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Effects of Single-Task Versus Dual-Task Training on Balance Performance in Older Adults: A Double-Blind, Randomized Controlled Trial

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Abstract

Objective—To compare the effect of 3 different approaches to balance training on dual-task balance performance in older adults with balance impairment.

Design—A double-blind, randomized controlled trial.

Setting—University research laboratory.

Participants—Older adults (N=23) with balance impairment (mean age, 74.8y). They scored 52 or less on the Berg Balance Scale (BBS), and/or walked with a self-selected gait speed of 1.1m/s or less.

Interventions—Participants were randomly assigned to 1 of 3 interventions: single-task training; dual-task training with fixed-priority instruction; and dual-task training with variable-priority instruction. Participants received 45-minute individualized training sessions, 3 times a week for 4 weeks.

Main Outcome Measures—Gait speed under single-task and dual-task conditions were obtained at baseline, the second week, the end of training, and the twelfth week after the end of training. Other measures, including the BBS and the Activities-specific Balance Confidence (ABC) Scale, were collected at baseline and after training.

Results—Participants in all groups improved on the BBS (*P*<.001, effect size [ES]=.72), and walked significantly faster after training (*P*=.02, ES=.27). When a cognitive task was added, however, only participants who received dual-task training with fixed-priority instruction and dual-task training with variable-priority instructions exhibited significant improvements in gait speed (*P*<.001, ES=.57 and *P*<.001, ES=.46, respectively). In addition, only the dual-task training with variable-priority instruction group demonstrated a dual-task training effect at the second week of training and maintained the training effect at the 12-week follow-up. Only the single-task training group showed a significant increase on the ABC after training (*P*<.001, ES=.61).

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Conclusions—Dual-task training is effective in improving gait speed under dual-task conditions in elderly with balance impairment. Training balance under single-task conditions may not generalize to balance control during dual-task contexts. Explicit instruction regarding attentional focus is an important factor contributing to the rate of learning and the retention of the dual-task training effect.

Keywords

Aging; Attention; Rehabilitation

Among older adults, impairment in the control of balance under dual-task conditions is a common occurrence. Because impaired dual-task balance performance predicts adverse outcomes such as falls,[1–3] and declines in both cognitive and physical function,[4–6] interventions that improve dual-task balance performance are a critical health care need.[7,8]

Studies have shown the positive effect of training on balance and gait in several populations including older adults,[9,10] and individuals with stroke.[11,12] Two studies demonstrated training-related improvements in dual-task balance performance; however 1 was a case study with limited sample size,[13] the other dealt with a stroke population.[14] While information on training dual-task balance performance is limited, Kramer et al[15] investigated dual-task training using 2 nonbalance related cognitive tasks. Results supported the importance of instructional set in dual-task training. Participants trained with variable-priority instructions (shifting attention between tasks) learned tasks faster and performed better than those who received training with fixed-priority instructions (placing equal amounts of attention on both tasks). The effect of instructional set on dual-task balance training in elders is not known.

The purpose of this double-blinded, randomized controlled trial study was to compare the effect of 3 different approaches to balance training on dual-task walking performance in community dwelling older adults with impaired balance. We hypothesized that dual-task training (including dual-task training with fixed-priority instructions and with variable-priority instructions groups) would be more effective at improving balance performance under dual-task conditions than single-task balance training. In addition, based on Kramer's work, we hypothesized that variable-priority instructions would be superior to fixed-priority instructions in terms of the rate of learning achieved during dual-task training.

