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Effect of dual-task training on motor-cognitive interference among older women: implication for postural control during sit to stand in different visual conditions

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Abstract
Introduction. **Postural control difficulty during sit to stand (STS) is a common and costly problem in older adults. A potentially important strategy to enhance postural control through exercise intervention is to add cognitive components.** Aim of Study. **To examine the effect of STS dual-task training on postural control during STS, in eyes open (EO) and closed (EC) conditions in older women.** Material and Methods. **A total of 20 participants were randomly allocated into dual task (STS training and simultaneous dual-task) (n = 10) and single task (only STS training) (n = 10).** Results. **Significant differences were observed pre to post in dual-task training for velocity in mediolateral (ML) ($p < 0.05$) in EO condition, anteroposterior (AP) ($p = 0.009$), ML amplitude ($p = 0.005$), and AP velocity ($p = 0.007$) in the EC condition.** Conclusions. **These findings suggest that dual-task training is an effective at improving postural control of older people with history of falling during STS.**

KEYWORDS: aging, vision, sit to stand, dual task, postural control, motor-cognitive interference.

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Introduction

It has been reported that adults aged over 65 years will experience falling at least once a year [2] especially when they are required to perform a concurrent cognitive or secondary motor task while performing daily activities. Falling can be associated with age-related muscle weakness, impaired balance and gait and poor postural control [7, 13]. Postural control requires integrating proprioceptive afferent inputs and complex sensorimotor actions as well as cognitive regulations [10, 11]. Effective daily functioning requires people to share their attention resources between the cognitive and the postural requirements necessary to complete the tasks. Due to the aging process and prevalence of chronic diseases, older adults show some levels of decline when performing postural tasks while dual-tasking [3]. Studies have shown that the effect of cognition on postural control increases with aging and is a key characteristic of mobility problems in this population [4, 17, 26]. In situations such as making telephone calls while walking the interference between cognitive and motor tasks is greater in older adults compared with young healthy adults.

Although the ability to prioritize and allocate attention between two or more tasks becomes progressively compromised throughout aging, dual-task training has the potential to improve the ability of older adults to share attention between motor and cognitive tasks [1, 5, 15, 19, 20, 23, 25]. Motor and cognitive tasks can be simultaneously performed – when a concurrent attentional focus is required for both activities.

Transition from siting to standing is one of main components of daily living tasks, which requires appropriate postural adjustments to maintain stability in response to the internal and external perturbation. Thus, the impaired ability of older adults to allocate attention during the dual-task in sit to stand (STS) movement may increase the risk of falling. In dual-task training protocols, participants are usually asked to sometimes focus attention on motor and at times on cognitive task performance. However, it is important to highlight that a large part of the daily motor and cognitive tasks is simultaneously performed, especially during activities that require maintaining body balance in domestic activities, and in activities such as sit to standing and talking or solving mathematical calculations [1, 5, 15, 19, 20, 23, 25, 27]. Although the literature offers some support for benefits of dual-task training, an optimal training method for dual-task abilities in some functional situations such as STS is yet to be determined.

Yet little is known which practice strategies are most effective in improving concurrent performance of postural and cognitive tasks during the STS maneuver. To our knowledge, there is no study reporting the effects of dual-task training as a treatment modality on the clinical findings of older people with history of falling. Thus, it seems reasonable to propose a training protocol, in which participants sometimes perform a simultaneous dual task, such as STS and performing mathematical operations.

Additionally, postural control involves the interaction of the visual, vestibular and somatosensory systems, but it is more influenced by the visual system than by other systems [14]. Although research results imply the role of vision in setting motor responses during postural control, some studies have shown that eliminating visual information in eye-closed (EC) situations improves visuospatial mechanisms of postural control and provides better cognitive performance compared to eyes-open (EO) situations in darkness during postural control [3, 6, 8, 9, 14]. However, little is known about the role of visual sensory information in the influence of dual-task training on the interference between a cognitive task and postural control during STS movement.

