ORIGINAL ARTICLE

A Randomized Controlled Study Investigating Static and Dynamic Balance in Older Adults After Training With Pilates

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ABSTRACT. Bird M-L, Hill KD, Fell JW. A randomized controlled study investigating static and dynamic balance in older adults after training with Pilates. Arch Phys Med Rehabil 2012;93:43-9.

Objective: To evaluate effects of a Pilates intervention on balance and function in community-dwelling older (aged >60y) adults.

Design: Randomized crossover study design lasting 16 weeks.

Setting: University exercise clinic.

Participants: Ambulatory older community-dwelling adults (N=32) were recruited, and 27 (mean ± SD age, 67.3±6.5y) completed the program.

Intervention: Participants were allocated to either 5 weeks of a group Pilates training intervention or 5 weeks of usual activity (control). After a 6-week washout period, participants performed the alternate intervention.

Main Outcome Measures: Static and dynamic balance measures (mediolateral sway range, Four Square Step Test, Timed Up and Go Test) and leg strength were recorded at 4 times before and after each intervention (baseline [t1], interim time immediately after the first group intervention [t2], after 5-week washout [before the second intervention period] [t3], and at study conclusion after the second group intervention [t4]).

Results: There were no significant differences between the Pilates and control groups for any measured variables ($P>.05$) despite static and dynamic balance significantly improving during the study and from pre- to post-Pilates ($P<.05$) without significant changes occurring during the control phase. Improvements that occurred during Pilates between t1 and t2 did not return to baseline after the washout period (t3). There were no changes in leg strength. Mediolateral sway range standing on a foam cushion with eyes closed improved −1.64cm (95% confidence interval, −2.47 to −0.82) and had the largest effect size post-Pilates (d=.72).

Conclusions: Although there were no significant between-group differences, participation in the Pilates component of the study led to improved static and dynamic balance. The absence of differences between conditions may be a result of small sample size or the crossover study design because Pilates may produce neuromuscular adaptations of unknown resilience.

Key Words: Exercise movement techniques; Exercise therapy; Older adults; Physical activity; Rehabilitation.

REDUCED LEG STRENGTH and poor balance have been identified as 2 factors that exercise programs targeted and effectively addressed for the prevention of falls in an older population.[1] Multicomponent exercise programs have effectively targeted strength and balance for the prevention of falls, with improvements in fall rates up to 34%.[2] Evidence also supports the benefits of balance training for all older adults regardless of risk status.[3] However, although a recent systematic review confirmed the beneficial role of exercise on balance in an older population, there was a degree of uncertainty about the efficacy of some of the investigated exercise interventions because of a lack of standardized outcome measures to determine balance ability.[4] Furthermore, although the evidence for benefits derived from interventions that included training activities, such as gait, balance, coordination, and functional tasks, with general physical activity, strength training, and multiple exercise types was good, evidence from research that used activities such as Tai Chi, yoga, and dance was less convincing.

Pilates has become a popular exercise modality that combines strength and flexibility training and, with the proposed benefits of improved muscular control of the deeper abdominal muscles (transversus abdominis, lumbar multifidus, respiratory and pelvic diaphragms), may provide an effective method of improving postural stability in a community-dwelling older population. Pilates is used to describe any of the set exercises developed by Joseph Pilates. However, quality research into the benefits of Pilates is limited,[5] with disparate measures and poor study design preventing definitive conclusions from the literature.