METHODS

Participants

Fifty older adults with balance impairment were recruited through flyers in the local community. The 2 step eligibility process included an initial telephone interview screen for the following inclusion criteria: (1) age 65 years or older, (2) able to walk 10m without the assistance of another person, (3) no neurologic or musculoskeletal diagnosis such as cerebral vascular accident, significant orthopedic involvement, significant visual and auditory impairments, and (4) approval of their primary care physician to participate. In a second inperson screen, persons were considered balance impaired if they scored less than 52 (out of a total of 56 points) on the BBS,[16,17] and/or completed a 10-m walk with a self-selected gait speed of 1.1m/s or less.[18,19] Scoring less than 52 on BBS[17] and a self-selected gait speed of 1.1m/s or less[20,21] are associated with a decline in the ability to maintain balance during stance and gait, respectively. Persons were ineligible for the study if they scored less than 24 on the Mini-Mental State Examination.[22]

Randomization

Eligible participants completed informed consent in accordance with the Human Subjects Compliance Committee of the University of Oregon and were randomly assigned to 1 of 3 training groups: (1) single-task balance training; (2) dual-task training with fixed-priority instructions; and (3) dual-task training with variable-priority instructions. Because it was not possible to train all participants simultaneously, we divided participants into 2 blocks (blocks of 12 participants) and then randomly assigned an equal number of participants to each of the treatments. This study was a double-blind, randomized controlled trial in which neither the testers nor the participants were aware of group identify.

Interventions

Participants received 45-minute individualized (1 trainer to 1 participant) training sessions, 3 times a week for 4 weeks. The duration and intensity of this training were chosen based on previous studies which showed that 10- to 12-hour balance training[23, 24] and 1- to 5-hour dual-task training[15, 25] programs were effective in improving balance function and dual-task performance in older adults, respectively. Training occurred using 4 separate training stations each with an instructor so that 4 participants could be trained simultaneously. Participants underwent a 12-minute training session at each station before rotating on until all 4 stations were completed. All participants received the same amount of contact time with each trainer.

The 4-week balance training program used progressive activities related to body stability (eg, standing with eyes closed, tandem standing, and standing on compliant surfaces), to body stability plus hand manipulation (eg, standing on foam with rapid alternating hand movement or while throwing and catching a ball, and tandem standing while holding a basket), then body transport (eg, narrow walking, walking backward, and transferring from 1 chair to another), and finally body transport plus hand manipulation. The participants in the single-task balance training group received balance activities under single-task conditions (only balance tasks were given). The participants receiving dual-task training with fixed-priority instructions practiced balance tasks while simultaneously performing cognitive tasks, and were instructed to maintain attention on both postural and cognitive tasks at all times. Examples of cognitive tasks included naming objects and remembering numbers, and have been described in detail elsewhere.[13] Participants in the dual-task training with variable-priority instructions participated in the same set of activities as the dual-task training with fixed-priority instructions group, but spent half the session focused on balance and half focused on cognitive task performance. Data on both balance and cognitive performance was recorded to confirm that the participants allocated attention to 1 task or the other.

Outcomes

The primary outcome measure was self-selected gait speed under single- and dual-task conditions. Participants walked 10m at their comfortable speed and the time to complete the middle 6m was recorded using a stopwatch. In the dual-task condition, participants responded to addition/subtraction questions (eg, 2+4) while walking. The single-task and dual-task conditions were randomized with 2 trials collected for each condition. Gait speed was chosen as a primary outcome because it has been reported as a global indicator of functional performance in older adults.[26,27] It is a good predictor of physical performance,[20,28] mortality,[26] and falls.[19,29,30] A MDC (minimal amount of change that is not due to measurement errors) and a MCID (the smallest change that is considered to be important to an individual) for single-task gait speed in older adults have been reported to be .05m/s[31] and .10m/s,[26,31] respectively. However, no values have been reported in the literature for gait speed under dual-task conditions.

Secondary outcomes included the BBS,[16] and the ABC Scale.[32] The BBS was used to quantify balance performance under single-task conditions on tasks such as standing with eyes closed, standing with feet together, and picking up an object from the floor. Scores range from 0 to 56, with higher scores suggesting better balance. The MDC for the BBS has been reported to be 3 points for older adults with balance problems.[33] The ABC was used to determine self-reported confidence when performing 16 different daily activities, such as walking around the house, walking up and down stairs, and walking on slippery floors. A confidence rating scale ranges from 0% to 100%, with 0% indicating no confidence, and 100% indicating full confidence. No MDC values have been reported for the ABC Scale. All measures were collected at baseline and at the end of training. In addition, the primary outcome measure was repeated after the second week of training in order to examine interim balance change and at 12 weeks following the end of training to test retention.

