on Your Feet; FAST = Fall Arrest Strategy Training.

($p = 0.007$, $\eta^2_p = 0.10$). Univariate analysis revealed significant group $\times$ time interactions for shoulder abduction, shoulder flexion, elbow extension strength, and wrist ROM ($ps = 0.011$, 0.001 , 0.005 , and 0.016 , respectively). Further post hoc analysis found that the SOYF-FAST group had a significant multivariate improvement across time ($p = 0.004$), with shoulder abduction strength significantly improved from pre- to posttesting and from pretesting to follow-up, but not from posttesting to follow-up ($ps = 0.047$, 0.015 , and 0.58 , respectively). The same pattern was found for shoulder flexion strength

Figure 4 Comparison of SOYF-FAST and SOYF-standard mean composite wrist extension ROM, with SE bars at pretesting, posttesting, and follow-up 12 weeks post-intervention.

* Significant change from pre- to post-testing ($p = 0.000$) and from pre-testing to follow-up ($p = 0.008$) for SOYF-FAST.

PRE = pretest; POST = posttest; FWUP = follow-up; SOYF = Staying on Your Feet; FAST = Fall Arrest Strategy Training; ROM = range of motion.

($ps = 0.007, 0.039, \text{ and } 0.60$, respectively) and grip strength ($ps = 0.018, 0.007, \text{ and } 0.83$, respectively). Elbow extensor strength significantly improved from pre- to posttesting, but not from pretesting to follow-up or post-testing to follow-up ($ps = 0.030, 0.10, \text{ and } 0.56$, respectively). Wrist ROM had the same pattern as UE strength, with significant improvements from pre- to posttesting and from pretesting to follow-up, but not from posttesting to follow-up ($ps = 0.000, 0.008, \text{ and } 0.321$, respectively). For SOYF-standard, there were no significant within-subject effects over time for upper body strength or ROM (see Table 1 and Figures 2, 3, and 4.)

DISCUSSION

Exercise programmes designed to focus on improving balance and strength have been found to be effective in improving fall risk status in older adults.^{23,24,53} However, there are no clinical practice recommendations regarding the potential benefits of exercise to address modifiable factors that may reduce the risk of injury when a fall is unavoidable. For example, it is surprising, given the high percentage of fall-related injuries to the upper body,¹ that there has been little focus on upper body strengthening in fall prevention programming. Our results do support fall prevention exercise programming (twice per week for 12 wk) to improve fall risk factors, with the additional benefit of FAST to improve UE strength and mobility.

FAST was designed to address the factors associated with the risk of injury in the most common type of fall in women: a forward fall, landing on the outstretched hands. The primary components of this simple and

feasible training programme included a progression of UE strength training, trunk and neck postural control practice, ROM exercises for the wrist and shoulders, and learning how to facilitate a soft landing on the hands. Our findings show that this training programme can result in gains in shoulder girdle, elbow, and forearm strength, combined with wrist ROM improvement, more so than a standard fall prevention programme that does not include these components. Previous research has supported the hypothesis that UE neuromuscular capacity is likely one of the most promising modifiable contributors to improving the ability to absorb the force of a fall on the hands and to absorb energy.^{8,16,54}

Ineffective arm response times, bracing the elbows at impact, and decreased wrist extension have been observed in both men and women,^{17,55} and they may contribute to the decreased ability of older adults to absorb energy during a fall and ultimately increase the risk of head, torso, shoulder, or wrist injury. Both Sran and colleagues¹⁶ and Lattimer and colleagues³⁰ found that the ability to absorb the energy of a controlled descent using the UE was diminished by 35%–40% in older women compared with younger women. Older women with age-related loss of arm strength may fear their elbows buckling and attempt to brace their arms. This is a poor strategy choice because of the higher impact forces and risk of UE fracture. However, women have a reduced ability to prevent elbow buckling than men, likely in part because of weaker triceps, which may put them at higher risk of head impact.⁵⁶

Most of the research evaluating the ability to train participants in fall strategies to decrease the risk of upper body injury has been limited to young adults. DeGoede and colleagues^{13,14} determined that the primary factors for significantly diminishing the force of hand impact (and the resultant ability to absorb energy) were optimizing the initial elbow-flexion angle (130° just before impact) and reducing the velocity of impact of the body mass relative to the hands. These two factors reduced the peak impact force up to 40%. Hsu and colleagues⁵⁷ determined that UE placement at impact predicted the risk of shoulder injury. The ability to place the UE in an effective loading position depends on several factors, including the available range of wrist extension motion.

