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博 士 論 文

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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冷 水 誠

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 year¹. Factors that contribute to falling in the elderly are classified as intrinsic or extrinsic². 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 training⁸ serve as fall prevention programs. Furthermore, the effects of multifactorial fall prevention programs have been reported⁹⁻¹³. For the extrinsic factors, effects on fall prevention were reported by the Cochrane review¹.

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 elderly¹⁴⁻¹⁷. 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 adults¹⁸⁻²¹, elderly people²²⁻²⁵, and patients with impaired standing posture control²⁶⁻²⁸. According to these reports, a decrease of attention ability and standing postural control was observed in the elderly²²⁻²⁵. In addition, studies using dual task methodology have shown that dual task performance affects standing posture and gait, and is an important predictor of falling²⁹⁻³³. 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 Test³⁶ 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 Test³⁷ 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 Test³⁸ 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 flexibility³⁹, 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 al⁴⁴. 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 attention⁴⁵. 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 Yamazaki⁴⁸. 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×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).

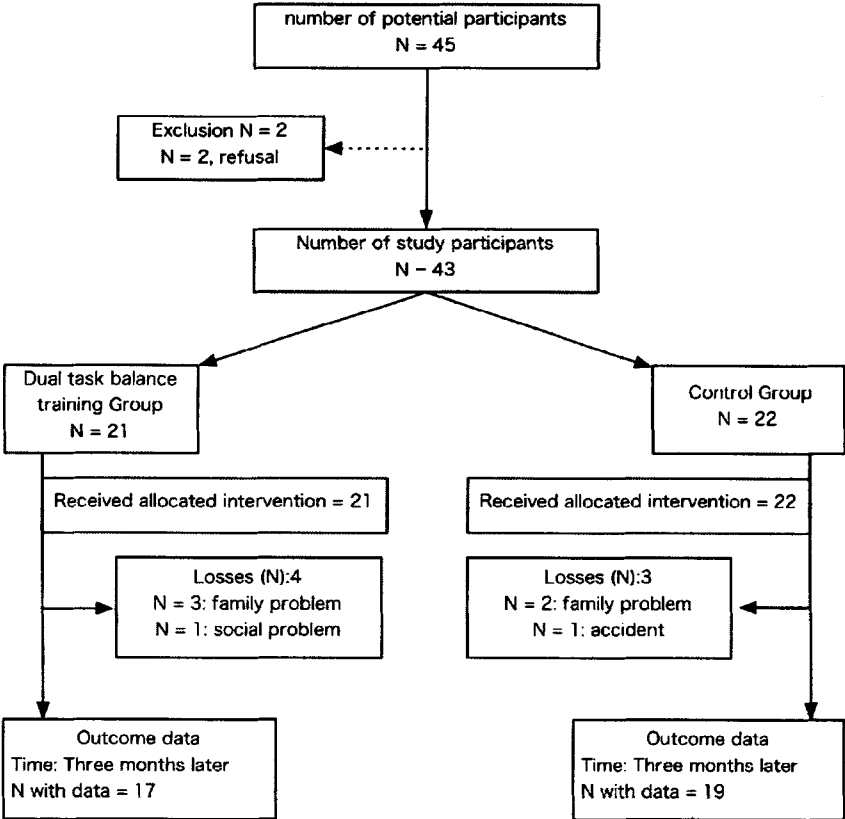


Figure 1 Flow diagram of randomized participant assignment.

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 elderly²⁻¹³. 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 function⁵⁰, 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, Pellechia³⁵ 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.