Sample Size

The sample size and power calculations were performed with G*Power3 (a statistical power analysis program).[34] The ES computation was based on our pilot study on the primary outcome measure. With a sample size of 6 in each group, a repeated-measure ANOVA will have 80% power to detect the interaction ES of .34 at the .05 level of significance. Due to the possibility that a small number of subjects would drop out over the course of the study (a 20% attrition rate), a total of 24 subjects was targeted for this study.

Statistical Analysis

Baseline characteristics were compared among intervention groups using a 1-way ANOVA for continuous variables and the chi-square test for categorical variables. The training effect on gait speed was performed using a 3-way mixed-effects repeated measures ANOVA with group (single-task balance training, dual-task training with fixed-priority instructions, dual-task training with variable-priority instructions) as the between-subjects factor and time (pretraining, posttraining) and testing condition (single-task testing, dual-task testing) as within-subject factors. The training effects on the BBS and ABC were determined using a 2-way mixed-effects repeated measures ANOVA with group as the between-subjects factor and time as the within-subjects factor. Dependent *t* tests also were conducted to examine changes across time. Partial η^2 values were reported as measures of ES. Data analysis was performed using SPSS version 15.0 for Windows.[a]

RESULTS

Fifty older adults were evaluated for potential enrollment (fig 1); 17 people did not meet the inclusion criteria. Of 33 people who may have been eligible, 10 declined to participate in the study. Twenty-three older adults who met the eligibility criteria and agreed to participate were randomly assigned to 1 of 3 training groups; 22 completed the training program (1 single-task balance training participant died, 1 variable-priority participant was excluded because of surgery just prior to posttesting). Twenty-one participants returned for 12-week follow-up testing. The process of recruitment began in April 2006 and the follow-up testing was completed in September 2007. The analysis was performed using an intention-to-treat basis. There were no adverse events associated with participation in the study.

Baseline Characteristics

The mean age ± SD of the participants was 75±6.1 years (range, 65–85y), and most were women. Table 1 summarizes the baseline demographic and clinical characteristics, which were equivalent (*P*>.05), for all 3 groups.

[a]Suppliers SPSS Inc, 233 S Wacker Dr, 11th Fl, Chicago, IL 60606.

Effect of Intervention

The results from the repeated-measures ANOVA showed that the group × time × testing condition interaction was not significant for gait speed (*P*=.54, ES=.07). In addition, the group × time interaction was not significant (*P*=.35, ES=.11) for single-task gait speed, indicating an equivalent amount of improvement across all training groups. There was a significant main effect of time (*P*=.02, ES=.27), signifying that all participants improved gait speed under single-task conditions.

For gait speed under dual-task conditions, we found a significant group × time interaction (*P*=.03, ES=.34) (table 2), with the dual-task training groups demonstrating significantly greater improvements compared to the single-task training group (*P*=.008) (fig 2). Participants who received fixed-priority and variable-priority instructional sets walked significantly faster after the training when they had to simultaneously perform a cognitive task (*P*<.001, ES=.57 and *P*<.001, ES=.46, respectively). However, no significant difference in walking speed under dual-task conditions between pre- and postscore was found for the single-task balance training group (*P*=.46, ES=.03). Fig 3 demonstrates the training effect for each participant in all groups. Any individual above the line of equivalence was a participant who improved after the training. The number of responses and the number of errors participants made on the mathematics tasks were comparable across groups both at baseline and at the end of training (*P*=.72, ES=.04 and *P*=.85, ES=.02, respectively).

There was a significant main effect of time (*P*<.001, ES=.72) on the BBS, suggesting that all participants improved balance under single-task conditions. However, no significant group × time interaction (*P*=.50, ES=.07) was found, indicating that the improvements on the BBS were comparable across the training groups. There was a significant group × time interaction for the ABC scale (*P*=.01, ES=.38); participants in the single-task balance training group increased their level of confidence more than those in the dual-task training groups (*P*=.004). In fact, only the single-task balance training group showed a significant increase in their confidence after training (*P*<.001, ES=.61).

