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Original Article

Effect of Acute Strength Training on the Posture Control during Dual Tasking and Executive Function in Older Adults. A Randomized Controlled Study

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SUMMARY

Background: It is well known that aging negatively affects the ability to perform a dual-task due to impaired motor and executive functions. Any method to improve posture stability and cognitive functioning in old adults is acceptable.
Methods: 30 old-aged men performed dual-tasks before and after intervention. They were randomly divided into control and experimental groups. The experimental group performed squats with a barbell, while control group had a rest.
Results: Elimination of visual feedback increased sway activity ($p < 0.05$) during single and dual tasks. There was no significant effect of the dual-task and strength training on sway activity. Dual-task and acute strength training did not affect executive functions during dual task (DT).
Conclusion: Our research suggests that acute strength training might be an effective intervention to improve cognitive functions in old adults. Unfortunately, we did not find any effect of intervention on motor – cognitive function interaction during dual-task, we found only a tendency of improvement.

1. Introduction

Postural control becomes increasingly critical with aging.[1] The negative effect of age on balance stability is dependent on sensorimotor dysfunctions,[2] muscle weakness,[3] and structural changes in brain grey and white matter.[4] Evidence from other studies suggests that, despite the previously mentioned neural deficits, older adults may recruit additional neural resources to reach sufficient level of sensorimotor control by increasing attention to the task.[5] Since accessibility of attentional resources and the ability to allocate attention efficiently is declining with aging,[6] the distribution of attentional resources toward a secondary cognitive task is expected to have a larger interference effect on balance in older adults compared with young adults.[7] This makes dual-task testing a sensitive predictor of age-or pathology-associated declines in balance control.[8]

Impaired behavior may appear particularly in complex tasks,[9] such as performing a dual-task, where cognitive functioning is usually involved as well. Normal aging is associated with progressive functional loss in many cognitive domains including working memory, attention[10] and executive functions[11,35] responsible for the control of behavioral activities.[12]

However, scientists argue that physical activity can be beneficial for old adults' physical and mental health.[13] It has been proven that resistance training increases muscular mass and strength in seniors and might positively influence cognitive performance.[14] Nevertheless, many studies focused on aerobic exercise, and some of them found a positive effect of resistance exercise on cognition.[15] Resistance exercise could be also effective in posture control improvement since it increases strength and stability in lower limbs, resulting in increases in lower body muscle mass, strength, and providing more stable base of support.[16] However, some studies did not find any differences in balance after training.[17] Thus, we can hypothesize that physical activity can improve balance control in various conditions. Nevertheless, there are few studies evaluating the effect of acute strength training on balance stability and executive function during dual tasking. Therefore the aim of our research was to evaluate postural control during dual tasking and executive function after acute strength training in old adults.

2. Methods

2.1. Participants

Participants were 30 old healthy men, enrolled by our research group supervisor and randomly divided into control and experimental groups using simple randomized method (Fig. 1). Participants completed a questionnaire about their demographic data, physical activity habits, and health status prior to their inclusion in the study (Table 1). All participants were free of physical and/or neurological disorders. They did not report using any medications that could act on the nervous system and/or motor/cognitive functions; and they were free of pain. All participants were tested at the same time of the day between 10–12 a.m. and were informed about the testing procedure. All participants signed inform consent forms before their inclusion in the study. Research was

