Table 1. Characteristics of subjects by cognition group

Variables	Cognitively healthy (n = 2,498)	MCI (n = 809)	p
Age, years	71.2±5.1	71.8±5.4	0.008
Women, %	52.6	52.8	0.935
Educational level, years	11.9±2.5	10.8±2.4	<0.001
BMI	23.3±3.1	23.4±3.1	0.670
Medical illness, %			
Hypertension	43.8	48.6	0.018
Heart disease	15.3	19.3	0.008
Diabetes mellitus	13.3	14.7	0.289
Respiratory disease	11.2	10.5	0.651
Medications, n	1.8±1.9	2.2±2.1	<0.001
Walking speed, m/s	1.31±0.20	1.26±0.22	<0.001
GDS, score	2.5±2.4	3.3±2.6	<0.001
Cognitive functions			
MMSE, score	27.4±1.8	26.6±1.8	<0.001
TMT-A[1], s	19.0±4.1	23.6±7.8	<0.001
TMT-B[1], s	35.8±10.6	51.5±19.8	<0.001
SDST[1], score	41.3±7.0	35.2±7.8	<0.001
Figure selection[1], score	11.6±1.7	11.2±1.7	<0.001
Story memory[1], score	7.6±1.5	6.4±1.8	<0.001
Word recognition[1], score	7.7±1.2	7.0±1.3	<0.001
Word recall[1], score	4.4±1.7	3.1±2.0	<0.001
Smoking, %	9.0	9.8	0.530
Alcohol consumption, %	46.8	46.4	0.839
Physical activity, min/day	289.5±162.0	274.7±154.7	0.022

Values are means ± SD or percentage. p values for scales and tests were calculated by the t test or χ^2 test. MMSE = Mini-Mental State Examination; TMT = trail making test; SDST = symbol digit substitution task.
[1] The assessment was conducted using the tablet version of the NCGG-FAT.

confounding factors. We calculated the odds ratio (OR) and 95% confidence intervals (95% CIs). Covariates were added sequentially to the logistic model (model 2) if they were significantly associated with MCI. In addition, a multiple logistic regression analysis was performed to compare subjects who did not participate in any cognitive activity to those who did participate in cognitive activities, adjusting for confounding factors. This logistic regression analysis regarding the number of activities was also conducted for the implementation of IADL. All analyses were performed using commercially available software (IBM SPSS statistics software, version 20; IBM Corp., Chicago, Ill., USA). Statistical significance was set a priori at $p < 0.05$.

Results

Comparisons between characteristics of cognitively healthy subjects and MCI subjects are summarized in table 1. Gender, smoking status, and alcohol consumption were not significantly different between cognitively healthy and MCI subjects. Significant differences were found for age ($p = 0.008$), education ($p < 0.001$), medications ($p < 0.001$), walking speed ($p < 0.001$), GDS score ($p < 0.001$), and physical activity ($p = 0.022$). In addition, MCI subjects had a lower performance on tests for cognitive function ($p < 0.001$).

Prevalence of participation in cognitive activities varied (table 2). Reading was the most frequent cognitive activity that participants engaged in (cognitively healthy, 97.4%; MCI,

Table 2. Logistic analysis of MCI according to participation in individual cognitive activities

Cognitive activities	Cognitively healthy, n (%)	MCI, n (%)	Model 1 (crude)			Model 2 (adjusted)		
			OR	95% CI	p	OR	95% CI	p
Reading	2,434 (97.4)	759 (93.8)	0.41	0.28–0.59	<0.001	0.53	0.35–0.78	0.002
Computer	1,044 (41.8)	213 (26.3)	0.50	0.42–0.59	<0.001	0.65	0.53–0.80	<0.001
Map	1,696 (67.9)	450 (55.6)	0.59	0.51–0.70	<0.001	0.74	0.62–0.89	0.002
Video or DVD	1,462 (58.5)	379 (46.9)	0.63	0.53–0.73	<0.001	0.72	0.61–0.86	<0.001

Participation in cognitive activities was dummy coded, with no participation as the reference category. Model 2 was adjusted for age, sex, BMI, education, medications, alcohol, smoking, walking speed, physical activity, and GDS.

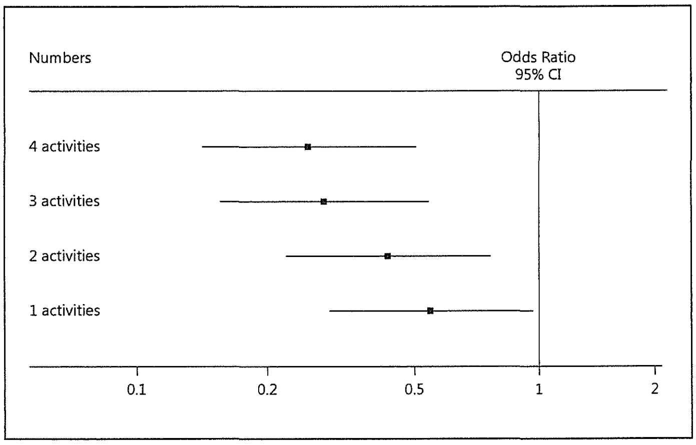

Fig. 1. OR of the number of cognitive activities and MCI. No participation was the reference category for any cognitive activity.

93.8%). Use of a personal computer was the cognitive activity that was engaged in the least (cognitively healthy, 41.6%; MCI, 26.3%). Every cognitive activity was significantly associated with MCI, even after adjusting for covariates ($p < 0.01$; table 2). Figure 1 shows that increased participation in cognitive activities was also associated with MCI [OR (95% CI): 1 activity: 0.54 (0.30–0.97), $p = 0.039$; 2 activities: 0.42 (0.23–0.76), $p = 0.004$; 3 activities: 0.29 (0.16–0.53), $p < 0.001$, and 4 activities: 0.27 (0.14–0.49), $p < 0.001$]. Among both cognitively healthy individuals and MCI subjects, more than 85% had all IADL items (table 3). Using a bus or a train was more common in cognitively healthy subjects than in MCI patients, but it was only significantly associated with MCI in univariate analysis ($p = 0.002$). Other activities in IADL were not significantly related to MCI. The number of implemented IADLs were not associated with MCI either.