To test the effect of instructional sets, dual task-training under fixed-priority versus variable-priority instructions were compared. The results showed that the performance on all outcome measures were comparable across the 2 groups (*P*>.05). However, only the dual-task training with variable-priority instructions group demonstrated a training effect on dual-task gait speed at the end of the second week of training and this training effect was maintained for 3 months after the end of the training (*P*=.003, and *P*=.006, respectively).

To verify that participants could in fact adhere to the instructional sets during dual-task training with variable-priority instructions training, the number of missteps on the narrow walking task and the number of responses on the counting backward by 3's task were evaluated during each training session. A successful trial was defined as the ability to reduce the numbers of missteps when attention was shifted to the walking task and increase the numbers of responses when the attention was directed toward the counting backward task. Percent of success was calculated by the number of successful trials divided by the total number of trials and multiplied by 100. The results showed that all participants in the dual-task training with variable-priority instructions group could allocate their attention to the task to which they were asked (the average percent of success = 80%; range, 70%–88%).

DISCUSSION

This randomized controlled trial provides evidence that an individualized training program was effective in improving balance under single-task contexts in older adults with balance impairment. After the 4-week intervention program, participants in all training groups significantly improved performance on single-task gait speed and the BBS. In fact, 15 and 18, respectively, (out of 21) older adults exceeded the boundaries of the MDC for the single-task gait speed (0.1m/s), and the BBS (3 points). Overall, the gait speed increased from 1.14m/s to 1.24m/s, suggesting that their performances were closer to the performance of healthy older adults without balance problems at the end of training.[18] According to Bohannon,[18] the mean gait speeds of healthy older adults are 1.33m/s, and 1.27m/s for men and women, respectively. In addition, the participants' gait speed after the training was higher than 1.22m/s, the speed required to cross the street safely.[20] The overall BBS scores increased about 5.85 points (from 48.75 to 54.60), suggesting a 40% reduction in fall risk.[17]

Even though both single-task and dual-task training programs were equally effective at improving balance and walking performance under single-task conditions, dual-task training programs were superior to single-task training in improving walking under dual-task contexts. We found that participants who received dual-task training (either with fixed or variable instructional sets) demonstrated greater improvements in dual-task gait speed. In fact, only participants who received dual-task training walked significantly faster after the training, when simultaneously performing a cognitive task. This finding suggests that older adults are able to improve their walking performance under dual-task conditions only following specific types of training and that training balance under single-task conditions may not generalize to balance control during dual-task contexts. According to the Task Integration Hypothesis, practicing 2 tasks together (not a single-task practice) allows participants to develop task-coordination skills. Thus, a possible explanation of this outcome is that the efficient integration and coordination between the 2 tasks acquired during dual-task training is crucial for improving dual-task performance.[15] Alternatively, according to the Task Automatization Hypothesis, practicing only one task at a time (single-task training) allows participants to automatize the performance of individual tasks. As a result, the processing demand required to perform the tasks is decreased, leading to a more rapid development of skills.[15,35] However, the results from this study and other labs[36,37] did not support the Task Automatization Hypothesis. For example, the research by Voelcker-Rehage and Alberts[37] demonstrated that the ability to coordinate multiple tasks did not improve after extended single-task practice. It is possible that participants in our study received a variety of balance activities and we did not specifically evaluate the tasks that they trained regularly.