Aim of Study

The aim of the present study was to investigate whether a dual-task STS training intervention is more effective than single-task STS training for improving postural control during STS under dual-task conditions under EO and EC conditions in community-dwelling older women.

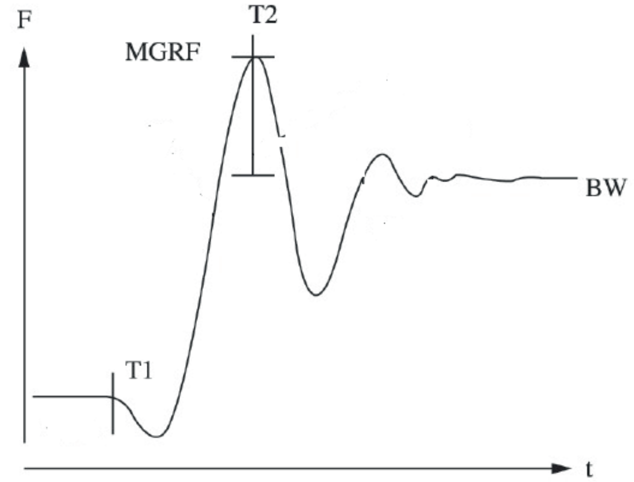
Material and Methods

A total of 20 elderly females were recruited in the local community according to the following inclusion criteria and they were randomly assigned to the dual-task (n = 10) and single-task (n = 10) STS training: being 65 years or older, having a history of at least one fall in the last three months, having efficient cognitive function to be able to communicate (a Mini-Mental State Examination score of 23 points and above) [9], walking independently 10 m, and being able to stand on both feet for at least 90 s without assistance. The exclusion criteria were having a severe hearing loss and/or visual impairment, uncontrolled hypertension, and vertigo. Exclusion criteria included the presence of a previous cognitive impairment or aphasia (determined by a clinical evaluation with a physiatrist), psychological disorder, an uncontrolled medical disease, or significant orthopedic pain or pain that limited participation in postural control testing. The protocol was reviewed and approved by the Institutional Review Board and Research Ethics Committee of the Ferdowsi University of Mashhad. All the participants provided their written informed consent before the selection procedure.

This study was a single-blind, randomized controlled trial, in which the participants were not aware of group type. Both groups received general physical programs (range of motion, strengthening, mat, and mobility exercises) and additionally STS exercises for 30 minutes per day, 5 days per week, for 4 weeks. All the participants were administered both general and STS training of the same amount and duration. The duration and intensity of this training were chosen based on previous studies. The participants in the single-task STS training group received activities under single-task conditions (only STS tasks were given). The participants receiving dual-task training practiced sit to standing tasks while simultaneously performing cognitive tasks, and they were instructed to maintain attention on both postural and cognitive tasks at all times. Examples of cognitive tasks included naming objects, counting n-back and remembering numbers.

Demographic characteristics (e.g., age, weight, dynamic balance ability, years of education, and employment status) were collected at the baseline. To evaluate the dynamic balance ability a test tool for the balance, the Berg Balance Test, was used at pre-test. It comprises a 5-point scale (0-4) composed of 14 items with a total score of 56 [3]. Postural control during a STS task was assessed before and after the 4 weeks of the training program while participants stood under EO and EC conditions. After explaining the sitting posture and movement pattern for the STS movement, the participants sat in an adjustable chair with legs shoulderwidth apart, the trunk stretched vertically in a straight line and their hips, knees, and ankles held at 90° while the feet were on the force platform (Kistler Instrument Inc.) with an acquisition frequency of 100 Hz [8]. For all the tests the participants were instructed to stand upright from a seated position at a self-selected speed while their gaze was fixed in the normal plane of vision during the STS maneuver, they rested for approximately 2 seconds, and then sat down again. They performed three trials in succession with an interval of 2 seconds. The force platform provided a curve of vertical ground reaction force during the STS movement at 100 Hz for further analysis.