In addition to the evidence provided by laboratory studies, video data of actual falls in older adults living in long-term care have confirmed that landing on the hands is common but is not associated with a reduced occurrence of hitting one's head.⁵⁸ This would suggest that the neuromuscular capacity of older adults may not be adequate to control their descent and prevent head impact. Kinematic analysis from these video surveillance data has also suggested that older adults have more time to react from the moment of imbalance until body contact, compared with predictions from lab-based studies of younger adults.⁵⁹ The current evidence implies that there is an opportunity to improve older adults' capacity

to modify forward-fall arrest strategies, which might avoid head injury and decrease the force of impact and the resultant risk of wrist fracture. To our knowledge, we are the first research team to investigate the feasibility and efficacy of such a training programme in older women.

The participants in this study received telephone follow-up calls every 2 weeks after the intervention was complete. This, in combination with the regular programming available at most of the sites, appeared to help motivate the participants to continue exercising up to 12 weeks later. Considering that wrist extension ROM was not maintained at follow-up, it is likely that participants did not continue with wrist extension stretching. The reasons for this are not clear. It is possible that wrist extension stretching was not considered a priority for inclusion in the ongoing group exercise programming at the sites that occurred after study intervention completion or that participants did not perceive it to be an important exercise to practise on their own. Unfortunately, the telephone monitoring and self-report documentation in calendars proved to be difficult to implement for this population, and we were unable to determine the frequency with which participants engaged in their home programmes. It is difficult to know whether further follow-up at 6 or 12 months would have seen retrogression to baseline, maintenance, or further gains; certainly, mechanisms to ensure the sustainability of exercise participation should be an important consideration in future fall prevention programming.

The strength of this study was that the FAST programme is designed to be simple and easy to implement; it requires little equipment or personnel training and is designed for a wide variety of functional levels and environments. The average participant was older than age 80 years, and some participants were well into their 90s. There were no difficulties with adherence, adverse effects, or feasibility in implementing the programme. In addition, FAST incorporated into SOYF still resulted in improved balance, fall risk, gait, and lower extremity strength (STS performance). These are significant fall risk outcomes, and they must be preserved when considering adding exercises to fall prevention programming.

One of the limitations of this study was the lack of a clinical measure of UE movement time and the ability to land softly to better absorb the energy of a descent. The arm kinematics used during a simulated fall arrest, as well as the ability to absorb energy, will be tested in a planned future study using a protocol that we have recently developed.^{28,29} This will help determine whether FAST has an effect on parameters more directly related to controlling forward descent using the UE and preventing injury. The improved strength and mobility of the UE verified in this pilot study is a first step to ensuring that the training programme is addressing the neuromuscular factors related to improving the biomechanics of controlling fall descent.

Another limitation of this study was the difficulty of maintaining the blinding of the testers because testing was conducted at the intervention site. Although we attempted to control this as much as possible, both staff and participants would sometimes approach the testers, revealing information that jeopardized the blinding process. Finally, we chose a simple clinical tool to measure isometric arm strength: the HHD. The change scores observed in this study must be interpreted with the same caution that other reviews have noted regarding the limited knowledge of MDC scores for this population. Also, it is not known whether isometric strength is an accurate indicator of the eccentric strength requirements of controlling a forward fall.

In summary, an exercise programme designed to address both the factors for fall risk and the factors associated with preventing injury did improve both fall risk and UE strength and agility compared with a standard fall prevention programme. FAST, a new approach to improving the specificity of fall prevention exercise, has preliminary efficacy because it can enhance upper limb strength and mobility without losing the benefit of other fall risk factors, such as leg strength and balance. The potential benefits of FAST could include an enhanced capacity to prevent injury in a forward fall, although further research is needed to confirm this.

KEY MESSAGES

What is already known on this topic

The most common fall direction in community-dwelling older adults is forward; older women are particularly vulnerable to sustaining an injury from this type of fall. Improved neuromuscular capacity of the upper extremity and trunk might help reduce the risk of devastating injuries, such as traumatic brain injury or wrist fracture. No studies have investigated the effect of a training programme designed to address these factors in older women.

What this study adds

This study shows that a simple exercise programme, delivered twice per week for 12 weeks and designed to improve upper limb strength, range of motion (ROM), and other fall risk factors such as balance and leg strength, can decrease fall risk and increase upper body strength and ROM. However, it is uncertain what impact these improvements have on the ability to prevent injuries from occurring in the event of an actual fall; this would be an important direction for future research.

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