Discussion

This study revealed that greater participation in cognitive activities was associated with lower odds of MCI. Among MCI subjects, participation in cognitive activities ranged from 26 to 94%, and fewer MCI subjects participated in these activities than healthy subjects did. IADL participation was ≥87% in each activity for both healthy controls and MCI subjects. Signif-

Table 3. Logistic analysis of MCI according to the implementation of individual IADLs

IADLs	Cognitively healthy, n (%)	MCI, n (%)	Model 1 (crude)			Model 2		
			OR	95% CI	p	OR	95% CI	p
Bus or train	2,314 (92.6)	721 (89.1)	0.65	0.50–0.85	0.002	0.90	0.67–1.19	0.448
Grocery shopping	2,426 (97.1)	783 (90.4)	0.89	0.57–1.41	0.629	1.07	0.66–1.75	0.775
Finance	2,288 (91.6)	731 (90.4)	0.86	0.66–1.13	0.279	1.04	0.77–1.40	0.796
Housekeeping	2,185 (87.5)	707 (87.4)	0.99	0.78–1.26	0.993	1.08	0.82–1.41	0.586
Telephone	2,362 (94.6)	760 (93.9)	0.89	0.64–1.25	0.510	1.06	0.74–1.52	0.737

The implementation of IADL was dummy coded, with no participation as the reference category. Model 2 was adjusted for age, sex, BMI, education, medications, alcohol, smoking, walking speed, physical activity, and GDS.

icant associations remained between cognitive activities and MCI but not IADL, even after adjustment for covariates such as demographic, psychological, and physical factors including physical activity.

Participation in cognitive activities decreased for subjects with MCI compared to cognitively healthy subjects. Participation in cognitive activities is believed to support an active lifestyle, and the cognitive reserve protects against cognitive decline and progression to AD [12]. Decreased participation in cognitive activities leads to cognitive decline [6, 7] and an increased risk of MCI [13], AD [6, 8], and dementia [9]. Associations between cognitive activities and cognitive impairment were confirmed for MCI subjects in our large study sample. Our results showed that the relationship between cognitive activities and MCI is independent of physical activity. Physical activities in parallel with cognitive activities were confirmed to have the potential to slow cognitive decline [30, 31] and reduce the risk of progression to dementia [5, 9]. In addition, each cognitive activity was significantly associated with MCI and the number of cognitive activities. Our results suggest that participation in cognitive activities in daily life decreases along with cognitive impairment and even MCI.

Our results were similar to those of other studies, although the types of cognitive activities were slightly different. Geda et al. [15] suggested that engagement in specific activities such as reading books, computer activities, craft activities, and playing games were associated with decreased odds of having MCI. We also found that reading and computer activities were associated with being cognitively healthy. Reading is generally regarded as a cognitive activity [6, 8, 9] and is significantly related to the incident risk of dementia even as a single item [9]. Operation of a home appliance such as a computer, DVD, or video equipment requires adequate understanding of the appliance (e.g., selecting a button). For older adults, operating home appliances in daily life is difficult and requires adequate cognitive function [32].

In our study, cognitive activities other than reading showed a lower participation of both healthy controls and MCI subjects. Using a map to reach a location requires planning ability as well as formulation and execution components [33]. A study testing the map usage of elderly participants suggests that some have problems in spontaneously developing logical strategies, whereas they are able to execute complex predetermined plans [34]. Using a map may be even more difficult for older adults with cognitive impairment. Participation in cognitive activities requires a certain level of cognitive functioning and decreases with the increase in cognitive impairment.

Participation in IADL was higher than participation in cognitive activities, with more than 87% of the subjects participating in IADLs. Univariate analysis showed an association between the use of a bus or a train and MCI. However, multivariate analysis revealed that no activity was significantly related to MCI. The functional deficits of IADL were predictors of the development of dementia [16, 17] and were frequent among older adults with MCI [18–23, 35]. One of the commonly used measurements for assessing IADL was developed by Lawton and Brody [22] in 1969. A few previous studies on subjects with MCI used IADL domains similar to those used by Lawton and Brody [18, 23, 35]. Our results showing a high prevalence of the implementation of IADLs among MCI subjects were consistent with the results of other studies [18, 23]. MCI was defined as a very early stage of functional decline between normal aging and AD [3]. Thus, the assessment of functional abilities itself, but not implementation, in IADL by items related to the Lawton and Brody IADL scales [22] can be used in order to detect functional decline in subjects with MCI earlier [23, 35]. Future studies using measurements evaluating the degree of deficits in IADL are required to clarify the association between IADL and MCI. More complex activities of IADL than the Lawton and Brody IADL scales [22] have also been used in studies of MCI [19–21]. Reppermund et al. [19] suggest that difficulties in IADL, especially those with a higher demand on cognitive capacities, are associated with MCI and cognitive function. Although IADL is defined as a more complex activity than ADL [22], it is unclear which activities for the assessment of MCI subjects are the most appropriate ones. To clarify the heterogeneity of the activities in IADL, each activity should be investigated independently and the classification of activities should also be investigated.

Our study had several limitations. First, it was cross-sectional. For a detailed examination of the relationship between participation in cognitive activities and MCI, a prospective or longitudinal study is needed. In addition, there is the potential of residual confounding for factors that we did not collect. Future studies should include these potential confounders, e.g., the burden of amyloid in the brain, structural changes in the brain, or APOEε4 as a genetic factor. Thus, additional studies on activities and cognitive impairment are required.

In conclusion, our study revealed that reduced cognitive activities are independently associated with MCI in older adults. Lower participation in cognitive activities may be characteristic of MCI subjects. Although our study has several limitations, it provides additional evidence that participation in cognitive activities may be useful for the detection of cognitive decline. The causal relationship between specific activities and cognitive impairment should be further investigated.

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Disclosure Statement

None declared.

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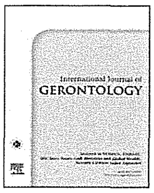

Original Article

Age-related Differences in the Influence of Cognitive Task Performance on Postural Control Under Unstable Balance Conditions☆

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SUMMARY

Background: Poor multitask performance is commonly used as an indicator of age-related changes in attentional capacity. An inability to allocate sufficient attention to postural control under multitask conditions is thought to be a contributing factor to the risk of falling in older adults. This study examined age-related differences in the influence of cognitive task performance on postural sway and muscle activity on unstable balance conditions.

Methods: Thirty healthy younger adults (22.2 ± 1.5 years of age, 15 men and 15 women) and 27 healthy older adults (71.3 ± 3.4 years of age, 13 men and 14 women) participated in the study. Participants performed a reaction time task under three conditions during standing on a compliant foam surface: holding a glass full of sand (control task), holding a glass of water (dual-manual task), and performing a control task while simultaneously performing a verbal fluency task (dual-cognitive task).

Results: Both younger and older adults had a longer reaction time for the dual-cognitive task compared to the other two tasks ($p < 0.01$). Older participants exhibited decreased lower limb muscle activity and increased anterior–posterior trunk acceleration during the dual-cognitive task, while these effects were not observed in younger adults.

Conclusion: Increasing attentional demand by implementing a cognitive task concomitant with a balance task had a greater influence on postural control in older compared to younger adults.

