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論文題目「Effects of dual task balance training on the ability of dual task performance in the elderly people: a randomized controlled trial」
（高齢者における二重課題遂行能力に対する二重課題バランス訓練効果の検証：無作為化比較試験）

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Effects of dual task balance training on the ability of dual task performance in the elderly people: a randomized controlled trial

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Objective: To investigate the effects of dual task balance training in the elderly on standing postural control while performing a cognitive task.
Design: A randomized two-group parallel controlled trial.
Participants: Forty-three subjects (all >65 years old) were enrolled in the study and were assigned randomly to either an experimental group ($n = 21$) or a control group ($n = 22$).
Interventions: Subjects in the experimental group were given strength and balance training while performing cognitive tasks simultaneously. Subjects in the control group were given strength and balance training only. The training was administered twice a week for 3 months.
Measurements: The Chair Stand Test (CST), Functional Reach Test (FR), Timed Up & Go Test (TUG) and Trail Making Test (TMT) were measured. The sway length of the center of gravity was measured during standing while performing the Stroop task. The Rate of Stroop Task (RST) was also measured. All measurements were collected at baseline and after the training period.
Results: There were no significant differences in FR, TUG and Sway length at baseline and after training between the two groups. However, the RST ($p < 0.05$) was significantly higher after training in the experimental group than in the control group.
Conclusions: These results suggest that dual task balance training in the elderly improves their dual task performance during standing postural control.

Introduction

Falls among the elderly are associated with high morbidity and mortality, and may involve high-cost medical intervention. Approximately 30% of community-dwelling people aged 65 and older experience a fall at least once each year[1]. Factors that contribute to falling in the elderly are classified as intrinsic or extrinsic[2]. Intrinsic factors are decreases in physical function, and include decreases that affect sensory function, strength, flexibility and balance abilities. Extrinsic factors are environmental maintenance factors such as the presence of a step. For the intrinsic factors, many studies have shown that muscle strengthening[3-5], balance training[6,7] and Tai Chi training[8] serve as fall prevention programs. Furthermore, the effects of multifactorial fall prevention programs have been reported [9-13]. For the extrinsic factors, effects on fall prevention were reported by the Cochrane review [1].

On the other hand, several recent studies have suggested that not only physical function such as strength, balance abilities and environments, but also attention ability is associated with falling in the elderly [14-17]. In addition, many studies using dual task methodology have investigated whether the performance of cognitive tasks during standing and gait influences standing postural control in healthy adults[18-21], elderly people[22-25], and patients with impaired standing posture control[26-28]. According to these reports, a decrease of attention ability and standing postural control was observed in the elderly[22-25]. In addition, studies using dual task methodology have shown that dual task performance affects standing posture and gait, and is an important predictor of falling[29-33]. The ability of dual task performance is important for everyone. However, it is generally more reduced in the elderly and, therefore, the elderly may have more difficulty in their standing balance while simultaneously concentrating on something else. Therefore, training to improve the ability of dual task performance should be included in a fall prevention program.

Studies of dual task balance training using motor tasks reported positive effects. However, studies that compared the effect of dual task balance training using cognitive tasks with that of the usual balance training showed only small positive effects[34,35], and agreed conclusions are not obtained. In addition, little work has been done to clarify clinical evidence because the studies were not randomized controlled trials examining the effect of dual task balance training.

The purpose of the present randomized controlled trial was to investigate whether the dual task balance training could not only improve standing postural control, but also improve the abilities of community-dwelling elderly subjects in dual task performance.

Methods

Forty-five healthy elderly people who lived in the local community were recruited by public announcement from the local city. The inclusion criteria was as follows: (1) age 65 years or older; and (2) no neurologic or musculoskeletal diagnosis such as stroke, orthopedic involvement, or significant visual and auditory impairments. The subjects were assigned randomly to either the dual task balance training (DT) group or the control group after they were assessed for the inclusion and exclusion criteria. The random assignment procedure was performed using random numbers generated by a computer program (Microsoft Office Excel 2003, Microsoft Co., Tokyo, Japan). An independent researcher enrolled and assigned subjects to each group in order of random table. The researcher was unaware of which numbers related to the experiment or control group until after the randomization to group was complete. The study protocol was explained to each participant who then provided informed consent. The research ethics committee of Kio University approved the study.