Reference

- 1) Gillespie LD, Gillespie WJ, Robertson MC, Lamb SE, Cumming RG, Rowe BH. Intervention for preventing falls in elderly people. *Cochrane Database of Systematic Reviews* 2003, Issue 4. CD000340
- 2) Lord SR, Sherrington C, Menz HB. *FALLS in older people*. United Kingdom, Cambridge University Press, 2001
- 3) Littbrand JL, Rosendahl E, Lindelof N, Lundin-Olsson L, Gustafson Y, Nyberg L. A high-intensity functional weight-bearing exercise program for older people dependent in activities of daily living and living in residential care facilities: evaluation of the applicability with focus on cognitive function. *Phys Ther* 2006;86:489-498
- 4) Orr R, Raymond J, Fiatarone SM. Efficacy of progressive resistance training on balance performance in older adults: a systematic review of randomized controlled trials. *Sport Med* 2008;38:317-343
- 5) Salminen M, Vahlberg T, Sihvonen S, Piirtola M, Isoaho R, Aarnio P, Kivela SL. Effects of risk-based multifactorial fall prevention program on maximal isometric muscle strength in community-dwelling aged: a randomized controlled trial. *Aging Clin Exp Res* 2008;20:487-493
- 6) Madureira MM, Takayama L, Gallinaro AL, Caparbo VF, Costa RA, Pereira RMR. Balance training program is highly effective in improving functional status and reducing the risk of falls in elderly women with osteoporosis: a randomized controlled trial. *Osteoporos Int* 2007;18:419-425
- 7) Nagy E, Feher-Kiss A, Barnai M, Domjan-Preszner A, Angyan L, Horvath G. Postural control in elderly subjects participating in balance training. *Eur J Appl Physiol* 2007;100:97-104
- 8) Logghe IHJ, Zeeuwe PEM, Verhagen AP, Wijnen-Sponselee RMT, Willemsen SP, Bierna-Zeinsträ SMA, et al. Lack of effect of Tai Chi Chuan in preventing falls in elderly people living at home: a randomized clinical trial. *J Am Geriatr Soc* 2009;57:70-75
- 9) Lin MR, Wolf SL, Hwang HF, Gong SY, Chen CY. A randomized, controlled trial of fall prevention programs and quality of life in older fallers. *J Am Geriatr Soc* 2007;55:499-506
- 10) Costello E, Edelstein JE. Update on falls prevention for community-dwelling older adults: Review of single and multifactorial intervention programs. *J Rehabil Res Dev* 2008;45:1135-1152
- 11) Shumway-Cook A, Silver IF, LeMier M, York S, Cummings P, Koepsell TD. Effectiveness of a community-based multifactorial intervention on falls and fall risk factors in community-living older adults: a randomized, controlled trial. *J Gerontol A Biol Sci Med Sci* 2007;62:1420-1427
- 12) Faber MJ, Bosscher RJ, Chin A, Paw MJ, van Wieringen PC. Effects of exercise programs on falls and mobility in frail and pre-frail older adults: A Multicenter Randomized Controlled Trial. *Arch Phys Med Rehabil* 2006;87:885-896
- 13) Sjosten NM, Salonoja M, Piirtola M, Vahlberg T, Isoaho R, Hyttinen H, Aarnio P, Kivela SL. A multifactorial fall prevention programme in home-dwelling elderly people: A randomized-controlled trial. *Public Health* 2007;121:308-318
- 14) Carlson MC, Fried LP, Xue QL, Bandeen-Roche K, Zeger SL, Brandt J. Association between executive attention and physical functional performance in community-dwelling older women. *J Gerontol B Psychol Sci Soc Sci* 1999;54:262-270
- 15) Tabbarah M, Crimmins EM, Seeman TE. The relationship between cognitive and physical performance: MacArthur studies of successful aging. *J Gerontol A Biol Sci Med Sci* 2002;57:228-235.
- 16) Hauer K, Pfisterer M, Weber C, Wezler N, Kliegel M, Oster P. Cognitive impairment decreases postural control during dual tasks in geriatric patients with a history of severe falls. *J Am Geriatr Soc* 2003;51:1638-1644
- 17) van Iersel MB, Kessels RP, Bloem BR, Verbeek AL, Olde Rikkert MG. Executive functions are associated with gait and balance in community-living elderly people. *J Gerontol A Biol Sci Med Sci* 2008;63:1344-1349.
- 18) VanderVelde TJ, Woollacott MH, Shumway-Cook A. Selective utilization of spatial working memory resources during stance posture. *NeuroReport* 2005;16:773-777
- 19) Huxhold O, Li SC, Schmiedek F, Lindenberger U. Dual-tasking postural control: a aging and the effects of cognitive demand in conjunction with focus of attention. *Brain Res Bull* 2006;69:294-305
- 20) Prado JM, Stoffregen TA, Duarte M. Postural sway