All the data were checked, amplified, and filtered before analysis using a digital Butterworth fourth-order low-pass filter with a 5 Hz cut-off frequency [16] using the MATLAB software (Mathworks Inc., Natick, MA, USA). Data normalization was performed using the body weight values. Analysis of data was performed for the preparation phase (F1), the beginning was determined by a decrease in vertical force greater than 2.5% relative to the weight of the feet on the platform, while the end was determined by the vertical peak force. Details of the division of STS movement into phases are presented in Figure 1. For this phase, the variables related to the center of pressure (COP) were calculated according to Duarte and Freitas's research [8]: i.e., the anteroposterior COP displacement amplitude (Amp AP), the mediolateral COP displacement amplitude (Amp ML), and the mean COP oscillation velocity (Vel AP, Vel ML).



Note: Preparation phase (T1-T2), BW – body weight, MGRF – maximum ground reaction force, T1 – start of movement, T2 – seat-off

Figure 1. The schematic representation of the Ground Reaction Force during STS movement

Outcome measures were first investigated applying descriptive and comparative statistical analyses. For comparison within and between the groups the data were analyzed by repeated measures ANOVA, the Mann–Whitney U-test and Student's-t test at $\alpha \leq 0.05$ according to the type and distribution of the recorded variables. All statistical tests were performed using the SPSS software version 25 for PC (IBM Corporation, Armonk, NY). A P value of < 0.05 was considered to be significant.

Results

Physical and demographic characteristics of the participants are given in Table 1. There were no statistical differences between the educational levels and the physical characteristics of the elderly in both groups. The mean and standard deviations for the all postural control variables of COP under the two vision conditions are shown in Tables 2 to 5. No significant changes in the amplitude and velocity of COP during the STS maneuvers were found between the EO and EC conditions before and after training. However, dual-task training showed significant changes in the Amp AP (U = 19.0; p = 0.005), Amp ML (U = 11.0; p = 0.001), Vel AP (U = 3.27; p = 0.02) and Vel ML (U = 2.61; p = 0.04) in the EO conditions (11.60 ± 0.62 vs 5.69 ± 0.81; p < 0.05) as well as (10.22 ± 0.74 vs 8.39 ± 0.93; p < 0.05). In the case of the dual task lower values were recorded for Vel ML compared with the control group (U = 2.99; p = 0.015). Additionally, significant differences were observed for pre- to post-test in dual-task training for the Amp AP (U = 4.1; p = 0.009), Amp ML (U = 4.7; p = 0.005), Vel AP (U = 4.4; p = 0.007) in EC condition. Significant differences in the amplitude and velocity of COP during the STS maneuver were found between the groups in the EC condition after training.

Table 1. Means ± SD for baseline demographic and clinical characteristics by groups

Characteristics	Single-task STS training (n = 10)	Dual-task STS training (n = 10)	P
Age	73.50 ± 0.93	74.20 ± 0.52	0.79
Women (n)	10	10	
Number of falls (previous year)	1.53 ± 1.51	1.15 ± 1.60	0.70
BBS (0-56)	50.00 ± 4.50	51.44 ± 3.61	0.53
Mini-Mental State Examination (0-30)	18.40 ± 1.68	23.5 ± 3.20	0.10

Table 2. Comparison between groups after intervention for amplitude of COP changes in ML and AP direction with EO

Variable	Group	Period	Paired t-test			Independent t-test		
			Means and standard deviation	Statistics	Sig.	Mean rating difference	Statistics	Sig.
Amplitude of COP changes in the AP direction with EO (mm/s)	Single-task STS training	pre-test	2.99 ± 0.9	–0/85	0/443	–0/8 ± 2/31 1/68 ± 4/07	2/64	0/27
		post-test	3.87 ± 0.6					
	Dual-task STS training	pre-test	3.78 ± 0.4	–5/91	0/2			
		post-test	7.85 ± 0.8					
Amplitude of COP changes in ML direction with EO (mm/s)	Single-task STS training	pre-test	5.75 ± 0.65	–3.26	0.31	–5.08 ± 0.48 –10.66 ± 0.49	2.25	0.49
		post-test	10.83 ± 0.8					
	Dual-task STS training	pre-test	7.15 ± 0.31	–5.80	0.20			
		post-test	17.81 ± 0.51					