Outcome measurements

All outcome measurements were evaluated at baseline and after intervention for all participants. Specific physiotherapists who were blinded to the group allocation of participants assessed all measurements.

The outcome measurements of physical performance were the Chair Stand Test, Functional Reach Test, and Timed Up and Go Test. The Chair Stand Test[36] measures lower extremity muscular strength. The participants were instructed to stand from a seated on the chair position as much as possible for 30 seconds. The total number of stands was counted in 30 seconds. The Functional Reach Test[37] measures static balance. Participants stood with their feet a comfortable distance apart and their dominant arm raised to 90° shoulder flexion. They were asked to reach as far forward as possible without overbalancing. Overbalancing was defined as needing to take a step or requiring hands-on assistance to maintain balance. The distance of additional reach was recorded. The Timed Up and Go Test[38] measures dynamic balance. The Timed Up and Go Test was started with the participants seated in an armchair. At the signal, participants were to stand up, walk 3m, turn, walk back, and sit down again with maximal speed. The score was the mean time measured using a stopwatch of two trials to complete the test.

The Trail Making Test is a widely used neuropsychological test of cognitive flexibility[39], and has been verified as having high reliability and validity[40,31]. Recently, the Trail Making Test was shown to be associated with walking ability and other physical performance in the elderly[42,43]. We used the Trail Making Test Japanese version translated by Hashimoto et al[44]. The Trail Making Test consists of parts A and B. The Trail Making Test -A requires an individual to connect randomly located numbers (1-25) in numerical order as rapidly as possible, and the Trail Making Test –B, which contains both numbers and letters, requires the participant to connect the numbers and letters in the Japanese alphabet, "hiragana", alternately (1,あ,2,い,... し,13). The time required to complete the task was measured on each part of the Trail Making Test. The time difference between parts B and A (B-A) was used as the main assessment parameter so that we were able to control for the effect of motor speed on Trail Making Test performance and to evaluate the ability of attention more accurately than simply using the performance of part B alone. A high Trail Making Test (B-A) score means that the evaluation of Trail Making Test is low.

In the dual task situation, the participant was requested to maintain a standing position on the force platform (Gravicorder GS-7; Anima Corp., Tokyo) for 30 seconds with eyes open, eyes closed and while performing the Stroop task in a Japanese version. We measured the sway length of the center of gravity at a sampling frequency of 50 Hz.

The Stroop task is a frequently used task in cognitive psychology and cognitive neuroscience to study attention[45]. In this task, participants have to name the ink color of a word that spells a color name. When the color and the word are congruent (the word "red" in red letters), the task is easy. However, when the color and the word are incongruent (the word "blue" in red letters), the subjects experience interference. This is thought to occur because word reading is a more practiced and more automatic skill than is the naming of colors, therefore, attentional control is required to overcome the tendency to respond to the word instead of to the color [46,47]. We used the Stroop task Japanese version translated by Yamazaki[48]. In this study, the Stroop task was presented as 45 words of incongruent color and words on a paper of approximately 1,189mm in height / 841mm in width at 2 m in front of the participant. The participant was instructed to respond with a color name as possible and as accurately as possible for 30 seconds during maintaining a standing position. The total numbers and the accurate numbers were measured for 30 seconds. We calculated the rate of the Stroop Task (accurate numbers / total numbers$\times$100) as the ability of dual task performance.

Intervention

All participants received strength and balance training to prevent falls twice a week for 3 months. The training was carried out as one session of training per day for one hour. Training consisted of 24 sessions in total. The training sessions did not require special equipment, and the procedures were easy to facilitate maintaining use after the end of the study. The details of the strength training were based on those reported by Hue A, *et al.*[49]. The balance and walking training were carried out on a regular floor, a Balance-Pad plus® and a Balance-Beam® (Airex AG, Switzerland).

In the DT group, a calculation task, a visual search task, and a verbal fluency task as the cognitive task were performed simultaneously during the balance training. In the calculation task, participants performed a 4 function calculation of up to 2 digit numbers presented aurally and answered verbally. In the visual search task, two presented drawings (or pictures) were compared and differences were identified. In the verbal fluency task, as many words as possible belonging to the presented category (for example, "animal" words) or starting with a presented letter were identified.

Specific therapist instructed the training and confirmed the participant in each session, and presented the tasks in the DT training.