One of the important issues in training studies is whether the benefit of training is retained several months after the training has ended. We found that the training effect on single-task performance was maintained at the 12-week follow-up in all training groups. However, the training effect on dual-task performance was maintained at 12-week follow-up only in the participants who received dual-task training with variable-priority instructions. This result may indicate the importance of instructions when training balance control under dual-task contexts. Research by Kramer et al[15] suggests that participants who receive dual-task training with variable-priority instructions have the advantage over those who receive training with fixed priority instructions. These researchers found that participants in dual-task training groups with either fixed priority or variable-priority instructions could learn to coordinate the 2 tasks. However, after training, the processing demand required to perform the tasks was less when their attention was shifted between the 2 tasks, as was required in the dual-task training with variable-priority instructions group.[15] This could explain why the participants in our dual-task training with variable-priority instructions group were able to learn the tasks faster (ie, training effect at the second week of training) and were able to maintain their skill level for a longer period of time (ie, training effect at 3-month follow-up) than our dual-task training with fixed-priority instruction group.

This study also showed that only the participants in the single-task balance training group increased their self-reported confidence when performing daily activities. One possible explanation for this finding is that the activities (balance + cognitive tasks) we gave to the participants in the dual-task training groups were much more difficult than the tasks (only balance tasks) given to the participants in the single-task training group. As a result, the balance skills of the participants in the dual-task training groups were continually challenged and this may have resulted in a reduced confidence in performing daily tasks. It is also possible that changes in cognitive constructs such as confidence and self-efficacy do not change at the same rate as physical function. Further research is necessary to understand this finding.

This study found that it was feasible to implement individualized dual-task training, combining a traditional intervention with a variety of cognitive tasks, in community-dwelling older adults with balance impairment. We also found that older adults could in fact adhere to the instructional sets regarding attentional focus. They successfully allocated their attention to the task to which they were instructed. Thus, results may generalize to similar older adults with balance impairment, excepting those with significant neurological or musculoskeletal diagnosis.

Study Limitations

Although the gait speed at baseline was found to have no significant difference between groups, the fact that participants in the single-task training group walked at 1.1m/s, compared to about 1.0m/s for dual-task training with fixed-priority instructions and dual-task training with variable-priority instructions groups, at the beginning of training may have limited the training effect. In addition, because the group × time × testing condition interaction was not significant, this suggested that the type of training was not only crucial for improvement in dual-task balance performance but also important for improvement in balance performance under single-task contexts. Dual-task training programs, which were found to be effective in improving dual-task balance performance, might also be superior to single-task training in improving single-task balance performance. Thus, it is not clear whether the training effect found in this study is specific to balance performance under dual-task conditions. With enough statistical power, we might observe the similar training effect on single-task balance performance as well. Another limitation of the study was the use of only gait speed to quantify performance under dual-task conditions. Even though gait speed was shown to be a good indicator of physical performance,[20,28] mortality[26] and falls,[29,30] there are several other measures that could be used. For example, the center of mass and center of pressure inclination angles have been shown to be a sensitive measure of balance control during gait in the elderly.[21]

CONCLUSIONS

Dual-task training is effective in improving gait speed under dual-task contexts in elderly individuals with impaired balance and single-task training may not generalize to balance performance under dual-task conditions. Instructional set was an important contributing factor for improvement in dual-task performance. The variable priority instructional set offered advantages over the fixed priority instructional set in terms of the rate of learning and the ability to maintain the skill level achieved during training. Additional research is needed to understand the underlying mechanisms of improving balance performance under dual-task conditions.

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List of Abbreviations

ABC, Activities-specific Balance Confidence; ANOVA, analysis of variance; BBS, Berg Balance Scale; ES, effect size; MDC, minimal detectable change; MCID, minimal clinically important difference.