*Significance level less than 0.05
Note: COP – center of pressure, ML mediolateral, AP – anteroposterior, EC – eyes-closed, EO – eyes-open, STS – sit to stand

Table 3. Comparison between groups after intervention for velocity of COP changes in ML and AP directions with EO

Variable	Group	period	Paired t-test			Independent t-test		
			Means and standard deviation	Statistics	Sig.	Mean rating difference	Statistics	Sig.
Velocity of COP changes in the AP direction with the EO (mm/s)	Single-task STS training	pre-test	10.00 ± 0.62	1.62	0.18	4.30 ± 0.94 9.18 ± 0.87	–1.24	0.24
		post-test	5.69 ± 0.81					
	Dual-task STS training	pre-test	17.58 ± 0.22	3.27	0.02*			
		post-test	8.39 ± 0.93					
Velocity of COP changes in the ML direction with the EO (mm/s)	Single-task STS training	pre-test	11.23 ± 0.46	–0.77	0.15	–7.88 ± 0.62 11.89 ± 0.89	–2.99	0.01*
		post-test	25.20 ± 0.47					
	Dual-task STS training	pre-test	25.85 ± 0.85	2.61	0.04*			
		post-test	13.16 ± 0.55					

*Significance level less than 0.05
Note: COP – center of pressure, ML mediolateral, AP – anteroposterior, EC – eyes-closed, EO – eyes-open, STS – sit to stand

Table 4. Comparison between groups after intervention for amplitude of COP changes in ML and AP directions with EC

Variable	Group	period	Paired t-test			Independent t-test		
			Means and standard deviation	Statistics	Sig.	Mean rating difference	Statistics	Sig.
Amplitude of COP changes in AP direction with EC (mm/s)	Single-task STS training	pre-test	6.80 ± 0.10	0.89	0.42	2.60 ± 0.47 2.44 ± 0.59	0.05	0.95
		post-test	4.20 ± 0.72					
	Dual-task STS training	pre-test	6.16 ± 0.92	4.10	0.009*			
		post-test	3.72 ± 0.80					

Amplitude of COP changes in ML direction with EC (mm/s)	Single-task STS training	pre-test	11.88 ± 0.77	–0.21	0.83	–1.65 ± 0.05 5.93 ± 0.04	0.60	0.55
		post-test	13.53 ± 0.71					
	Dual-task STS training	pre-test	9.57 ± 0.08	–4.77	0.005*			
		post-test	15.49 ± 0.78					

*Significance level less than 0.05
Note: COP – center of pressure, ML mediolateral, AP – anteroposterior, EC – eyes-closed, EO – eyes-open, STS – sit to stand

Table 5. Comparison between groups after intervention for velocity of COP changes in ML and AP directions with EC

Variable	Group	period	Paired t-test			Independent t-test		
			Means and standard deviation	Statistics	Sig.	Mean rating difference	Statistics	Sig.
Velocity of COP changes in the AP direction with EC (mm/s)	Single-task STS training	pre-test	11.34 ± 0.63	0.69	0.52	1.21 ± 0.92 4.99 ± 0.76	–1.87	0.09
		post-test	9.92 ± 0.23					
	Dual-task STS training	pre-test	13.06 ± 0.65	4.42	0.007*			
		post-test	8.06 ± 0.44					
Velocity of COP changes in ML direction with EC (mm/s)	Single-task STS training	pre-test	21.76 ± 0.20	–0.98	0.38	–4.58 ± 0.45 –9.25 ± 0.65	–0.59	0.56
		post-test	26.35 ± 0.85					
	Dual-task STS training	pre-test	21.38 ± 0.73	–1.54	0.18			
		post-test	30.99 ± 0.68					