Statistical analysis

JMP®7 statistics software was used for all statistical analyses. Age and physical features were compared between the control and DT groups by the independent *t*-test or the chi-square test according to the characteristics of data. The average was calculated for each measurement, and to determine the difference in before and after training, the numbers before and after intervention were compared between the control and DT groups by the independent *t*-test. In all statistical analyses, a p value less than 5% was considered statistically significant.

Results

Of 45 candidate participants, 2 were excluded according to the exclusion criteria (musculoskeletal disease). The remaining 43 participants were divided randomly into two groups: 22 in the control group and 21 in the DT group.

During the 3 months intervention, 2 participants in the control group dropped out of the protocol due to family problems and 1 participant dropped out due to an accident. In the DT group, 3 participants dropped out because of family problems and 1 dropped out due to a social reason. The 3 months intervention was completed in 19 participants (3 males and 16 females, mean age of 71.2 (4.4) years) in the control group and 17 participants (7 males and 10 females, mean age of 72.0 (5.1) years) in the DT group (Figure 1).

There was no statistical difference in age, male to female ratio, height, and body weight between the two groups. According to the survey, the number of experienced falls in the last six months averaged 1 or less in both groups. The number of training sessions was 24 sessions in total during 3 months and the number of real sessions was 19.7 (4.0) in the control group and 20.9 (3.7) in the DT group, and showed no statistical difference (Table 1).

At baseline, the Chair Stand Test (p = 0.37), Functional Reach Test (p = 0.91) and Timed Up and Go Test (p = 0.53) showed no statistical difference between the control and DT groups. In addition, The Trail Making Test -A (p = 0.07), Trail Making Test -B (p = 0.10) and Trail Making Test (B-A) (p = 0.23) revealed no statistical difference between the control and DT groups. All the sway lengths at the baseline showed no statistical difference between the control and DT groups (eye open, p = 0.95; eye closed, p = 0.44; and dual task, p = 0.37). The rate of Stroop Task was 87.25% (24.26/26.15) in the control group and 90.55% (23.11/25.11) in the DT group, which showed no statistical difference (p = 0.52) (Table 1).

After the intervention, the Chair Stand Test (p = 0.78), Functional Reach Test (p = 0.63) and Timed Up and Go Test (p = 0.86) showed no statistical difference between the control and DT groups. Similarly, there was no statistical difference in the Trail Making Test -A (p = 0.28), Trail Making Test -B (p = 0.35) and Trail Making Test (B-A) (p = 0.56). The sway lengths showed no statistical difference between the control and DT group (eyes open, p = 0.70; eyes closed, p = 0.21; and dual task, p = 0.81). However, the rate of Stroop Task during maintaining a standing position was significantly higher in the DT group (97.13%: 26.23/26.94) than in the control group (88.02%: 24.57/26.23) ($p < 0.05$) (Table 2).