To date, 3 studies were published that provided some preliminary support regarding balance benefits from participating in Pilates. Kaesler et al[6] reported improvements in postural

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List of Abbreviations

CHAMPS	Community Healthy Activities Model Program for Seniors
FSST	Four Square Step Test
ICC	intraclass correlation coefficient
t1	baseline
t2	interim time immediately after the first group intervention
t3	after 5-week washout (before the second intervention period)
t4	at study conclusion after the second group intervention
TUG	Timed Up and Go

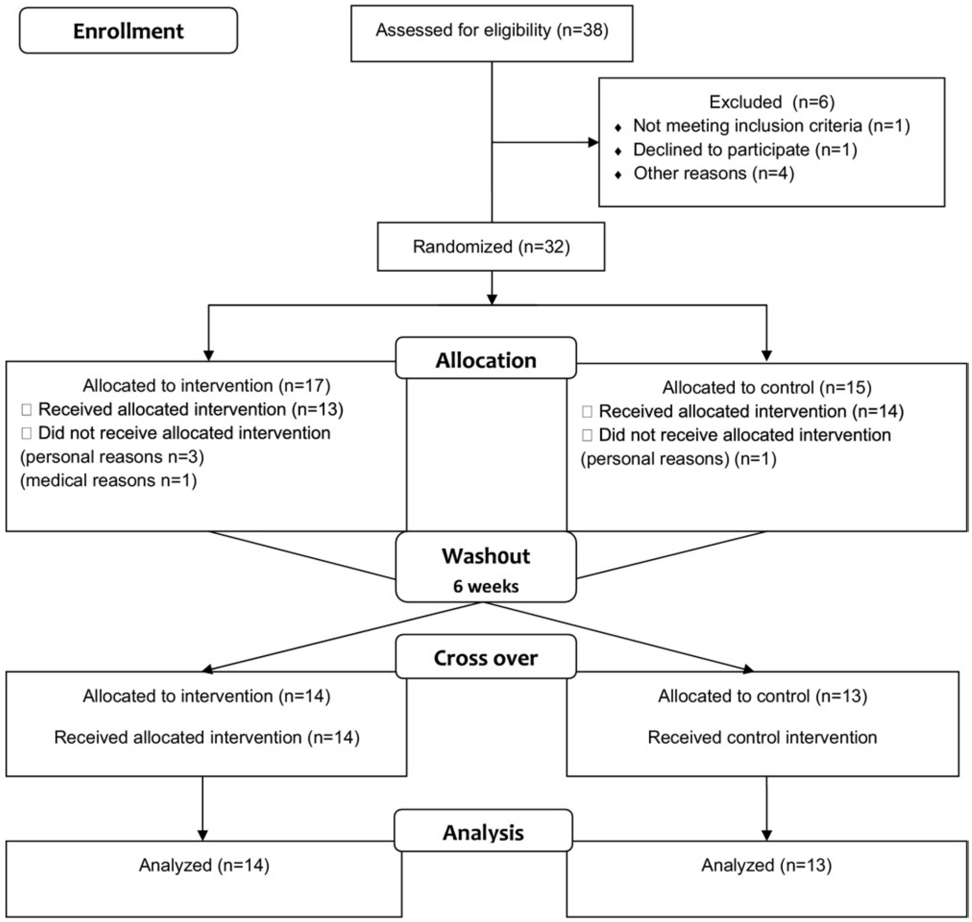

Fig 1. Consolidated Standards of Reporting Trials flow diagram of study design.

sway and dynamic balance in an older adult population (age range, 66–71y) after 8 weeks of Pilates classes 2 times per week. However, their study was uncontrolled, with a sample size of only 7 completing the training. In a controlled study of 34 healthy younger adults (age, 27.3±3.6y; n=17 in each group), Johnson et al[7] reported significant improvement in Functional Reach Test results after 5 weeks of Pilates training that was not evident in the control group, although the group-by-time interaction was not significant and the effect of this improvement was only small (Cohen d=.49). More recently, a larger randomized controlled study (n=60) of older (age >65y) nursing home residents found significant improvements (P<.05) in dynamic force platform measures, muscle strength, reaction time, and fall rates compared with a control group after a 12-week Pilates intervention.[8] However, whether these findings translate beyond the population targeted in their study was identified as a limitation by the investigators.

