those who had 23 points or lower as having a possible cognitive impairment. A meta-analytic study for the accuracy of the MMSE for the detection of dementia (Mitchell, 2009) reported that the sensitivity and specificity were 79.8% and 81.3% in memory clinic settings, respectively, and that the sensitivity and specificity were 85.1% and 85.5% in non-clinical community settings, respectively. This indicates that the MMSE alone has modest accuracy for dementia diagnosis. As dementia diagnosis was not conducted by a specialist in our study, we cannot exclude the possibility that potential cases of dementia, who generally have poor survival rates (Dewey and Saz, 2001), may have been accidentally included in the group exhibiting a mild deficit in global cognition.

The second possible reason is that individuals who exhibit a mild deficit in global cognition may represent individuals with *mild cognitive impairment* (MCI) (Petersen *et al.*, 2001). Because individuals with MCI are prone to develop dementia (Kluger *et al.*, 1999), they may also be more likely to have a shorter lifespan. In addition, recent studies have demonstrated that individuals with MCI *per se* are more likely to have a shorter lifespan (Guehne *et al.*, 2006).

The third possible reason is physical health status. Cognitive performance among older adults is prone to be affected by physical health status (Tombaugh and McIntyre, 1992), such as functional disability, hearing loss, and chronic disease, which are all closely related to mortality (Korten *et al.*, 1999; Ostbye *et al.*, 1999; Kattainen *et al.*, 2004; Spiers *et al.*, 2005; Takata *et al.*, 2007; Lee *et al.*, 2008). Thus, individuals who exhibited a mild deficit in global cognition (MMSE scores of 24–27) may be likely to have poor physical health, and consequently, they may be more likely to have shorter lives as well. However, because we conducted a multivariate analysis, adjusted for such confounders (including, IADL, sensory function, and chronic disease), to examine the independent associations between cognition and mortality, this possibility is unlikely.

The fourth possible reason may be related to *health literacy*. Individuals who exhibit a mild deficit in global cognition may be less likely in their everyday life to seek appropriate medical care and health information to promote and maintain good health. Thus, they may tend to have a shorter lifespan, especially among older adults. Recent public health studies have focused on health literacy, which are skills that determine the motivation and ability of individuals to gain access to, understand, and use health information (Nutbeam, 1998). Health literacy was reportedly positively associated with cognitive function among older adults (McDougall *et al.*, 2012). In addition, older adults who have low cognitive function were less likely to take part in health surveys (Launer *et al.*, 1994) and checkups (Yoshida *et al.*, 2008) conducted in the community, suggesting that they are less likely to be motivated to keep fit. Therefore, it is possible that because of poor health literacy, individuals who exhibit a mild deficit in global cognition may be more likely to have a shorter lifespan.

The MMSE subscale scores including *time orientation, place orientation, calculation, reverse spelling, delayed recall, repeating a sentence,* and *copying figures* were significantly and independently associated with mortality, suggesting that these subscales individually can predict early death among older adults. The associations of the MMSE subscales *place orientation, calculation,* and *delayed recall* with mortality remained statistically significant after excluding subjects with possible cognitive impairment, defined by a cut-off MMSE score of 23 (Tombaugh and McIntyre, 1992). This finding suggests that these items predict mortality independently of cognitive impairment. In contrast, the associations of the subscales *time orientation, reverse spelling, repeating a sentence,* and *copying figures* with mortality diminished when subjects who had possible cognitive impairment were excluded from the analyses. These findings suggest that the associations between these four tasks and mortality are significantly affected by cognitive impairment. That is, performance in the four tasks may predict mortality among older adults, but apparently, only in combination with cognitive impairment. As mentioned earlier, because we did not conduct dementia diagnosis at baseline in this study, we cannot completely exclude the influence of possible cases of dementia. Therefore, our preceding interpretations need to be further investigated.

The generalization of our findings may also be limited for two reasons: First, the representativeness of the sample in this study may have been restricted. The participation rate at baseline was relatively low (43.2% participation) because we acquired the data by administering mass health checkups. Therefore, participants in our study may differ in health characteristics from non-participants because of self-selection bias (Iwasa *et al.*, 2007). Second, the relationship between cognitive performance on the MMSE items and mortality found in this study might differ from those in Western countries. Although the validity of the Japanese version of the MMSE has already been confirmed and its mean scores are remarkably similar to those of the Westerners (Ishizaki *et al.*, 1998), a recent study pointed out differences in performance on subscales of the MMSE between Japanese and a US cohort

(Dodge *et al.*, 2009). We therefore should attend to these previous findings when considering the generalizability of our findings.

Conclusions

In this study, we examined the relationship between cognitive performance and all-cause mortality among community-dwelling older individuals in Japan. Our findings indicated that global cognition (assessed using the MMSE) predicted mortality after adjusting for potential confounders. Among the MMSE subscales, *place orientation*, *calculation*, and *delayed recall* were significantly and independently associated with mortality. Given that the MMSE is relatively easy to administer, it could be of value during annual health checkups and in primary care settings to detect risk of early death in the community older population. Our results may thus help to facilitate the development of longevity-promoting strategies, and they underscore the importance of early detection and treatment of cognitive decline in older adults. Future research using a longer continuous follow-up survey would be of value to elucidate the relationship between cognition and mortality more clearly, with accompanying data regarding cause of death and professional diagnosis of possible dementia.