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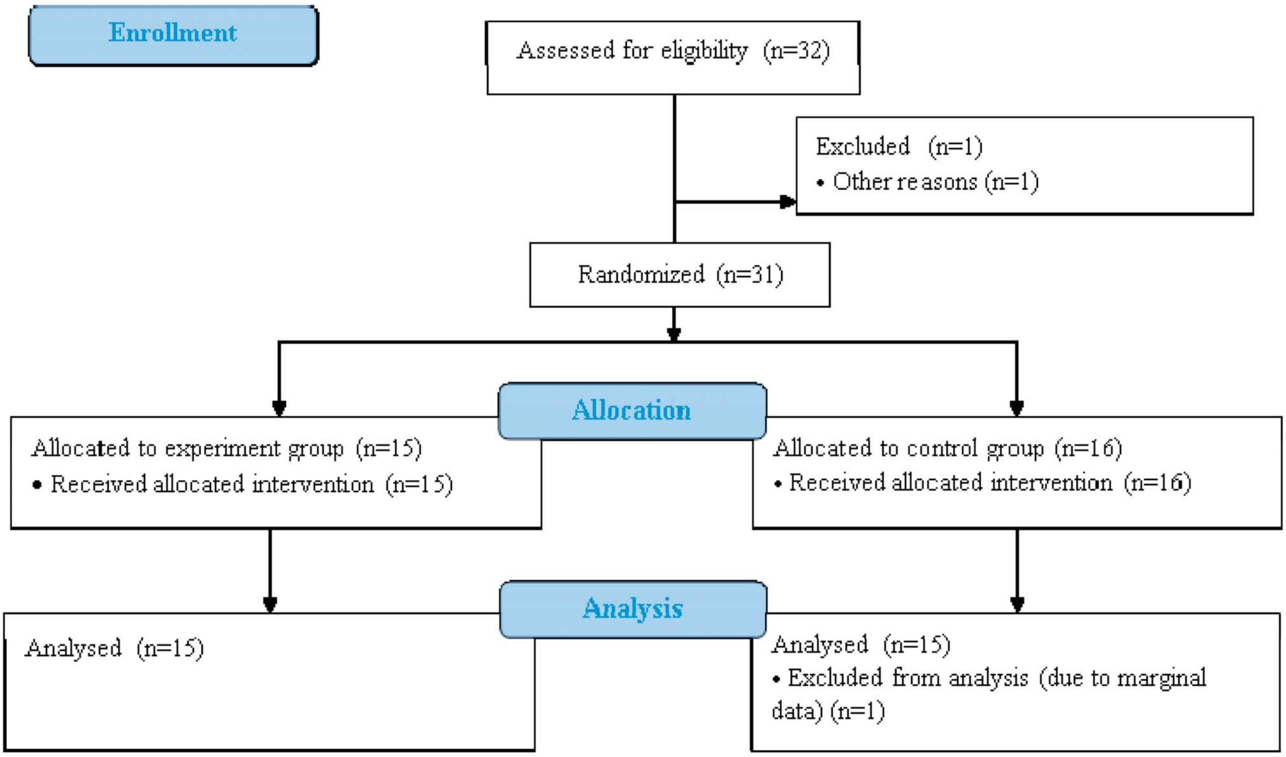

Fig. 1. Design of randomized trial.

Table 1
Baseline characteristics of participants.

	Control group (n = 15)	Experimental group (n = 15)	p
Age (years; mean ± SD)	67.5 ± 5.3	67.3 ± 5.0	0.9
Height (cm; mean ± SD)	175.3 ± 4.2	177.0 ± 5	0.3
Weight (kg; mean ± SD)	75.6 ± 7.8	77.9 ± 8.9	0.3
BMI (kg/m^2; mean ± SD)	24.4 ± 2.1	24.8 ± 2.1	0.6
Mini Mental State Examination (mean ± SD)	29.2 ± 0.9	29.4 ± 0.7	0.5
Hypertension (%)	60	40	
Medium physical activity (%)	46.6	66.6	

conducted at the Lithuanian Sports University, Institute of Sport Science and Innovations. The study lasted for 12 weeks from March to June 2017. It was approved by the Kaunas Regional Biomedical Research Ethics Committee (No. BE-2-46).

2.2. Procedure

A posturography method with a single piezoelectric force plate (KISTLER, Switzerland, Slimline System 9286) was used to measure postural sway activity. The signals collected were sampled at 100 Hz. The application point (center of pressure - CoP) of the measured foot-ground reaction forces in the anteroposterior (AP) and mediolateral (ML) directions was calculated on the basis of the known geometric locations of the piezoelectric transducers. All participants were instructed to step barefoot on the force plate and to stand still in a double stance position with eyes open and eyes closed. CoP recordings were made under these conditions: (i) double stance eyes open/eyes closed (S-EO)/(S-EC) as a single task, (ii) double stance eyes open/eyes closed while performing a verbal Mathematical Processing Task (DT-EO)/(DT-EC) as a dual task, and (iii) after intervention dual task eyes open (DT-EO-post) and eyes closed (DT-EC-post). Participants exercised under single task condition once, and under dual task condition – three times, resulting in a total of 14 trials per participant: 8 trials before and 6 trials after intervention. The trials were presented in random order. For each trial, participants were asked to stand on the platform for 25 seconds for which data were collected over a period of the last 20 seconds. All of them were allowed to practice all the stances prior to data collection.

For the cognitive function during DT we used verbal Mathematical Processing Task: negative or positive one-digit integer-numbers (10 in total) were verbally presented in each trial at 2 second intervals and participants were instructed to calculate and at the end of each trial verbally report the correct answer. For example, the correct answer “10” was expected for the numbers [+6, +8, -3, +9, -5, -1, +6, -8, -4, 2]. We instructed to concentrate on the calculation and to memorize the answer in their mind. Also it was performed familiarization with the cognitive task before the experiment. Following familiarization, participants were instructed to perform 3 trials of this task while seated (i.e., cognitive single task) of the beginning DT conditions. Performance measures for the Mathematical Processing Task were considered as the number of correct and incorrect responses in each task condition.