Several studies did not identify beneficial effects associated with Pilates programs. A recent study by Kloubec[9] did not find balance improvements in an active middle-aged group (aged 26–59y) after a 12-week Pilates program, and this finding was similar to another study that investigated Pilates training in college-aged participants.[10] However, improving balance in already highly functioning younger populations may be more difficult and less relevant than improving balance in a higher risk older population.

Consequently, the aim of this study was to conduct a randomized controlled trial to investigate the effects of a Pilates intervention on the variables of static and dynamic balance and leg strength in a group of community-dwelling adults older than 60 years.

METHODS

Participants

Independently living and ambulating adults (N=32; age >60y) were recruited through local community groups in an urban area using radio and print media. Participants were included if they did not currently have or had not recently had an acute medical condition. Volunteers who had controlled chronic conditions such as arthritis or stable chronic cardiovascular or metabolic conditions (eg, hypertension, diabetes mellitus) were included in the study. Ethical approval for this study was given by the institutional health and medical human research ethics committee, and written informed consent was obtained from all participants before participation (reference number H0010572).

Study Design

A randomized crossover design (fig 1) was used, which meant that all participants would receive the intervention (Pilates) during the study period. This approach was considered to increase likely recruitment of participants. Each participant was given a number at entry into the program and then initially allocated to either the control or exercise group in a random-order process (using a random-number generator) by an independent researcher. Researchers involved in testing participants were blinded to group allocation. Dependent variables were measured at 4 times: baseline (t1), an interim time immediately after the first group intervention (t2), after a 6-week washout (before the second intervention period) (t3), and at study conclusion after the second group intervention (t4). Each group completed 5 weeks of the Pilates (2 group sessions/wk) or control conditions. Participants under the control condition were requested to maintain normal physical activity, monitored by using the Community Healthy Activities Model Program for Seniors (CHAMPS) questionnaire. Class attendance was monitored by class leaders.

Outcome Measures

An AMTI force platform[a] (Accugait PJB101) measured center-of-pressure sway for 30 seconds under the conditions of eyes open and eyes closed, both standing on a firm surface and with the additional challenge of a medium-density foam cushion (65-mm Airex Elite Balance-pad).[b] Sway data were analyzed using Balance Clinic software (AMTI balance software, version 1.4,[a] Accugait, Massachusetts) and mediolateral sway range was recorded (in centimeters). We previously established high test-retest reliability with a similar sample group for mediolateral sway range using the AMTI force platform (intraclass correlation coefficient [ICC]=.87; M. Bird, unpublished data).

Dynamic balance was measured by using the Four Square Step Test (FSST) and the Timed Up and Go (TUG) Test. The FSST measures the speed of rapid stepping in forward, sideways, and backward directions over 4 walking sticks arranged to divide the floor into 4 squares. The sequence of steps initially was shown by an investigator, and standardized instructions were given.[11] This test was shown to discriminate older nonfallers and single fallers from multiple fallers and has both high interrater reliability (ICC=.99) and retest reliability (ICC=.98).[12] The functional TUG Test was included as a simple clinically appropriate measure of dynamic balance and functional capacity that requires good lower-limb strength.[13] Participants stood up from a chair 45-cm high and were instructed to walk at a comfortable fast pace to a marker 3m away, turn, walk back to the chair, and sit down again.

Strength for knee extensors and ankle dorsiflexors was measured for both legs by using a spring-based measurement system[c] developed as part of a battery of fall risk assessment tests.[14] Knee extensor strength was measured in a seated position with the hip and knee angles set at 90°. Participants were instructed to straighten the leg, pushing into the strap as hard as possible. Participants performed 3 maximal efforts to extend the knee. The highest value was recorded (in kilograms). To measure ankle dorsiflexion strength, the foot was stabilized in a specially designed mobile footplate and a strap was secured around the metatarsal heads, which anchored the forefoot.[14] Participants were instructed to raise the forefoot as forcefully as possible while keeping the heel down on the rear of the plate. Three attempts were performed on each side, and the highest value for each leg was recorded (in kilograms).