- during dual tasks in young and elderly adults. *Gerontology* 2007;53:274-281
- 21) Siu KS, Woollacott MH. Attentional demands of postural control: the ability to selectively allocate information-processing resources. *Gait Posture* 2007;25:121-126
 - 22) Jamet M, Deviterne D, Gauchard GC, Vancon G, Perrin PP. Age-related part taken by attentional cognitive processes in standing postural control in a dual-task context. *Gait Posture* 2007;25:179-184
 - 23) van Iersel MB, Ribbers H, Munneke M, Borm GF, Rikkert MGO. The effect of cognitive dual tasks on balance during walking in physically fit elderly people. *Arch Phys Med Rehabil* 2007;88:187-191
 - 24) Sin KS, Chu LS, Mayr U, Donkelaar P, Woollacott MH. Does inability to allocate attention contribute to balance constraints during gait in older adults? *J Gerontol A Biol Sci Med Sci* 2008;63:1364-1369.
 - 25) Liu-Ambrose T, Katarynych LA, Ashe MC, Nagamatsu LS, Hsu CL. Dual-task gait performance among community-dwelling senior women: the role of balance confidence and executive functions. *J Gerontol A Biol Sci Med Sci* 2009;64:975-982.
 - 26) Brown LA, Sleik RJ, Winder TR. Attentional demands for static postural control after stroke. *Arch Phys Med Rehabil* 2002;83:1732-1735
 - 27) Hynsman D, Ashburn A, Yardley L, Stack E. Interference between balance, gait and cognitive task performance among people with stroke living in the community. *Disabil Rehabil* 2006;28:849-856
 - 28) Hyndman D, Pickering RM, Ashburn A. Reduced sway during dual task balance performance among people with stroke at 6 and 12 months after discharge from hospital. *Neurorehabil Neural Repair* 2009;23:847-854
 - 29) Lundin-Olsson L, Nyberg L, Gustafson Y. "Stops walking when talking" as a predictor of falls in elderly people. *Lancet* 1997;349:617
 - 30) Bootsma-van der Wiel A, Gussekloo J, de Craen AJ, van Exel E, Bloem BR, Westendorp RG. Walking and talking as predictors of falls in the general population: The Leiden 85-plus study. *J Am Geriatr Soc* 2003;51:1466-1471
 - 31) Beauchet O, Dubost V, Allali G, Gonthier R, Hermann FR, Kressig RW. 'Faster counting while walking' as a predictor of falls in older adults. *Age Ageing*. 2007;36:418-423
 - 32) Andersson AG, Kamwendo K, Seiger A, Appelros P. How to identify potential fallers in a stroke unit: validity indexes of four test methods. *J Rehabil Med* 2006;38:186-191.
 - 33) Zijlstra A, Ufkes T, Skelton DA, Lundin-Olsson L, Zijlstra W. Do dual tasks have an added value over single tasks for balance assessment in fall prevention programs? A mini-review. *Gerontology* 2008;54:40-49.
 - 34) Vaillant J, Vuillerme N, Martigné P, Caillat-Miosse JL, Parisot J, Nougier V, Juvin R. Balance, aging, and osteoporosis: effects of cognitive exercises combined with physiotherapy. *Joint Bone Spine* 2006;73:414-418
 - 35) Pellecchia GL. Dual-task training reduces impact of cognitive task on postural sway. *J Mot Behav* 2005;37:239-246
 - 36) Jones CJ, Rikli RE, Beam WC. A 30-s chair-stand test as a measure of lower body strength in community-residing older adults. *Res Q Exerc Sport* 1999;70:113-119
 - 37) Duncan PW, Weiner DK, Chandler J, Studenski S. Functional reach: a new clinical measure of balance. *J Gerontol* 1990;45:M192-197.
 - 38) Podsiadlo D, Richardson S. The timed "Up & Go": a test of basic functional mobility for frail elderly persons. *J Am Geriatr Soc* 1991;39:142-148.
 - 39) Reitan RM. Validity of the Trail Making Test as an indicator of organic brain damage. *Percept. Mot. Skills* 1958;8: 271-276.
 - 40) Amodio P, Wenin H, Del Piccolo F, Mapelli D, Montagnese S, Pellegrini A, Musto C, Gatta A, Umiltà C. Variability of trail making test, symbol digit test and line trait test in normal people. A normative study taking into account age-dependent decline and sociobiological variables. *Aging Clin Exp Res* 2002;14:117-131.
 - 41) Tombaugh TN. Trail making test A and B: normative data stratified by age and education. *Arch Clin Neuropsychol* 2004;19:203-214
 - 42) Ble A, Volpato S, Zuliani G, Guralnik JM, Bandinelli S, Lauretani F, Bartali B, Maraldi C, Fellin R, Ferrucci L. Executive function correlates with walking speed in older persons: the InCHIANTI study. *J Am Geriatr Soc* 2005;53:410-415.
 - 43) Coppin AK, Shumway-Cook A, Saczynski JS, Patel KV, Ble A, Ferrucci L, Guralnik JM. Association of executive function and performance of dual-task physical tests among older adults: analyses from the InChianti study. *Age Ageing* 2006;35:619-664
 - 44) Hashimoto R, Meguro K, Lee E, Kasai M, Sshii H, Yamaguthi S. Effect of age and education on the trail

- making test and determination of normative data for Japanese elderly people: the Tajiri project. *Psychiatry Clin Neurosci*. 2006;60:422-428.
- 45) Stroop JR. Studies of interference in serial verbal reactions. *J Exp Psychol* 1935;8:643-662
- 46) Egner T, Hirsch J. The neural correlates and functional integration of cognitive control in a Stroop task. *Neuroimage* 2005;24:539-547
- 47) van Veen V, Carter CS. Separating semantic conflict and response conflict in the Stroop task: a functional MRI study. *Neuroimage* 2005;27:497-504
- 48) Yamazaki A. Interference in the Stroop color-naming task. *Shinrigaku Kenkyu*. 1985 Oct;56(4):185-91. Japanese.
- 49) Hue OA, Seynnes O, Ledrole D, Colson SS, Bernard PL. Effects of a physical activity program on postural stability in older people. *Aging Clin Exp Res* 2004;16:356-362
- 50) Liu-Ambrose T, Donaldson MG. Exercise and cognition in older adults: is there a role for resistance training programmes? *Br J Sports Med* 2009;43:25-27
- 51) Silsupadol P, Shumway-Cook A, Lugade V, van Donkelaar P, Chou LS, Mayr U, Woollacott MH. Effects of single-task versus dual-task training on balance performance in older adults: a double-blind, randomized controlled trial. *Arch Phys Med Rehabil* 2009;90:381-387