1. Introduction

Many activities of daily living require the integration of multiple physical and cognitive functions, including common tasks such as walking on unlevel ground and talking at the same time. To produce appropriate behavior in these situations, attentional resources must be divided to enable multiple tasks to be performed simultaneously. The dual-task paradigm allows the extent of attentional resource-sharing to be examined. Dual-task methods have been successfully applied to the measurement of postural control[1] and poor multitask performance is commonly used as an indicator of age-related changes in attentional capacity[2]. The results of several previous studies have indicated age-related declines in dual-task performance[3–5]. The simultaneous performance of postural and cognitive tasks has been found to have a deleterious effect on balance control, particularly in older adults, owing to a reduction in or misallocation of attentional resources[1]. In addition, poor multitask performance has been found to constitute a risk factor for falling in older people[5–10].

In experimental paradigms using reaction time (RT) as a dependent variable, measures of the relative cost of performing concomitant tasks can provide a conservative estimate of age-related changes in dual-task performance[11]. For example, Sparrow et al reported that RTs in older adults under dual-task conditions were significantly longer than those of a younger group, but RTs did not differ between age groups under single-task conditions[12]. Moreover, concomitant cognitive tasks have been found to substantially decrease postural stability because of increased attentional demands. Importantly, several previous studies indicated that an inability to allocate sufficient attention to postural control under multitask conditions is a contributing factor to the risk of

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☆ All contributing authors declare no conflicts of interest.

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falling in older adults[5,8]. Pellecchia reported that postural sway in young participants while standing on a compliant surface increased with the difficulty of a concurrent cognitive task[13].

Brauer et al reported that in older adults, both healthy and balance-impaired individuals showed reduced activity in the lower muscles under dual-task compared to single-task conditions[14]. In addition, frail older adults who demonstrated poor dual-task performance with a manual task (i.e., carrying a glass of water) exhibited a high risk of falling[15]. These findings support the notion that cognition and motor performance are related. However, few studies have shown age-related differences between healthy younger and older adults in the influence of cognitive demands on postural sway and muscle activity during the performance of postural tasks under unstable balance conditions.

We hypothesized that the additional attentional demand under challenging balance conditions, such as standing on a compliant foam surface, would result in a greater decrease in postural stability with any changes in lower-extremity muscle activity in older adults compared to younger adults. Previous studies have postulated that the relationships between postural control and cognitive demand in dual-task situations could be U-shaped[16,17]. In these opinions, postural control performance is either improved or attenuated, depending on whether the cognitive demand of the secondary task is low or high, respectively. In a previous study, when performing more demanding cognitive tasks, older adults showed increased body-center pressure displacements measured by a force platform, in line with the predicted U-shaped function, whereas young adults did not[18]. However, to the best of our knowledge, there are few data regarding differences in the effects of additional manual and cognitive tasks on postural sway and lower muscle activity under unstable balance conditions in older adults. Thus, the aim of the current study was to examine age-related differences in dual task performance and to determine age-related differences in the influence of concurrent manual and cognitive tasks on postural sway and lower muscle activity under unstable balance conditions between younger adults and community-dwelling healthy older adults.

2. Methods

2.1. Participants

Fifty-seven volunteers participated in the current study, divided into two age groups: 30 healthy younger participants aged between 20 and 25 years (22.2 ± 1.5 years, 15 men and 15 women) and 27 healthy older participants aged 65–78 years (71.3 ± 3.4 years, 13 men and 14 women). All older participants were community-dwelling volunteers who lived independently without assistance. We confirmed general cognitive status in older participants using the Mental Status Questionnaire (MSQ)[19]; all of them exhibited normal general cognitive functioning (less than one error on the MSQ). Young volunteers were a mixture of undergraduate university students, postgraduate students, and employees of the university. We excluded participants with a history of serious neurological or musculoskeletal diagnoses, abnormal hearing, or an inability to stand on their preferred leg with eyes open for 15 seconds. Demographic characteristics and physical performance test scores for the 57 participants are presented in Table 1. The Sapporo Medical University ethics committee approved the experimental protocols. All participants provided written informed consent.

2.2. Materials and apparatus

Participants were instructed to press a handheld button as quickly as possible in response to the presentation of an auditory stimulus. RT was measured using a time counter (PTS-010, DKH Inc., Tokyo, Japan) and displayed in milliseconds. RT in each trial was defined as the temporal interval between presentation of an auditory stimulus and the onset of a button-press response.

Table 1
Participant characteristics.

	Younger ($n = 30$)	Older ($n = 27$)
Age (y)	22.2 ± 1.5	71.3 ± 3.4
Female (%)	50.0	51.9
Body height (cm)	166.7 ± 9.8	157.7
Body mass (kg)	57.8 ± 9.9	58.8
Education (y)	15.5	12.7
Fallen at least once in past 6 mo (%)	0.0	3.7
Exercised at least three times per wk (%)	13.3	77.8
TUG score (s)	3.8 ± 0.5	4.5 ± 0.5
OLS time (s)	60.0 ± 0.0	54.8 ± 11.3

OLS = one-legged standing; TUG = timed up-and-go test (maximum pace).

Surface electromyographic (EMG) signals were recorded from the tibialis anterior (TA) and medial gastrocnemius (MGAS) muscles of the right leg. Bipolar surface EMG sensors (SX230, Biometrics Ltd, United Kingdom; interelectrode distance 20 mm) were placed on the skin over the TA and MGAS muscles for EMG recording. Before recording, unilateral (right leg) maximum isometric voluntary contraction (MVC) of the TA and MGAS muscles was measured during 5-second maximal contractions. EMG signals were digitized at a sampling frequency of 1000 Hz (full-wave-rectified and low-pass-filtered-50 Hz signal), and root mean square (RMS) voltages of the EMG signal (rEMG) were calculated. For each subject, we normalized rEMG activity to the individual MVC, resulting in a percentage MVC (%MVC) value for each muscle.

We used a triaxial accelerometer (MA3-04Ac, Micro Stone Inc., Nagano, Japan; fluency range 0.8–1000 Hz) to measure postural sway. A triaxial accelerometer was placed on the lower back of the subject at the level of the third lumbar vertebra. Acceleration signals (measured in G, where $1 \text{ G} = 9.8 \text{ m/s}^2$) were used to determine anterior–posterior sway during the postural response. Sway variability was quantified by calculating the RMS of anterior–posterior acceleration. We used acceleration signals as a measure of postural sway because previous studies reported that trunk accelerometry could quantify the stochastic–dynamic structure of postural sway[20] and discriminate between populations and conditions during quiet standing[21]. In addition, trunk acceleration has been used as a measure of sway responses to differing conditions in older people[22]. To clarify the interaction between postural sway and muscle activity while standing in an unstable balance condition, we measured anterior–posterior sway and EMG activity of the ankle musculature, which contributes to anterior–posterior postural control.