Pilates Intervention

Classes were held in small groups of no more than 6 people. These classes were held twice per week and lasted 60 minutes. Classes consisted of standing and mat exercises followed by a circuit style session of Pilates reformer and mat-based exercises (table 1). A reformer is a spring-based piece of equipment that requires both concentric and eccentric muscle action to move a semistable platform. Focus included balance and lower-limb strength, and circuit style exercises were individualized to specific participant needs within the group structure. Small group sizes ensured that each participant performed the exercises using the best technique possible and was progressed in terms of repetitions and load of exercises at the earliest opportunity. Participants also were given a copy of the mat exercises to complete on 1 other occasion per week at home (see table 1), with a diary (which included exercise description and graphics) to assist in compliance with this request. Classes were supervised by Pilates instructors who had undertaken training accreditation (Pilates Alliance).

Table 1: Description of Exercise Content for Classes and Home Program

Class Program	Class and Home Program
Reformer: footwork	Standing roll down
Reformer: standing series	Arm arcs (performed in standing)
Reformer: scooter	Side leg series (performed in standing)
Trapeze: assisted squats	Bent knee fall out
Quadruped (arm and leg extension using foam roller)	Toe taps
	Side to side
	Quadruped
	Side kick
	Bridging

Statistical Analyses

Repeated-measures analysis of variance using general linear modeling was performed to compare between-group changes with Pilates and usual activity (control) as the between-group factor and within-group changes over time using STATA software (version 10.0).[d] Post hoc testing using the Holms test was used to identify within-group changes over time. A priori power calculations were performed for the key dependent balance variable of TUG Test result based on previous research[6,15] indicating that a sample size of 30 participants would be required to provide greater than 80% power at α level of .05. We anticipated a 10% dropout rate and aimed for a starting population of 33. Clinically meaningful change was assessed by calculating Cohen d for effect size in relation to changes that occurred during the Pilates intervention and control period. Data were analyzed by using an intention-to-treat model.

RESULTS

Characteristics of the Study Population

Thirty-two of the 38 people who responded to media promotion about the project (mean ± SD age, 67.2±6.6y; 27% men) were eligible for inclusion and 27 participants (22% men; mean age, 67.3±6.5y) completed the program. All participants were independently mobile and living independently within the community. No participant had a joint replacement or used a walking assistive device. Baseline physical activity, measured by using the CHAMPS questionnaire, was 61.2 metabolic equivalent unit hours per week (95% confidence interval, 46.5–76.0). There was no change in CHAMPS score during the control condition (P>.05). Five participants withdrew from the study after initial recruitment because of back pain (not asso-

Table 2: Comparison of Change in Each Variable While Undertaking the Pilates Treatment Period Compared With Change While Undertaking the Usual Activity (Control) Period