2.3. Intervention

Acute strength training included squats with a barbell using Smith Machine for the experimental group. Before testing, participants in the experimental group were familiarized with the type of intervention. They were trained to do squats correctly. One repetition maximum (1RM) value was calculated.

Chang (2014) found that strength intervention designs in loads of 60–80% 1RM with approximately seven movements in two sets separated by 2 min of rest, could positively affect cognition, including information-processing speed, attention, memory and executive function.[15] About 2–3 min rest is recommended for untrained persons.[17] According to this finding, we chose similar intensity: 3 × 90% 1RM (3 min rest between rep.); 5 min rest; 3 × 95% 1RM (3 min rest between rep.); 5 min rest; 3 × 100% 1RM (3 min rest between rep.). HR was measured for the experimental group during training. Before training, participants in the experimental group performed warm-up on a veloergometer for about 10 minutes.

2.4. Data processing and statistics

Sample size was determined using Sample Size Calculator. Firstly, mean and linear trends of the AP and ML components of the CoP trajectory were subtracted and spectral analysis was performed to determine the frequency characteristics of the raw signals. Since 99% of the overall power of the signals was below 15 Hz and contribution of higher frequencies was nearly zero, a fourth-order low pass Butterworth bi-directional filter with a cutoff frequency of 15 Hz was applied. To estimate the dynamical characteristics of the posturogram, CoP velocity vector (Vcop) was used.[18] The Vcop refers to the amount of sway activity and appears as a conventional, scale-dependent characteristics of the posturogram.

The posturographic dependent variables Vcop and errors in the cognitive task were averaged over the three repeated trials in each of the dual-task conditions. Single task conditions were applied one time. The Wilcoxon Signed-Ranked test was used for pairwise comparisons. For independent sample comparison, Mann-Whitney U test was used. Intervention effect was calculated applying the formula = [dual task post – dual task pre)/dual task pre] * 100, which was modified by Doumas et al. (2008).[19] In line with our research questions, we compared (I) sway activity of the posturogram with and without visual feedback, (II) the dual-task effect (DTE) on sway activity (III) sway activity of the posturogram in dual-task after intervention. For all variables, negative DTE values indicate deteriorated performance in dual-task (i.e., dual task cost), whereas positive values represent an improvement in dual-task with respect to single-task (i.e., dual task benefit).

All statistical analyses were performed using SPSS for Windows software (version 20.0). The level of significance was set at $p < 0.05$.

3. Results

Table 2 represents mean Vcop values of dual-task performance with EO and EC for both groups before and after acute strength training. Both groups showed higher Vcop ($p < 0.05$) after the elimination of visual feedback than that performing DT-EO in similar conditions. Acute strength training did not change Vcop during dual-task performance in experimental group (DT-EO 24.9 ± 8.3 vs. 25.3 ± 7.7 mm/s; DT-EC 31.6 ± 7.7 vs. 29.3 ± 9.0 mm/s), whereas Vcop in EC condition was significantly lower in the control group after a rest break (35.2 ± 5.2 vs. 31.1 ± 8.1 mm/s) ($p < 0.05$; Table 2).

Comparison of single and dual-tasks showed no significant differences in Mathematical Processing Task errors. Elimination of visual feedback showed no significant effect on cognitive task results in both groups. Acute strength training effect on cognitive task for the dual-task EO and EC condition in both groups was not significant ($p > 0.05$; Table 3).

4. Discussion

The aim of the present study was to evaluate postural control in dual-task and executive function after acute strength training in old adults. No significant effect was found for strength training and dual-task effect on postural control and executive function during dual-tasking. We found a tendency of executive function improvement and Vcop decrease in eyes closed condition after acute strength training.

Bherer (2005) found a possible decrease of postural stability performing concurrent cognitive tasks, and this effect significantly increased in old adults with balance impairments and a recent history of falls. The results of our study did not show dual task effect on the postural control of participants. This finding could be because our participants were healthy without any history of falls and balance impairments. Moreover the stance conditions were ordinary and did not require much effort to maintain postural stability. Shumway-Cook (2000) reported that postural sway increases when sensory information is reduced. As expected that restricting visual feedback increased Vcop, but we found that changes in Vcop affected by restricting visual feedback remained the same performing the dual-task. As sensory redundancy of older adults decreased, the attentional demands associated with maintaining a stable standing position increased.[21] Remy and coauthors (2010) suggests that dual-task interference may arise due to overlapping cortical fields in the frontal and parietal lobes and excessive working memory demands. Our results show only a tendency of Vcop increase by performing dual-task when visual feedback was restricted. Generally, the central nervous system uses two main strategies to restore balance if it is distorted: feedforward control prior to the expected body perturbations and feedback control that are initiated

Table 3
Mathematical Processing Task mistakes performing dual-task, before and after intervention.