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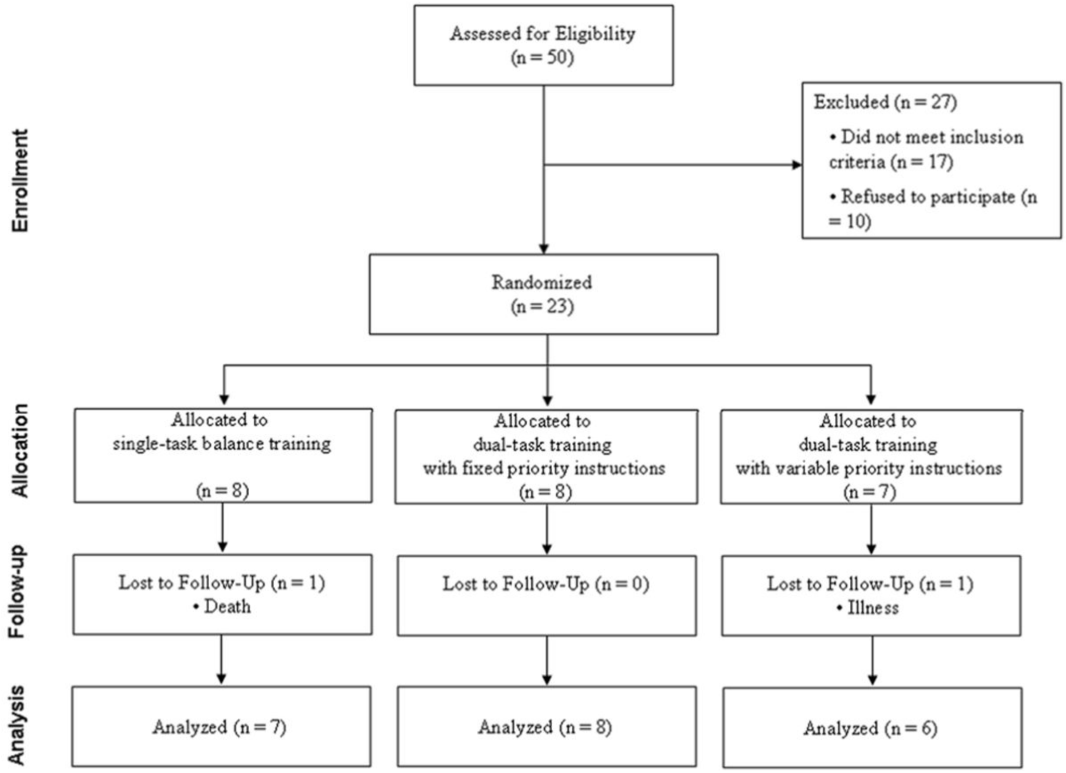

Fig 1.
Flow diagram of participant progress through phases of randomized controlled trial.