Surface EMG and triaxial accelerometer data were acquired and analyzed using a PowerLab system with Chart v5.0 software (ADInstruments, Castle Hill, Australia).

2.3. Procedure

After exclusion criteria were applied, vital signs were assessed and information about education, falling incidents in the previous 6 months, and the amount of exercise per week was collected in face-to-face interviews. All participants performed the timed up-and-go test (TUG) and one-legged standing test (OLS) as clinical measures of gait and balance to exclude serious balance impairments. The TUG is generally used to assess mobility performance. In this task, participants are instructed to rise from a chair, walk 3 meters, turn around, walk back to the chair, and sit down at their usual pace[23]. In this study, participants were asked to perform the TUG at their maximum pace, because we sought to assess mobility performance under conditions with a high risk of falling due to challenging balance conditions.

In the experimental session, participants performed the RT task under three conditions:

(1) standing with feet close together (Romberg stance) on a compliant foam surface (Airex Balance Pad Plus, Airex AG, Sins, Switzerland; $50 \times 41 \times 6$ cm^3, weight 0.7 kg, apparent density 55 kg/m^3, tensile strength 240 kPa) with a glass full of sand (250 g) in the left hand (control task);
(2) standing on a compliant foam surface in the Romberg stance with a glass of water (250 g) in the left hand (dual-manual task); and
(3) performing the control task condition while simultaneously performing a verbal fluency task (dual-cognitive task).

In all task conditions, participants were asked to stand under unstable balance conditions. We defined the lowest cognitive and physical demands of the secondary task as a control task. In the dual-manual task, to increase the physical demand, participants held a glass full of water instead of sand, with the surface of the water 1 cm from the top edge of the glass. We added a verbal fluency task to the control task to increase cognitive demand in the dual-cognitive task. The verbal fluency task was selected from two categories at random from the following four categories: animals, vegetables, countries, and Japanese prefectures. For each trial in the dual-cognitive task, participants were instructed to think of as many examples in each category as possible, but not to verbalize their answers. Immediately after the recording session, participants then had to verbally name as many item names in each category as possible within a 40-second response period. The number of item names was used as a measure of cognitive demand.

Each participant practiced at least twice before data collection. The experimenter confirmed that the participants were standing quietly in a stable position and then issued the verbal command "ready" as a starting signal to the participants before RT measurement began. An assessor (a physical therapist) explained the details of the test protocols to each participant and conducted practice sessions of RT measurement to ensure that participants understood the test protocols. RT was then measured for each participant under the three task conditions (control, dual-manual, and dual-cognitive tasks), randomly presented to avoid any learning or task effects, to measure the speed of response to an auditory stimulus. Each condition was tested in two sessions and a single session comprised five trials. Five auditory stimuli were presented at randomly generated intervals of 6, 7, 8, 9, or 10 seconds in a session for a total of 40 seconds. Thus, in total we recorded each variable in each task condition in 10 trials. Surface EMG and triaxial accelerometer data were recorded from 5 seconds before the stimulation was presented. In each task condition, the average of each variable over eight trials (excluding the single fastest and single slowest RT trial to exclude accidental responses) was used for statistical analysis. Fig. 1 shows the experimental methods.

2.4. Statistical analysis

Differences between younger and older adults in RT, %MVC of EMG, and RMS values of anterior–posterior acceleration in the different tasks were examined using repeated-measures two-way analysis of variance (ANOVA; subject group × task condition). *Post hoc* tests of coefficients with Bonferroni correction for multiple comparisons were conducted for main effects that were statistically significant. Unpaired Student *t* tests were used to compare verbal fluency (number of words) between younger and older adults. Statistical results were assumed to be significant at $p < 0.05$. All statistical analyses were performed using SPSS 17.0 for Windows (SPSS Inc., Chicago, IL, USA).

3. Results

ANOVA revealed significant effects of the group × task condition interaction on RT [$F_{(2,110)} = 5.167$, $p = 0.001$] and EMG of the TA [$F_{(2,110)} = 9.766$, $p < 0.001$] (Fig. 1A,C). By contrast, no significant interaction effects were found for RMS values of anterior–posterior acceleration [$F_{(2,110)} = 1.760$, $p = 0.177$] or EMG of the MGAS

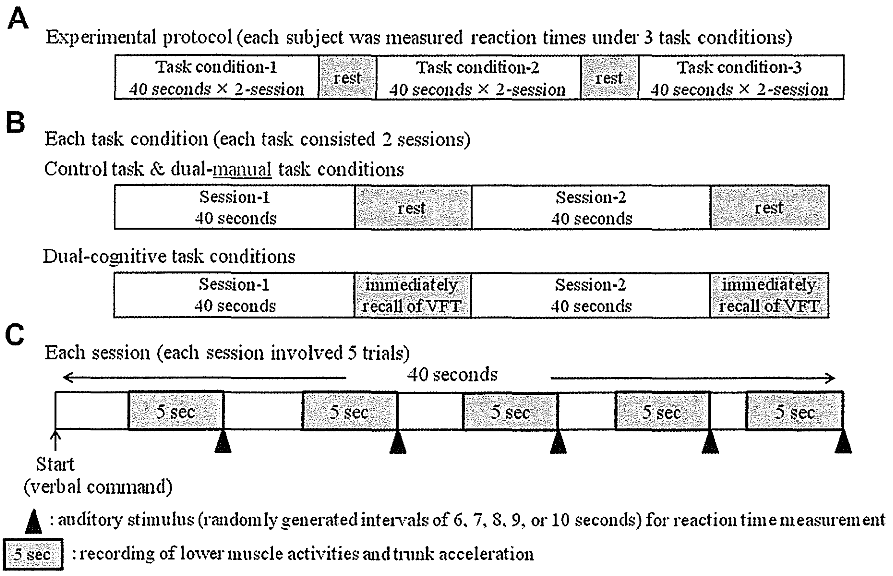

Fig. 1. (A) Experimental protocol, (B) each task condition, and (C) each session condition. Each task condition was randomly selected from control task, dual-manual task, and dual-cognitive task conditions. Each task consisted of two sessions and each session involved five trials of reaction time measurements. VFT = verbal fluency test.