	Control group (n = 15)		Experiment group (n = 15)	
	Pre	Post	Pre	Post
DT-EO	0.6 ± 0.6	0.3 ± 0.6	0.3 ± 0.4	0.2 ± 0.4
DT-EC	0.3 ± 0.5	0.1 ± 0.3	0.3 ± 0.4	0.1 ± 0.3

DT-EO/EC, double stance eyes open/eyes closed while performing verbal Mathematical Processing Task; Pre, before intervention; post, after intervention; DTE, dual task effect. Negative dual task effect scores indicate deteriorated performance whereas positive dual task effect scores indicate improved performance relative to performance of the dual task before intervention.

Table 2
Posturographic outcome measures, intervention and visual feedback effects on performance of the dual-task.

	Control group (n = 15)			Experiment group (n = 15)		
	Pre (mm/s)	Post (mm/s)	DTE (%)	Pre (mm/s)	Post (mm/s)	DTE (%)
DT-EO	22.7 ± 3.7	22.5 ± 5.2	1.8 ± 14.3	24.9 ± 8.3	25.3 ± 7.7	-4.3 ± 23.4
DT-EC	35.2 ± 5.2	31.1 ± 8.1*#	7.1 ± 28.0	31.6 ± 7.7	29.3 ± 9.0*	2.1 ± 18.6

* $p < 0.05$ comparing with DT-EO-post condition; # p < 0.05 comparing with DT-EC-pre condition.

by the sensory feedback signals after the perturbations.[23] On the other hand, participants may stabilize their posture in order to focus attention on the cognitive tasks without losing their balance.[24] They prepared themselves prior to the performance of the cognitive task by stabilizing to a greater extent.[24]

Previous investigations reported that trength training could be effective not only for motor function, but also for mental health.[14] Cassilhas and coauthors (2007) found that moderate and high-intensity resistance exercise programs had equally beneficial effects on cognitive functioning. Our results showed the tendency in the decrease of errors in the verbal Mathematical Processing Task after acute strength training. We believe that verbal Mathematical processing task could be not enough sensitive to obtain significant results. However, we chose this type of task because it did not require any additional movements that could affect Vcop registration. Other authors also found improved correct response rate after strength training.[14] Executive control processes encompass cognitive functions concerned with the selection, coordination of computational processes, mediated mainly by pre-frontal brain functions,[25] and physical activity selectively improves older adults' performance in executive function tasks and leads to increases in prefrontal cortex activity.[26] Our results show the same trend.

It has been showed that old people have strategies to compensate vision impairments and some motor disorders with other resources such as muscle strength to maintain safe and independent mobility and posture control.[27] Physical activity may improve sensory integration,[28] so we evaluated short term training effect on postural control during a dual-task. Following Berryman (2014), Caldow (2015), Chang (2014), Labelle (2103), we choose acute strength training as short-term training. We observed the only tendency of Vcop decline after training. Nevertheless, it has been shown that physical activity produces muscle strength and functional autonomy levels.[32] Some studies found significant improvement of static balance after physical activity program.[33,34] Wang with coauthors (2018) found improved gait during dual-task activity after multicomponent exercise. Other authors have established that the elderly who engage in regular physical activity may have greater balance and less fear of falling.[33] In our case, acute training was not sufficient to achieve significant effect on postural control performing a dual-task. On the other hand, only healthy men participated in our research and they did not have any history of falling or other balance impairments.

5. Conclusions and perspectives

Our research suggests that acute strength training might be an effective intervention to improve cognitive functions in old adults. We found decreased number of errors in the Mathematical processing task. Unfortunately, we did not find any effect of intervention on motor – cognitive function interaction during a dual-task, we found only a tendency of improvement.

For further studies and deeper knowledge of strength training effect on static postural control and cognitive function during dual-task we need to evaluate long term strength training effect. In the future studies it would be appropriate to measure muscle parameters before, during and after the program of strength exercise, to investigate the possibilities of the improvement related to postural control.

5.1. Limitations

Involving healthy old participants in the study, we needed to have more complicated conditions to maintain balance because in the simple stance we not observe any differences. Cognitive task has no influence on postural behavior in simple position. Cognitive tasks should be more individualized according to each participant's cognitive level. In this study we used the same task for everyone, therefore for some participants they could have been too easy. Too easy cognitive tasks do not ž leave a trace in balance behavior.

Another limitation is that we used general Vcop, and in the next step, the results will be presented by separate postural behavior components, like anterior-posterior sway activity, mediolateral sway activity and entropy.

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