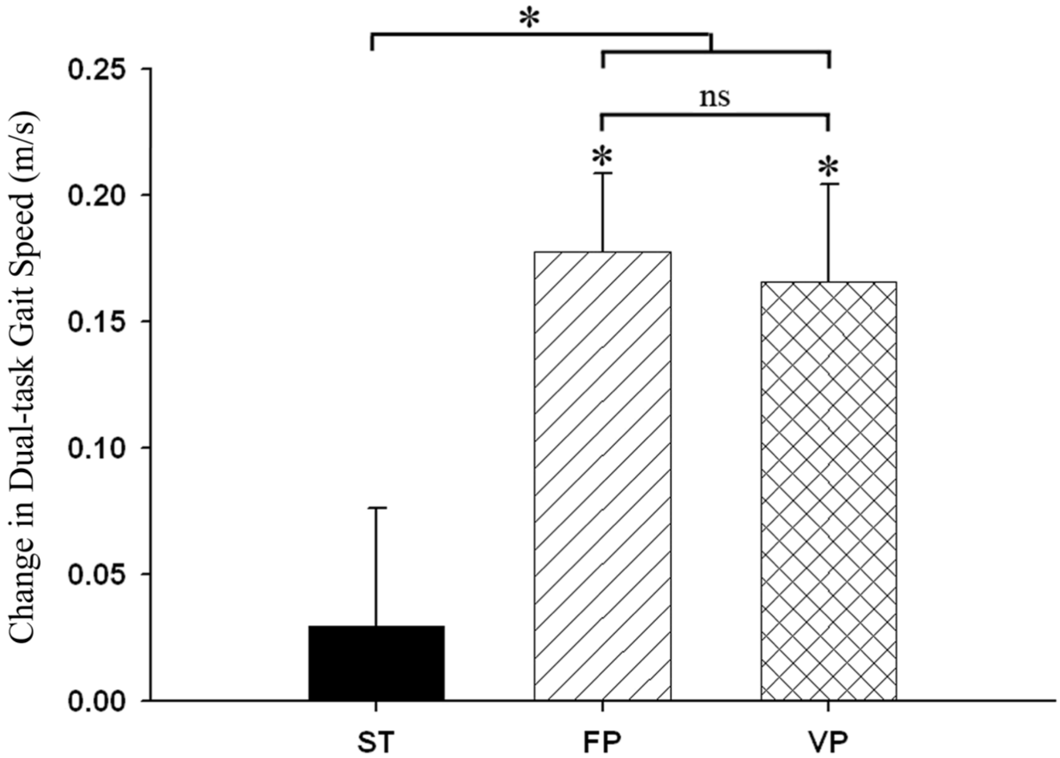

Fig 2.

Bar graph of change (post testing - baseline) on self-selected walking speed under a dual-task condition (walking + mathematics task) by group (mean ± SE). Solid bar represents single-task balance training group (ST); lined bar represents dual-task training with fixed-priority instructions (FP); hatched bar represents dual-task training with variable-priority instructions (VP). Significant baseline to post intervention changes indicated by asterisk above bar. Group differences indicated by horizontal lines above bars.

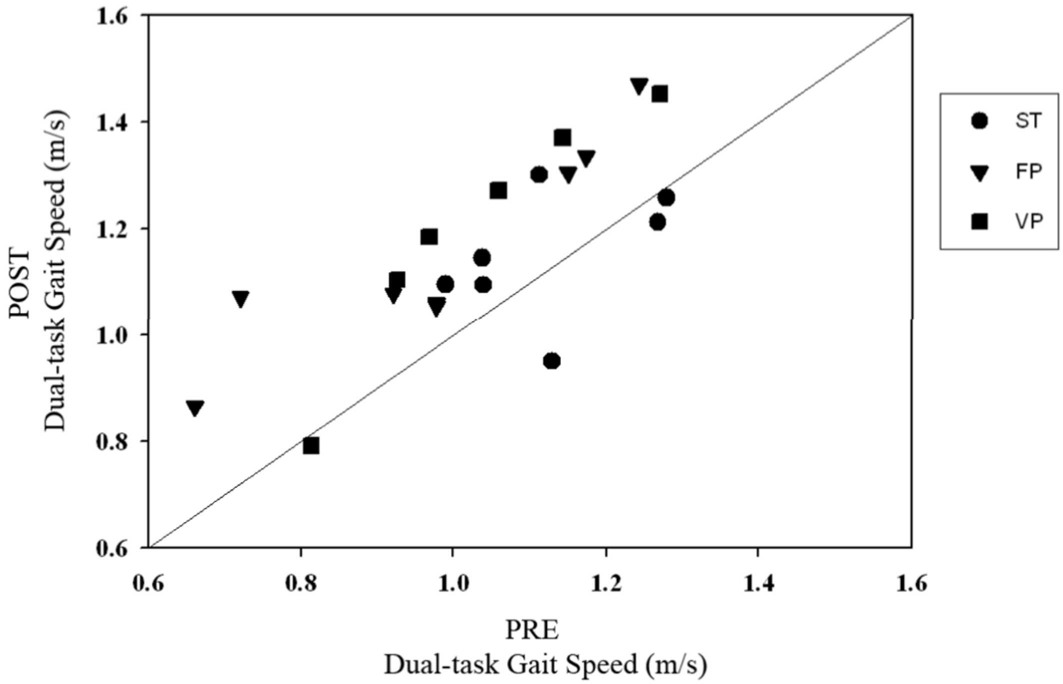

Fig 3.

Scatter plot with line of equivalence of self-selected walking speed under a dual-task condition (walking + mathematics task) before and after the training. Circle represents the single-task balance training group (ST); triangle represents the dual-task training with fixed-priority instructions (FP); rectangle represents the dual-task training with variable-priority instructions (VP). Any individual above the line of equivalence is a participant who improved after training.