*Significance level less than 0.05
Note: COP – center of pressure, ML mediolateral, AP – anteroposterior, EC – eyes-closed, EO – eyes-open, STS – sit to stand

Discussion

The aim of the present study was to investigate whether a dual-task STS training intervention would improve postural control during the STS maneuver to a higher extent when compared to single-task STS training in the EO and EC conditions. With respect to the results, during the STS maneuver the Amp ML, Vel AP and Vel ML in the EO condition were decreased (11.60 ± 0.62 vs 5.6 9 ± 0.81) as well as (10.22 ± 0.74 vs 8.39 ± 0.93). In the dual task lower values were found for Vel ML compared with the single task group under the EO conditions, which was consistent with those reported in other studies. They reported a significant improvement in postural stability of healthy older people [22]. Araújo et al. [1], in a systematic review of the dual-task effect, including seven studies of 194 participants, suggested evidence for the positive impact of combining balance training for enhancing postural control of the elderly population at the risk of falling. Hiyamizu et al., incorporated the Stroop task in a dual-task training duration of two sessions per week for 3 months [12]; however, Li et al. used an n-back counting task with a training duration spread [18]. This finding suggests that older adults are able to enhance their STS postural control under a concurrent motor-cognitive task only after specific STS training. A dual task acutely directs the attention toward an external source of attention (e.g., n-back, random letter generation tasks), while performing a primary task. According to the constrained action hypothesis, this attentional change might allow the motor systems to function in an automatic manner, resulting in more effective performance. It is, therefore, not surprising that repetitions of STS maneuvers concurrently with a cognitive task had a positive effect on postural sway outcome measures over time. It appears that for older individuals with a history of falling, the practice would lead to a lesser attention demand of a task. Variables such as COP velocity and amplitude are the most sensitive parameters for the diagnosis of the postural control deficit [24]. With respect to results there is no significant baseline difference between the dual- and single-task training group. While subjects in the dual task group decreased postural sway after intervention, for the control group the same values were found. Considering the present findings, it appears that the activities (balance cognitive tasks performed by the participants in the dual-task training groups) were much more difficult than the single tasks given to the participants in the ST group. Therefore, the postural control of the participants in the dual-task training groups were continually challenged and this may have resulted in reduced postural sways during STS maneuvers. In addition, some studies have also suggested that dual-task training may act as a cognitive therapy for patients with attentional deficits, because certain centers of the brain associated with dual-task processing showed less activation post-training and reduced processing demands [12, 25].

Although evidence suggests that cognitive-motor training compared to single-task interventions offers greater benefits to older adults with respect to the risk of falling [23], little is known about the effect of specific dual-task STS training. Neither studies considered a training program that prioritized STS activities combined with cognitive tasks. Taking into account that in daily living activities sit to stand maneuvers take place concomitantly with talking on the cell phone, thinking about a shopping list, etc., it is important to develop protocols that combine dual-task training to improve postural control. During the STS maneuver the Amp AP, Amp ML, and Vel AP decreased from the pre- to post-test period under the EC condition after dual-task training. Based on previous studies, vision is more important for postural control than the vestibular and proprioceptive senses in healthy individuals [6, 21]; therefore, body sway increases when vision is interrupted [15]. It seems that dual-task training enhances the proprioceptive function that compensates for interrupted vision, improving the balance ability of older adults with a history of falling. However, there was no significant change in postural sways between the EO and EC conditions, both pre and post training.

Conclusions

These findings demonstrated that dual-task training improves the proprioceptive function that compensates for interrupted vision, improving the balance ability of older adults with a risk of falling or a history of falling. Therefore, our findings suggest that dual-task training focused on balance control and the cognitive function improved postural control during sit to standing maneuvers. The results of the current study revealed that dual-task training may increase the effectiveness of STS exercise by enabling more sensory inputs during the exercise in older adults with a history of falling. Cognitive dual-task training can be applied easily and simply without the burden of time and cost, so it can be effectively used as a rehabilitation aid for older adults in clinical practice.

Conflict of Interest

The authors declare that there are no conflicts of interest.

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