[$F_{(2,110)} = 1.043, p = 0.356$] (Fig. 1B,D). As shown in Fig. 1A, a *post hoc* analysis of the main effect for task condition with Bonferroni correction indicated that RTs during the dual-cognitive task were significantly longer than those during the control and dual-manual tasks for both groups ($p < 0.001$). Although there was no significant difference in RMS values of anterior–posterior acceleration between task conditions in younger adults, anterior–posterior acceleration in older adults was significantly increased during the dual-cognitive task compared with the control and dual-manual tasks ($p < 0.05$; Fig. 1B). No significant difference in TA muscle activity was found in younger adults, but a significant decrease was observed in older adults in the dual-cognitive compared to the control and dual-manual tasks ($p < 0.01$; Fig. 1C). We also found a significant decrease in MGAS activity in older adults while performing the dual-cognitive task compared with the control task ($p < 0.05$; Fig. 1D). Table 2 shows the number of immediate recall words after the dual-cognitive task in the verbal fluency task. Significant differences in the number of responses and correctly answered words were found between younger and older adults, with younger adults reporting a significantly greater number of words compared to older adults ($p < 0.01$).

4. Discussion

The goal of this study was to examine age-related differences in the influence of manual and cognitive tasks on postural sway and muscle activity under unstable balance conditions. In all three task conditions (control task, dual-manual task, and dual-cognitive task) all participants were able to maintain the task while avoiding a loss of balance, which could lead to falling or tripping. The results revealed that both younger and older adults exhibited longer RTs under dual-cognitive compared to control and dual-manual task conditions. Anterior–posterior trunk acceleration significantly increased in the dual-cognitive task for older adults, while no similar increase was observed in younger adults. EMG measurements revealed that older adults exhibited decreased TA and MGAS muscle activity during the dual-cognitive task, but these effects were not observed in younger adults. Older adults showed a substantial reduction in their ability to maintain posture when a cognitive task was performed simultaneously, but younger adults did not.

As shown in Fig. 2A, a significant interaction effect was found on RT, and this result revealed an age-related increase in RT under dual-cognitive task conditions, in agreement with the results of a number of earlier studies[11,12,24–26]. Furthermore, our results reveal age-related differences in the influence of cognitive tasks on postural control in the unstable balance condition. Olivier et al confirmed that the interference between mental activity and postural control could be attributed mainly to attentional limitations[27]. In our dual-cognitive task condition, addition of a verbal fluency task concomitant to the challenging balance condition (standing in the Romberg stance on a compliant foam surface), older participants exhibited a significant increase in anterior–posterior trunk acceleration and a decrease in TA and MGAS muscle activity. Younger participants did not exhibit either of these changes. The decrease in muscle activity and increase in postural sway exhibited by older participants during the verbal fluency task may indicate that fewer attentional resources were available for balance control in the cognitively demanding dual-task condition. The results also indicate that performing balance and cognitive tasks concurrently has a greater impact on the interaction between body posture and muscle activity for balance control in older compared to younger adults. Simoneau et al demonstrated that during complex posture, postural instability, as well as EMG activity of the ankle joint muscles, was decreased in older adults when a difficult memory task was added[28]. Our results are partly in accord with previous studies reporting a decrease in TA and MGAS muscle-response amplitudes when older participants performed a cognitive task simultaneous to standing platform perturbations[14,29].

Table 2
Number of recall words in the verbal fluency task immediately after the dual-cognitive task period.

	Younger ($n = 30$)	Older ($n = 27$)
Total number of responses (words)	41.7 ± 8.2	32.4 ± 11.2 **
Number of correct responses (words)	41.3 ± 8.2	29.7 ± 11.5 ***

**$p < 0.01$, ***$p < 0.001$, Student t tests.

Redfern et al reported that performance of an RT task was associated with an increase in postural sway in older but not younger participants[30]. These findings suggest that attentional processes may be affected by inhibitory balance control in older adults when sensory integration requirements are high, and that aging may modify the interference between postural and cognitive tasks in the adjustment of behavior in complex situations. Performance of cognitively demanding tasks diminishes central nervous system resources that govern self-regulation of physical tasks requiring maximal voluntary effort[31]. In our study, even when standing under unstable balance conditions, younger adults were able to divide attention into concurrent cognitive tasks while maintaining postural stability without changing trunk sway and lower-limb muscle activity during a control task. However, in older adults, divided attention for cognitive tasks might lead to failure to activate lower limb muscles to control posture. On the basis of these findings, we hypothesize that older adults cannot help but increase body sway to perform dual-cognitive tasks under unstable balance conditions, as in our experimental situations.

Previous studies reported that a combination of sufficiently challenging motor and postural tasks and concurrent cognitive tasks could be used to reveal early signs of deterioration in the ability of older people to control posture[32,33]. In the present study, we measured RT, activity in the lower muscles, and body sway while dual-cognitive tasks were being performed during quiet standing under unstable balance conditions. The results revealed age-related differences in the influence of cognitive tasks on postural sway and lower-limb muscle activity, as well as slower RT responses. The current findings thus indicate that multitask performance had a greater impact on balance control in older compared to young adults. Although quiet standing is a relatively simple postural task, it is now well established that it requires some level of cognitive resources[34]. Recent studies using randomized controlled trials have demonstrated that multitask training in older adults has an effect on the performance of physical activities (e.g., gait speed, cadence, and balance tasks) under dual-task conditions[35–37]. Our findings indicate that further research should be undertaken to determine whether a multitask intervention program could improve balance control in the interaction between muscle activation and body sway under multitask conditions involving cognitive demand in older adults.

We assessed the impact of increased cognitive demand during dual-cognitive task conditions by instructing participants to immediately recall words after the measurement period in the dual-cognitive task condition. A previous study reported a mean (SD) category fluency score of 18.3 (5.3) words (mean 3.1 words per 10 seconds) in the animal naming test (animals named within 1 minute) in a group of 117 healthy older adults with no cognitive impairments[38]. Another study in Brazil reported a similar mean category fluency score in the animal naming task in older adults with no cognitive impairments[39]. In the present study, the mean (SD) score in the category fluency task (calculated as the scores for