Variable	Pre-Pilates	Mean Difference From Baseline	P	Effect Size	Pre-Control	Mean Difference From Baseline	P	Effect Size	Difference Between Change in Pilates and Change in Control
TUG Test (s)	6.26 (5.97 to 6.72)	−0.41 (−0.61 to −0.21)	<.001	.34	6.02 (5.55 to 6.48)	−0.14 (−0.46 to 0.18)	.119	NS	−0.20 (−0.62 to 0.10)
FSST (s)	7.86 (7.30 to 8.42)	−0.57 (−0.91 to −0.23)	.001	.44	7.58 (7.07 to 8.09)	−0.34 (−0.76 to 0.07)	.107	NS	−0.23 (−0.72 to 0.26)
Eyes open M-L sway range (cm)	1.96 (1.49 to 2.42)	−0.19 (−0.40 to 0.02)	.072	NS	1.81 (1.57 to 2.05)	−0.26 (−0.52 to −0.00)	.047	0.37	0.07 (−0.40 to 0.39)
Eyes closed M-L sway range (cm)	2.18 (1.72 to 2.64)	−0.28 (−0.57 to 0.02)	.069	NS	2.24 (1.76 to 2.73)	−0.43 (−0.89 to 0.04)	.073	NS	0.15 (−0.38 to 0.68)
Eyes open on foam M-L sway range (cm)	4.61 (3.90 to 5.32)	−0.78 (−1.22 to −0.34)	.001	.46	4.61 (3.98 to 5.24)	−0.48 (−1.05 to 0.06)	.079	NS	−0.28 (−1.11 to 0.54)
Eyes closed on foam M-L sway range (cm)	7.43 (6.62 to 8.30)	−1.64 (−2.47 to −0.82)	<.001	.72	7.20 (6.18 to 8.22)	−1.08 (−2.17 to 0.02)	.054	NS	−0.56 (−1.96 to 0.84)
Ankle strength (kg)	11.80 (10.6 to 13.0)	0.50 (−0.60 to 1.60)	.356	NS	11.60 (10.42 to 12.80)	0.20 (−0.89 to 1.30)	.715	NS	0.29 (−0.92 to 1.51)
Knee strength (kg)	21.00 (18.81 to 23.26)	0.61 (−0.80 to 2.02)	.396	NS	21.94 (19.57 to 24.31)	−0.94 (−2.45 to 0.56)	.218	NS	1.56 (−0.35 to 3.46)

NOTE. N=27 at all times. Values expressed as mean (95% confidence interval) unless noted otherwise.
Abbreviations: M-L, mediolateral; NS, not significant.

ciated with the program; n=1) lack of time (n=2), and personal reasons (n=2) (see fig 1). There were no significant differences between those who withdrew and those who completed for any key dependent variable ($P>.05$). All participants completed at least 80% of the Pilates sessions during the intervention periods.

Descriptive Statistics

There were no significant between-group differences (Pilates vs control) for any variable (table 2). Over the entire duration of the study (t1–t4), there were significant improvements in all dependent static and dynamic balance variables ($P<.001$), but not for lower-limb strength (knee extensor strength, $P=.396$; ankle dorsiflexor strength, $P=.356$).

During the first intervention period, the Pilates training group experienced significant improvements in results for the TUG Test (.90s faster), FSST (.95s faster), and mediolateral sway on a foam cushion with eyes open (0.66cm less) and eyes closed (2.6cm less; all $P<.016$); with no significant improvement in the control group during this period (figs 2, 3). None of these parameters returned to baseline values during the 6-week washout period (see figs 2 and 3). Pooled data at study completion showed significant changes pre- to post-Pilates training for most static and dynamic balance variables (see table 2), whereas for the pre- to post-control condition, there were no significant changes in any variables except mediolateral sway range with eyes open (firm surface; $P=.047$). Effect sizes of significant changes are listed in table 2. The largest effect size was evident for the variable mediolateral sway range on the foam cushion with eyes closed for the Pilates condition ($d=.72$).

The improvements in mediolateral sway range on the foam cushion with eyes closed that occurred in the Pilates group during the first intervention period remained at the start of their control period (1.4cm; $P=.08$). Conversely, during this time, the control group showed no significant improvement ($P=.284$) despite decreasing by a mean of 1.1cm. During the second group intervention period, between t3 and t4, both the control and intervention conditions responded to a similar degree, improving sway range by approximately 1cm (see fig 2). Both dynamic balance measures of the TUG Test and FSST showed a similar pattern, with significant improvement in the Pilates condition between t1 and t2, not evident for the control condition. Both groups improved during the second intervention period (t3–t4), although to a lesser extent (see fig 3).

DISCUSSION

This study provided the first controlled evaluation of the effects of Pilates on the variables static and dynamic balance in community-dwelling older (>60y) adults. Although the overall finding that participation in Pilates did not lead to significantly greater improvements compared with the control condition of usual activity, this study adds to the existing literature regarding the potential benefits of Pilates exercise. Overall, participants showed significant improvement in some key balance variables during the study. Although these improvements could be suggestive of a learning response, changes generally were largest while undertaking the Pilates intervention (see table 2). Factors that may have contributed to the overall improvement and nonsignificant difference between the 2 conditions include the mentioned learning effect, study design, and seasonal influences.