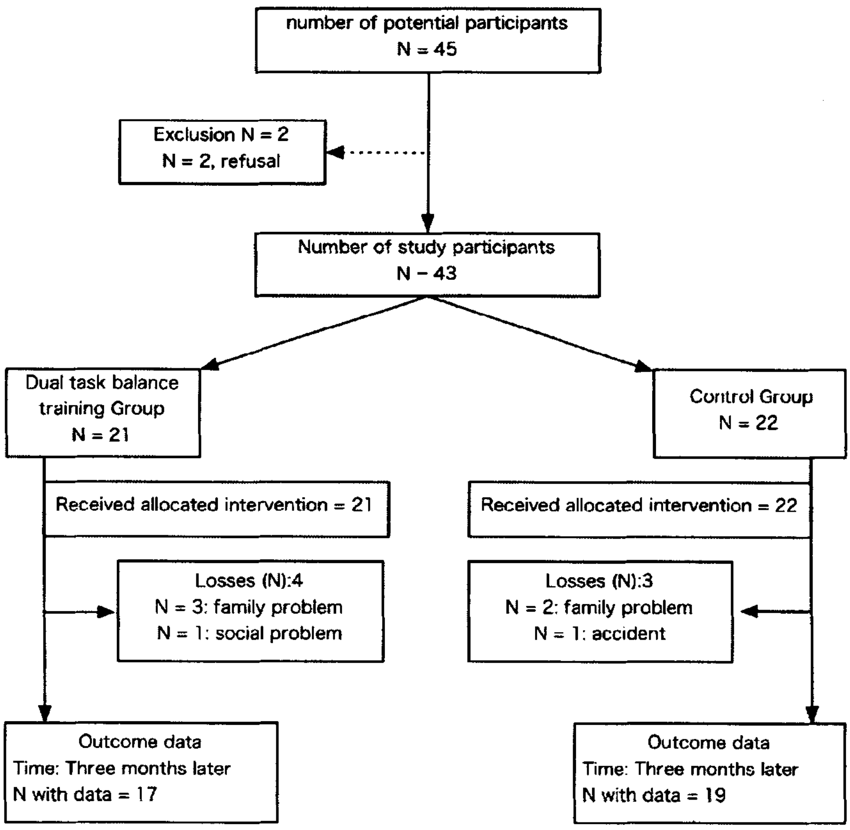

Figure 1 Flow diagram of randomized participant assignment.

Table 1 Comparison at baseline between the control and DT group

	Control group (n=19)	DT group (n=17)	p value
Age (years)	71.2 (4.4)	72.9 (5.1)	0.28
Gender Female (%)	16 (84%)	10 (60%)	0.18※
Body weight (kg)	53.6 (7.1)	54.4 (6.8)	0.71
Height (cm)	152.1 (7.0)	158.0 (8.0)	0.02
Number of falls within the last 6 months (times)	0.4 (0.8)	0.6 (0.9)	0.42
Total number of intervention (sessions)	19.7 (4.0)	20.9 (3.7)	0.36
Physical performance			
Chair Stand Test (times)	20.21 (4.34)	18.70 (5.61)	0.37
Functional reach test (cm)	32.91 (5.92)	32.72 (3.84)	0.91
Timed Up & Go Test (sec)	6.73 (0.84)	6.97 (1.49)	0.53
Cognitive function			
TMT A (sec)	67.79 (35.66)	50.94 (13.79)	0.07
TMT B (sec)	181.11 (90.82)	136.43 (63.68)	0.10
TMT B - A (sec)	113.32 (75.16)	85.48 (60.55)	0.23
Sway length of COG			
Eyes opened (cm)	43.73 (12.68)	43.96 (13.47)	0.95
Eyes Closed (cm)	58.46 (19.33)	65.96 (36.57)	0.44
performing stroop task (cm)	60.66 (34.69)	52.25 (18.12)	0.37
Stroop task			
Number of answers	26.15 (10.34)	25.11 (7.71)	0.73
Number of correct answers	24.26 (11.57)	23.11 (8.44)	0.73
A rate of stroop task (%)	87.25 (19.40)	90.55 (8.67)	0.52

Values are mean (SD) or (%), TMT: Trail Making Test, COG: Center Of Gravity, ※Chi-square test

Table 2 Comparison after training between the control and DT group

	Control group (n=19)		DT group (n=17)		p value	effect size
	At 3 months	Change	At 3 months	Change		
Physical performance						
Chair Stand Test (times)	22.00 (5.77)	1.79 (4.53)	21.47 (5.93)	2.77 (2.33)	0.78	.09
Functional reach test (cm)	32.40 (4.77)	-0.51 (3.29)	33.17 (4.80)	0.45 (5.07)	0.63	.16
Timed Up & Go Test (sec)	6.91 (1.06)	0.18 (1.08)	6.82 (1.78)	-0.15 (0.80)	0.86	.06
Cognitive function						
TMT A (sec)	60.15 (39.33)	-7.64 (25.08)	48.63 (19.22)	-2.31 (16.78)	0.28	.37
TMT B (sec)	136.45 (78.73)	-44.66 (62.14)	115.89 (45.36)	-20.54 (52.86)	0.35	.32
TMT B - A (sec)	76.30 (50.31)	-37.02 (64.04)	67.26 (40.64)	-18.22 (59.48)	0.56	.20
Sway length of COG						
Eyes opened (cm)	47.20 (12.44)	3.47 (7.75)	45.24 (17.98)	1.28 (15.90)	0.70	.13
Eyes Closed (cm)	55.84 (20.53)	-2.62 (12.81)	69.19 (40.33)	3.23 (16.30)	0.21	.42
performing stroop task (cm)	63.15 (44.22)	2.49 (23.81)	60.19 (26.34)	7.94 (18.00)	0.81	.08
Stroop task						
Number of answers	26.63 (9.66)	0.48 (5.10)	26.94 (7.89)	1.83 (3.04)	0.91	.03
Number of correct answers	24.57 (11.35)	0.31 (5.07)	26.23 (8.07)	3.12 (3.96)	0.62	.17
A rate of stroop task (%)	88.02 (18.50)	0.77 (12.68)	97.13 (4.33)	6.58 (7.77)	0.04	.66