Table 1

Baseline Demographic and Clinical Characteristics by Intervention Group

Characteristics	Single-Task Balance Training (n=7)	Dual-Task Training Fixed Priority (n=8)	Dual-Task Training Variable Priority (n=6)	P
Age	74.71±7.80	74.38±6.16	76.00±4.65	.89
Women (n)	7	6	4	.66
Number of falls (the previous year)	1.43±1.51	1.13±1.64	1.00±0.89	.85
Number of losing balance without a fall	3.18±3.59	2.03±3.10	1.44±2.74	.61
BBS (0–56)	50.00±4.58	47.25±6.61	49.00±4.90	.63
Single task self-selected gait speed (m/s)	1.20±0.10	1.12±0.26	1.12±0.22	.75
Dual task self-selected gait speed (m/s)	1.12±0.11	0.98±0.21	1.03±0.16	.28
ABC Scale (0–100%)	72.67±15.67	76.60±24.84	69.78±16.49	.82
Mini-Mental State Examination (0–30)	28.86±1.68	27.5±1.77	29.00±0.89	.15

NOTE. Values are mean ± SD for continuous variables and number for categorical variables.

Table 2

Findings on Outcome Measures at Pretraining (Pre), the End of Training (Post), and Change Scores by Intervention Group

Measures	Single-Task Balance Training Group (n=7)			Dual-Task Training With Fixed-Priority Instruction Group (n=8)			Dual-Task Training With Variable-Priority Instruction Group (n=6)			P*	P†‡
	Pre	Post	Change (95% CI)	Pre	Post	Change (95% CI)	Pre	Post	Change (95% CI)		
BBS (0–56)	50.00±4.58	55.29±1.25	5.29 (2.19–8.39)	47.25±6.61	54.50±2.45	7.25 (4.35– 10.15)	49.00±4.90	54.00±2.76	5.00 (1.65–8.35)	.50	.65† .30‡
Single-task gait speed (m/s)	1.20±0.10	1.23±0.14	0.03 (−0.10–0.16)	1.12±0.26	1.28±0.21	0.16 (0.04–0.27)	1.12±0.22	1.21±0.22	0.09 (−0.05–0.23)	.35	.24† .45‡
Dual-task gait speed (m/s)	1.12±0.11	1.15±0.12	0.03 (−0.05–0.11)	0.98±0.21	1.16±0.20	0.18 (0.10–0.25)	1.03±0.16	1.20±0.23	0.17 (0.08–0.25)	.03	.008† .83‡
ABC Scale (0–100%)	72.67±15.67	85.87±11.67	13.20 (7.94–18.46)	76.60±24.84	78.91±20.50	2.31 (−2.61–7.24)	69.78±16.49	73.72±15.83	3.94 (−1.75–9.62)	.01	.004† .66‡
Number of responses	2.86±0.80	3.14±0.63	0.28 (−0.30–0.87)	2.81±0.75	3.06±0.32	0.25 (−0.23–0.80)	3.17±1.21	3.67±1.03	0.5 (0.03–0.97)	.72	.75† .45‡
Error rate	0.10±0.14	0.06±0.07	0.04 (−0.11–0.20)	0.13±0.12	0.04±0.07	0.09 (−0.02–0.19)	0.10±0.11	0.03±0.07	0.07 (−0.05–0.19)	.85	.62† .81‡

NOTE. Values presented as mean ± SD for pre- and posttraining scores; and mean (95% CI) for change scores.

Abbreviations: CI, confidence interval; error rate, ratio of the number of errors to the number of responses for mathematic tasks; number of responses, average number of responses to mathematics questions.

*Group × time interaction effect as calculated by using a 2-way mixed-effects repeated measures ANOVAs.

†As calculated by comparing single-task training group versus dual-task training groups on postintervention change.

‡As calculated by comparing dual-task training with fixed-priority instructions group versus dual-task training with variable-priority instructions group on postintervention change.