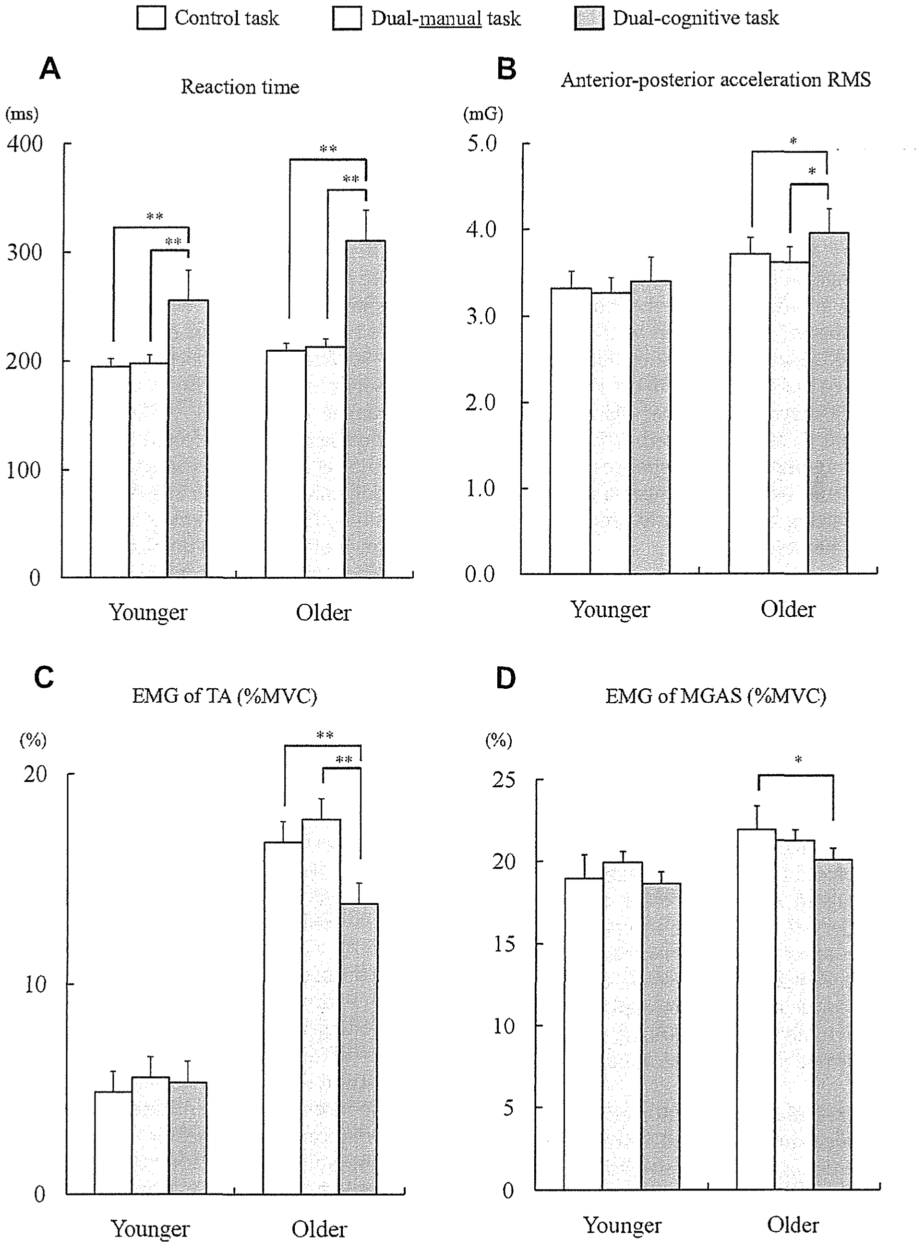

Fig. 2. Group means and standard errors in each task condition for younger adults ($n = 30$) and older adults ($n = 27$). *$p < 0.05$; **$p < 0.01$; the Bonferroni *post hoc* test was used to test the significance of differences between task conditions. Error bars represent one standard error. EMG = electromyographic; MGAS = medial gastrocnemius; MVC = maximum isometric voluntary contraction; RMS = root mean square; TA = tibialis anterior.

two category fluency trials selected randomly from animals, vegetables, countries, and Japanese prefectures, and the score in each trial counted as the total number of correct items named within 40 seconds) completed immediately after the dual-cognitive task in older adults was 29.7 (11.5) (total number of correct answers named within 80 seconds, mean 3.7 words per 10 seconds). Our sample of older adults thus exhibited similar category fluency scores to those reported in previous studies, although we used four categories (animals, vegetables, countries, and Japanese prefectures). The results indicated that the older adults in our study were able to focus despite the cognitive demand in the RT measurement period in the dual-cognitive task condition. However, we found that older adults named significantly fewer items than younger adults, and exhibited a significant decrease in lower muscle activity and an increase in anterior–posterior trunk acceleration in the dual-cognitive task. This pattern was not shown by younger adults. These results suggest that performance of a dual-cognitive task has a greater influence on postural control in older compared to younger adults.

Some limitations of this study should be noted. Although we confirmed that all older participants exhibited normal general cognitive functioning (less than one error on the MSQ), we did not perform other standardized cognitive tests to examine the influence of cognitive functioning on the dual-task performance. In addition, there was no quantitative measure of the cognitive demand associated with the dual-cognitive task condition. In the dual-cognitive task condition, participants were instructed to think of as many examples as possible in a particular category in the recording period and then name them immediately after the recording period finished. However, the number of immediate recall words did not necessarily reflect an increase in cognitive demand in the dual-cognitive task condition. In addition, 77.8% of our older sample exercised three times per week and exhibited higher levels of physical activity than our younger sample and general aged populations. Thus, it is unclear whether our findings can be applied to elderly people in general.

In conclusion, our findings indicate that cognitive task performance has a greater influence on postural control in older compared to younger adults. Although both younger and older adults exhibited longer RTs under the dual-cognitive compared to the control and dual-manual task conditions, we found a significant effect of the group × task condition interaction on RT. In addition, we found age-related differences in the influence of cognitive task performance on postural sway and muscle activity. A significant decrease in lower-limb muscle activity and an increase in anterior–posterior trunk acceleration under dual-cognitive task conditions were exhibited by older adults, but not by younger adults. Overall, we found that increasing attentional demand by implementing a cognitive task concomitant to a balance task had a greater influence on postural control in older compared to younger adults.

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特集 高齢者における健康増進

Seminar
9．認知症予防と健康増進

島田　裕之

KEY WORD
- 認知症
- 非薬物療法
- 運動
- 認知的活動
- 社会的ネットワーク

SUMMARY

■認知症は，今後の高齢者数の増大に伴い，より大きな問題となる．特に，アジアにおける認知症者の急激な増大に対応するためのシステムづくりが急がれている．認知症の予防のためには，身体活動や認知的活動が有効である可能性が示されつつあり，高齢者の活動的なライフスタイルの確立が重要な課題といえる．活動性の向上を目的とした社会的ネットワークを構築し，高齢者の社会参加を促進することが，継続的な認知症予防のための取り組みを実現するために必要であろう．

認知症の危険因子

今後数十年間の間に世界の平均年齢は上昇すると予想され，経済協力開発機構加盟国の年齢の中央値は，2010年の37.9歳から2030年には42.8歳に上昇する．日本は最も年齢の中央値が高く，2010年が45歳で2030年には52歳まで向上すると予想されている．高齢者数の増加とともに進む生産人口の減少は，抜本的な社会保障の見直しを余儀なくし，特に高齢者に対する社会保障制度改革が急がれている．人口の高齢化は疾病構造の変化を招き，加齢とともに顕在化する老年症候群の予防と改善が，適正な社会保障費を維持するために大きな課題となるだろう．