Values are mean (SD)

TMT: Trail Making Test, COG: Center Of Gravity

Discussion

The results of this study indicate that muscle and balance training performed mostly by therapeutic guided training without using specific equipment can maintain physical function and balance ability in healthy elderly people. In addition, dual task balance training performed simultaneously with a cognitive task maintained not only balance ability, but also significantly improved the dual task performance compared to the usual balance training.

Recently, a number of studies have reported a positive effect of muscle training and balance training in the elderly [2-13]. In this study, similar results that maintenance of sufficient physical performance was achieved were obtained. In particular, the DT group showed larger improvement in all measurements of physical performance. Furthermore, an improvement tendency on the Trail Making Test was found after training in both groups. A preliminary study of cognitive function has reported that continuation of periodical exercise improves cognitive function[50], and the intervention in this study may have improved general cognitive function.

The dual task balance training, as a new challenge in this study, showed favorable results in the correct answering rate in the Stroop task. There was a significant difference in the rate of correct answering after intervention between the two groups, and the dual task training was presumed to have a positive effect.

In a report on dual task balance training in healthy elderly people, Vaillant, *et al.* [34] showed that there was no significant difference in the one leg balance test and the Timed Up and Go Test between a control group and a dual task training group. However, they did not verify the results of a cognitive task. In contrast, Pellechia [35] reported a significant difference in postural sway in a dual task training group compared with a control group, but there was no significant difference in the cognitive task. Therefore, a definite consensus has not been reached. The difference was attributed to the task priority in the dual task training. Although the subjects were instructed to perform standing postural balancing and a cognitive task as accurately as possible in our present intervention, the participants were healthy elderly people with a certain level of balance, and a marked positive effect on standing postural balancing was not obtained because attention was paid preferentially to the achievement of the cognitive task. Consistent with this speculation, Silsupadol, *et al.* [51] showed that instruction on the priority of targets for attention elicited different effects in the dual task balance training.

The Stroop task is a cognitive task used to evaluate the control ability of cognitive function, and is used often in the field of neuropsychology and cognitive neuroscience. Research on brain function imaging has revealed that a brain area related to working memory can be activated[46,47]. Therefore, it was presumed that a component necessary for smooth standing postural control was contained in this area. Our results that the present intervention improved performance in the Stroop task may contribute to the smoothness in various cognitive activities in a standing position in our daily life. Therefore, this effect may contribute to the prevention of falls in the elderly.

There are several limitations in this study. First, the sample size of our study was small. There is the possibility of a type I-II error. Second, task priority, as described before, is a limitation. Under the dual task condition, prioritizing one task determines the direction of attention to tasks and potentially influences the improvement in dual task performance. However, it is also possible that task priority is dependent on the kind of task. More specifically, priority differs among subjects according to the ability of the subjects and the difficulty of the task to complete. Therefore, it is desirable to advance the dual task balance training while task priority is advised according to the capacity of the subjects.

A third limitation is from verification of the long-term effect of the study results. Since the effect of 3 month training was verified in this study, continuity of the effect remains to be clarified. It is necessary to evaluate the long-term effect to clarify the preventive effect against falls in the elderly.

A final limitation is the fact that the subjects in this study were healthy elderly people. Since they were healthy, they were active and, therefore, training did not exert a positive effect on physical function and performance. Nevertheless, it is noteworthy that intervention with dual task balance training improved dual task performance even in these active elderly people. It is necessary to verify the long-term effect of the dual task balance training in the elderly and in patients with balance impairment that have high risk for falls due to decreased balance capacity.

Clinical messages

- Adding a cognitive task to standard balance training (dual-task training) did not adversely affect the improvement in balance.

Dual-task training did improve in dual task performance during standing postural control in the elderly.

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