The significant improvement in static and dynamic balance variables after Pilates training agrees with findings of Irez[8] and Kaesler,[6] and colleagues with the latter study reporting significant improvements of the same magnitude as our study in the vicinity of 27% for mediolateral sway range with eyes closed on a foam pad (25% in the present study) and 7% for the TUG Test (also 7% in the present study). During the present study, participants did not improve to the same extent during the control condition as during the Pilates training condition, which to some extent discounts the possibility that seasonal changes or learning were solely responsible for significant improvements.

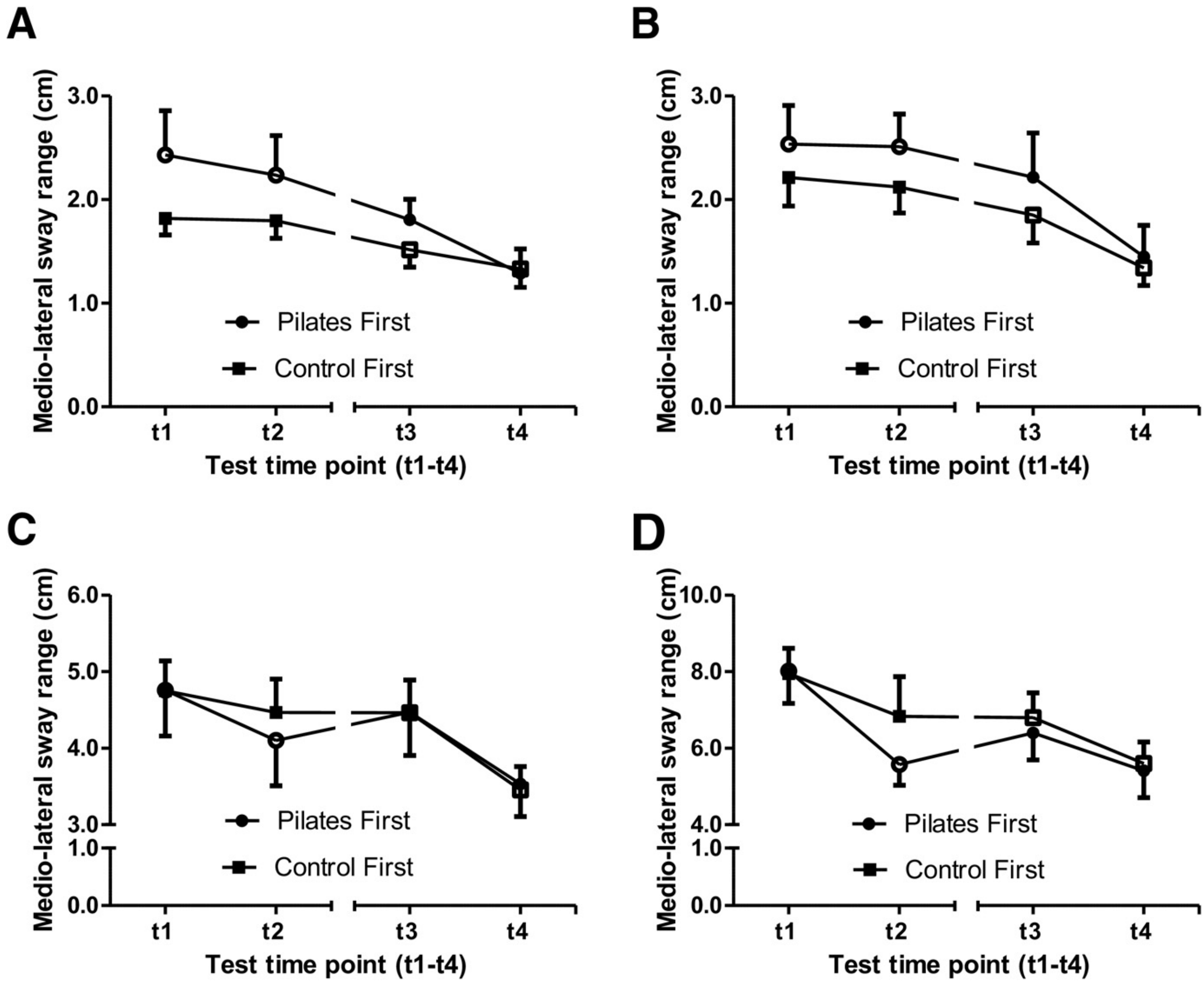

Fig 2. Force platform determined mediolateral sway range (centimeters) with (A, C) eyes open and (B, D) closed and while (C, D) standing on a 65-mm foam cushion over 4 time points (t1–t4) before and after either Pilates training or usual activity (control). Data presented as mean and SE (n=27 at all times).

Because it was impossible to blind participants to the treatment condition, we cannot discount that a belief that Pilates training is of benefit could have contributed to some of the changes observed. Furthermore, it also is possible that social interaction during classes may have had a positive impact on outcomes. However, if these were contributing factors, we would expect similar improvements across all measured variables. Instead, only some measured variables significantly changed during participation in Pilates classes, with the largest effect evident for the balance platform variable of mediolateral sway range on the foam cushion with eyes closed. Encouragingly, Kaesler[6] found a similar result with no significant improvements in their other static balance variables, only eyes closed on a foam cushion. It may be that balance on an unstable surface is highly dependent on proprioception and muscle control, both of which respond favorably to Pilates exercise. Experience-dependent changes in motor control have been documented to occur within the central nervous system at multiple levels, from changes within synaptic connections to rearrangement of cortical maps,[16] although measurement of this is beyond the scope of this study.

The moderate improvements in mediolateral sway range, primarily when standing on the foam cushion with eyes closed when visual and tactile cues are limited, infers that neural adaptations have occurred. The longevity of the functional implications of these adaptations is unclear and may have contributed to the improvement evident across the duration of the study. The improvements in balance measures at t2 for participants in the initial Pilates intervention may have been maintained through to t4 due to resilience in learned muscle recruitment strategies that did not disappear during either washout or the subsequent period when participants continued to perform usual activity (total, 12wk). Improvements in functional balance were found in a similar population, with a Tai Chi intervention producing sustained improvement in balance measures and decreased fall rates when reassessed at the 6-month follow-up.[17] Furthermore, a more recent study attributed balance changes post–Tai Chi training to improvements in