とりわけ認知症は加齢とともに増加し，80歳代から急激な有病率の上昇が認められ，90歳以上では地域にかかわらず30％以上の高齢者が認知症を有すると推定されている（図1上）1)．特にアジアにおける高齢者数の増大は，今後40年間において認知症者の著しい増大を迎えると予想されている（図1下）1)．日本における認知症の有病率は，全国で460万人を超えると推定され，これは全高齢者の15％に達し，軽度認知障害を有する高齢者を含めると，28％の高齢者が認知症，あるいはその予備軍であると考えられている．

認知症の主要な原因疾患であるアルツハイマー病の危険因子は，加齢の過程に伴い出現，変化，あるいは重畳し，その結果，高齢期における脳の機能的予備力を低下させる原因となる．この20年間に行動・社会科学的側面から，アルツハイマー病および認知症の危険因子が多数報告され，一定の見解がまとまりつつある．2004年に報告されたFratiglioniらのレビュー2)を参考に，認知症の危険因子と保護因子をまとめると図2のようになる．若年期においては，遺伝的あるいは社会・経済的な危険因子が存在し，教育を受ける機会が減少すると認知的予備力を十分蓄えることができないことなどが，将来の認知症の発症に関連すると考えられている．成人期においては，高血圧，脂質異常，糖尿病などの生活習慣に関連した危険因子が現れる．これらは脳血管疾患のみではなくアルツハイマー

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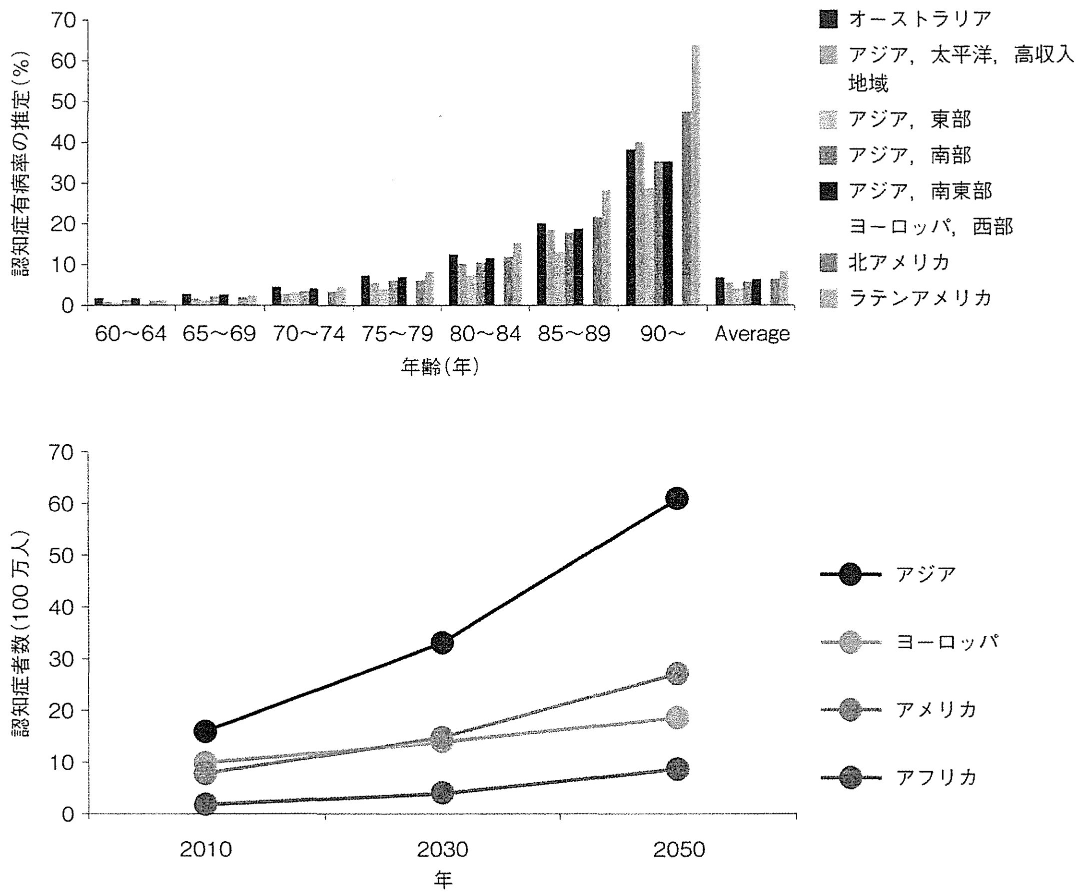

図１　認知症の推定有病率と人数の推移(文献１より作図)

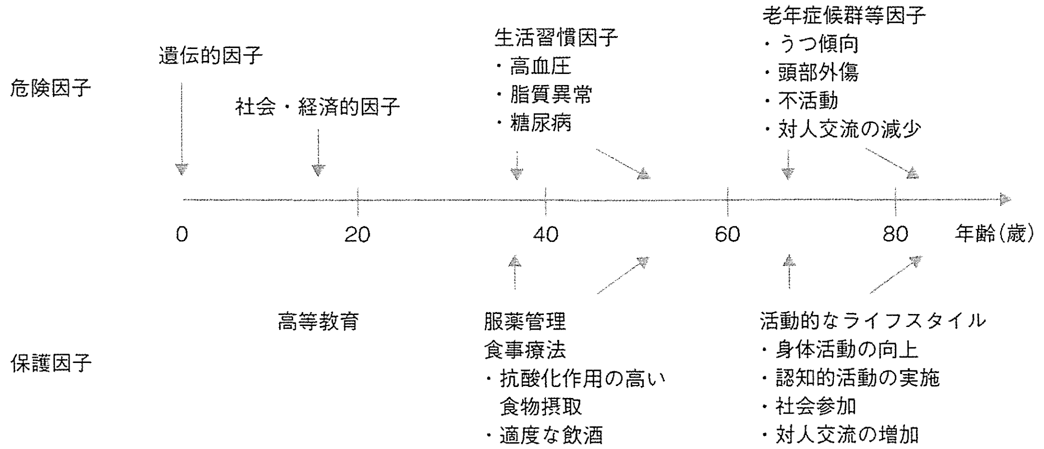

図２　認知症の危険因子と保護因子(文献２を参考に作図)

病の危険因子でもあり，将来の認知症を予防するためには，服薬管理と食事療法3)を実践することが重要な課題となる．高齢期になると，老年症候群と呼ばれるうつ傾向，転倒による頭部外傷や不活動に伴う対人交流の減少が起こり，これらが認知症の発症を促進する．そのため高齢期においては，定期的な運動や身体活動の促進4)，社会参加，知的活動，生産活動への参加5)，社会的ネットワークの向上6)などの活動的なライフスタイルの確立が，認知症予防のために重要であると考えられる．

高齢者に対する認知症予防対策

1．運動による認知症予防対策

高齢者を対象とした認知症の予防対策の中で，運動介入プログラムは比較的低コストで実施でき，短期間で効果を得ることが期待できることから，認知症予防事業の中核を果たす可能性をもっている．

われわれは，愛知県大府市在住の65歳以上の軽度認知障害(mild cognitive impairment：MCI)高齢者100名を対象として，運動介入の効果を検証するためのランダム化比較試験を実施した．研究に参加した100名の対象者を健忘型MCIで層化して，ランダムに健康講座群(対照群)と運動教室群(介入群)とに割り付けて1年間の介入を実施した．運動教室群の介入は，週2回，1回につき90分間，計80回実施した．教室は理学療法士1～2名，運動補助員4名で介入を実施した．運動プログラムには，先行研究において効果が認められている有酸素運動に加え，記憶や思考を賦活する運動課題を取り入れた．また健康行動を促進する目的で，加速度センサー付きの歩数計と記録手帳の配布，ホームエクササイズの指導，健康講座の開催などを定期的に行った．記憶と思考を賦活する運動課題には，例えばステップ運動としりとりを同時に行う課題，屋外を歩きながら俳句を考える課題，ラダー(はしご)トレーニングのように，決められたパターンに従って正確なステップを踏む課題などが含まれ，対象者に応じてその方法や難易度を変化させた(**図3**)．健康講座群には，介護や疾病予防に関する健康講座(60～90分間)を3回実施した．

介入開始から6カ月後の中間評価においては，週2回の運動を実施した群に処理速度や言語能力の向上が認められた．また，健忘型MCI高齢者(n＝50)に限定した分析では，全般的な認知機能(mini mental state examination)の低下抑制，記憶力の向上や，脳萎縮の進行抑制効果も認められた7)．これらの効果は1年後の最終評価においても継続した8)．

2．知的活動による認知症予防対策

米国のアインシュタイン加齢研究における，身体や認知的活動の実施状況と認知症発症の追跡調査によると，ボードゲーム，読書，楽器演奏といった認知的活動を実施していた高齢者は，実施していなかった高齢者と比較して認知症になる危険(ハザード比)が，それぞれ0.26(95%信頼区間0.17～0.57)，0.65(95%信頼区間0.43～0.97)，0.31(95%信頼区間0.11～0.90)であり，これらの活動が認知症抑制に効果をもち得る可能性が示された4)．認知トレーニングの効果を示したAdvanced Cognitive Training for Independent and Vital Elderly(ACTIVE) studyでは，2,832名の高齢者を対象として，記憶，推論，処理速度に着目した10回のトレーニングによる5年間の長期効果を検証した．その結果，記憶機能は記憶トレーニング群のみで効果が認められ，推論は推論のトレーニング群のみで効果を認めた．処理速度においては，推論と処理速度のトレーニング群で効果が認められ，トレーニング内容と向上する機能との対応関係が明らかとされた．また推論のトレーニングは，手段的日常生活活動の保持に有効であることが示された9)．

これらの先行研究から，少なくとも一部の認知機能については，非薬物療法が高齢者の認知機能にとって有益な効果をもつといえる．ただし，これらの取り組みが認知症の発症遅延にどの程度の効果をもつかは明らかとされていない．

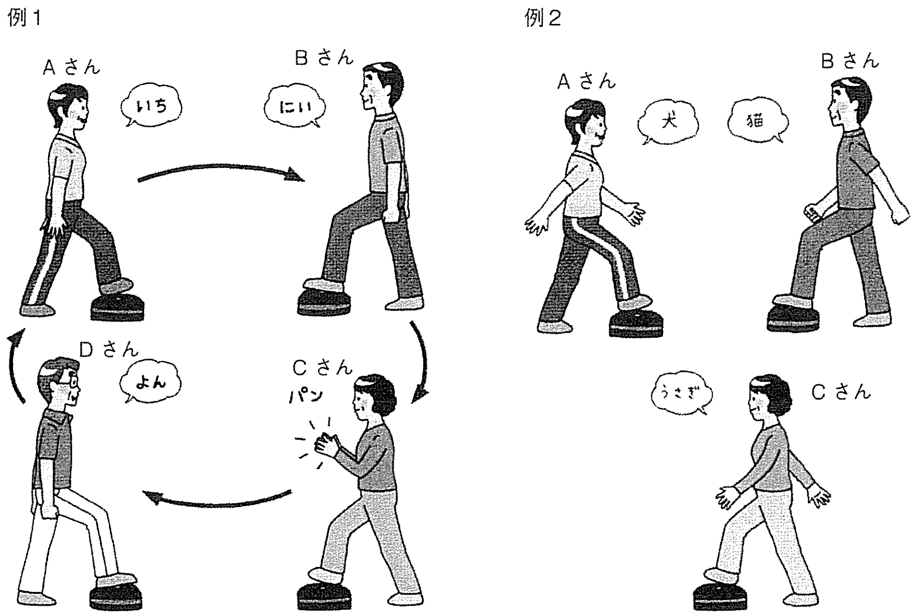

図３　脳の賦活を促す運動の例

例１：４人１組になって，順番に１人１つずつ数を声に出して数え，「３の倍数」のときは数を数えず，手をたたく．これを運動(ステップ運動や歩行)のリズムに合わせて実施する．

例２：３人１組で実施する．まず，順番(例：A→B→C)と３つの言葉(例：犬，猫，うさぎ)を決める．１番目の人(A)が３つの言葉の中うち１つをいう(例：犬)．２番目の人(B)が３つの言葉のうち残り２つのどちらかをいう(例：猫)．３番目の人(C)が残った１つをいう(例：うさぎ)．１周したら次は，最初に言葉をいう人をBさんとして，Cさん，Aさんの順に答えていく．その次は最初の言葉をCさんが選んでAさん，Bさんの順にいう．これを運動のリズムに合わせて繰り返す．

今後の研究

現在，認知症を予防できる明確な方法は明示されていないが，発症遅延を実現できる可能性のある介入として身体や認知的活動の促進が挙げられる．これらの活動を担保する社会的ネットワークを構築し，高齢者が社会参加できる場を創出していくことが，継続した認知症予防活動を実現するために必要とされる．現在，独立行政法人科学技術振興機構のコミュニティで創る新しい高齢社会のデザインのプロジェクトとして「認知症予防のためのコミュニティの創出と効果検証」を実施している．これは住民参加型認知症予防プログラムを地域に根付かせ，認知症予防効果を確かめる実証研究である[10]．ポピュレーションアプローチを含めた総合的な取り組みが，認知症の発症遅延に効果をもつものと期待している．

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