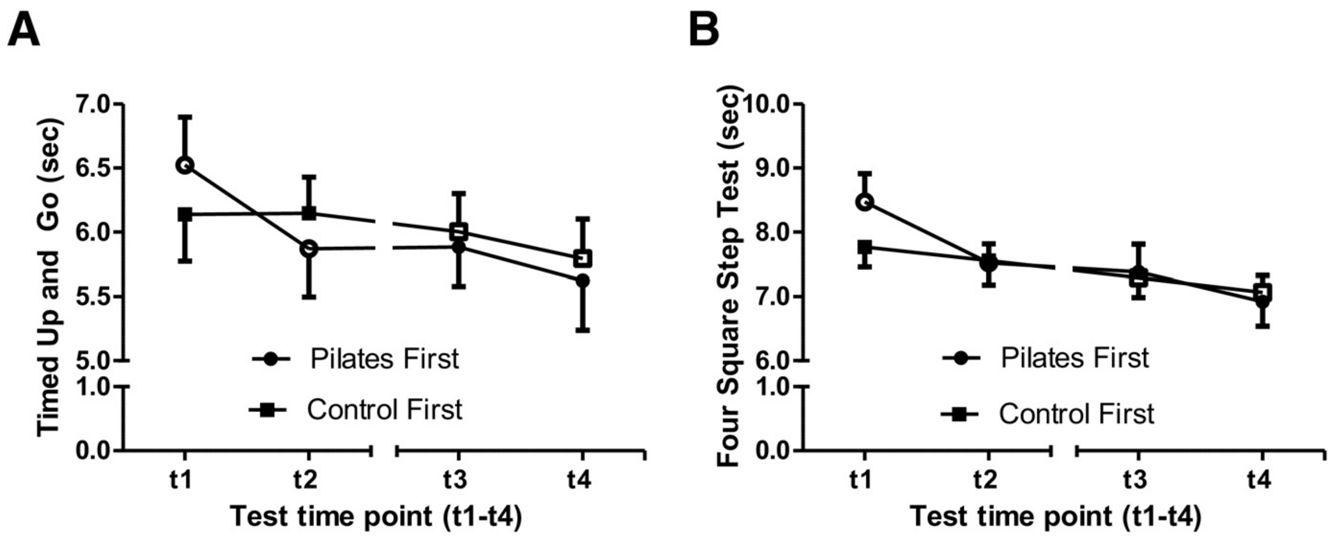

Fig 3. (A) TUG Test and (B) FSST values (seconds) over 4 times (t1–t4) before and after either Pilates training or usual activity (control). Data presented as mean and SE (n=27 at all times).

the nonvisual components of balance control.[18] Similarly, resistance training has produced strength improvements attributed to neural adaptations[19] in a similar population that were not completely lost after as much as 24 weeks of return to usual activity.[20]

The improvements in balance that we attributed to neuromuscular adaptations initially occurred during a brief 5-week training period (~15 Pilates sessions). This is the same time frame as a previously published Pilates controlled intervention.[21] Although this is similar to the time taken to achieve changes in strength with resistance training,[22] a recent meta-analysis of exercise interventions and falls prevention proposed that 50 hours was required to reduce the incidence of falls.[3] Given that improvements in both mediolateral sway and functional balance tests such as the FSST were associated with reduced risk for falling,[23] from our study, it appears that balance improvements may occur early in an exercise intervention, whereas translation to a reduced incidence of falling takes longer. Changes for mediolateral sway in this study are larger than those previously reported for resistance training or flexibility training alone in a similar aged cohort,[15] and this has implications for fall risks. Improvements in static and dynamic balance, although small, also may be clinically important. Consequently, the improvements in static and dynamic balance variables described in the present study also may have positive longer term implications for decreasing physical fall risk in this population, and this warrants further investigation.

Study Limitations

Long-term improvements in balance with Pilates were not reported previously in the literature, giving us little to base further recommendations for appropriate washout times for the crossover study design. Thus, a crossover study design may not be appropriate in an exercise intervention that aims to produce neuromuscular adaptation. The intervention was of only 5 weeks' duration, it is possible that longer duration training may achieve greater effects. The small sample size of this study may have limited our ability to detect between-group differences, and the information from this study may be useful for developing methods for future studies.

CONCLUSIONS

Although there were no between-condition differences between the Pilates and control conditions, significant improvements were observed in the pooled static and dynamic balance data from the 2 Pilates conditions. The absence of a difference between conditions may have been a result of the small sample, which may mean that the study was underpowered to detect real between-group differences. Another factor to consider is the study design because Pilates may influence neuromuscular adaptations with unknown resilience. The reported improvements in mediolateral sway range and dynamic balance may have positive functional implications for physical fall risk factors in an older population.

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Suppliers

a. JC Measurements Pty Ltd, Ste 332, 236 Hyperdome, Loganholme, Queensland, Australia.
b. Sportstek Physical Therapy Supplies Pty Ltd, Park Rd, Oakleigh, Victoria, Australia.
c. Prince of Wales Medical Research Institute, Barker St, Randwick, Sydney, Australia.
d. Statacorp LP, 4905 Lakeway Dr, College Station, TX 77845-4512.