Conflicts of interest

None declared.

Author contributions

HI engaged in study conceptualization, data collection, data analysis, and interpretation of results, in addition to writing and editing the manuscript. YY, TS, HK, and HY contributed to data collection, interpretation of results, and discussions on the manuscript. IK contributed to interpretation of results and discussions on the manuscript.

Key points

- This study found the longitudinal relationship between global cognition (measured by the MMSE) and all-cause mortality among community older adults.
- Among the MMSE subscales, *place orientation*, *calculation*, and *delayed recall* were also associated with mortality.

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ORIGINAL ARTICLE: EPIDEMIOLOGY, CLINICAL PRACTICE AND HEALTH

Evaluation of multidimensional neurocognitive function using a tablet personal computer: Test–retest reliability and validity in community-dwelling older adults

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Aim: This study sought to confirm the test–retest reliability and validity of the National Center for Geriatrics and Gerontology functional assessment tool (NCGG-FAT), a newly developed assessment of multidimensional neurocognitive function using a tablet personal computer (PC).

Methods: This study included 20 community-dwelling older adults (9 females, aged 65–81 years). Participants were administered the NCGG-FAT twice, separated by approximately 30 days to determine test–retest reliability. To test the validity of the measure, participants underwent established neurocognitive measurements, including memory, attention, executive function, processing speed and visuospatial function within a week from the first administration of the NCGG-FAT.

Results: Test–retest reliability was in an acceptable range for each component of the NCGG-FAT, with intraclass correlation coefficients ranging from 0.764 to 0.942. Each task in the NCGG-FAT showed a moderate to high correlation with scores on widely-used conventional neurocognitive tests ($r = 0.496$ to 0.842).

Conclusion: We found that the NCGG-FAT using a tablet PC was reliable in a sample of community-dwelling older adults. The NCGG-FAT might be useful for cognitive screening in population-based samples and outcomes, enabling assessment of the effects of intervention on multidimensional cognitive function among older adults. **Geriatr Gerontol Int 2013; 13: 860–866.**

Keywords: aged-population, assessment, cognitive functioning, screening.

Introduction

Declining cognitive function is one of the most important health problems in an aging population, and older adults showing cognitive decline are at increased risk for progressing to mild cognitive impairment (MCI) and dementia. MCI is a heterogeneous condition associated with the transitional phase between normal cognitive aging and dementia,[1,2] and might be the optimum stage at which to intervene with preventive therapies.[3,4]

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The prevalence of MCI in older populations has been estimated in previous community-based epidemiological studies, and the reported prevalence estimations of MCI have varied widely.[5] For instance, the reported prevalence of MCI in adults aged 70 years and older ranges from 16% to 39%,[6,7] and the reported progression rates to dementia and Alzheimer's disease (AD) for individuals with MCI vary from 6% to 25% per year, depending on the criteria for MCI.[8] A reliable quantitative tool for assessing neuropsychological function is required for early and accurate screening of MCI.

Variable neurocognitive tests are used to determine cognitive decline in a clinical community-based setting. Most of these measures for assessment of multidimensional cognitive functions among older adults need to be administered by well-trained assessors, such as clinicians, clinical psychologists and speech or occupational therapists. However, it is difficult to manage

large numbers of well-trained assessors to assess multidimensional cognitive functions in clinical community-based settings with large populations. As such, developing a valid tool for assessing multidimensional neurocognitive function that does not require a specialized assessor is important in countries with large populations of older adults, because the capacity to administer specific assessments with specialized assessors is limited for large samples.

We developed the National Center for Geriatrics and Gerontology functional assessment tool (NCGG-FAT), which includes measurements for evaluating multidimensional neurocognitive function using a tablet personal computer (PC). The purpose of the present study was to confirm the test–retest reliability and validity of the NCGG-FAT among Japanese adults aged 65 years or older. If the test–retest reliability and validity of our assessment system for evaluating multidimensional neurocognitive function using a tablet PC can be confirmed, the system could be useful for cognitive screening in large populations of older adults.

Methods

Participants

A total of 20 older adults (nine females), aged 65–81 years, and independently in a community, participated in the present study, after giving written informed consent. None of the participants had a history of major psychiatric illness (e.g., schizophrenia or bipolar disorder), other serious neurological or musculoskeletal diagnoses, or clinical depression. All participants showed general cognitive functioning (Mini-Mental State Examination[9] scores between 24 and 30) and did not meet the definition of MCI using the Petersen criteria.[10] Although seven participants reported subjective memory complaints, none of them showed objectively determined memory impairment, as assessed by the education-adjusted score on the Wechsler Memory Scale-Revised (WMS-R) Logical Memory II.[11] Table 1 shows a summary of participant characteristics in the present study. The study protocol was approved by the ethics committee of the National Center for Geriatrics and Gerontology.

Protocol

To examine test–retest reliability, participants were administered the computerized multidimensional neurocognitive task battery on two separate occasions, separated by approximately 30 days to determine test–retest reliability of the tablet version of the multidimensional neurocognitive task battery. To examine validity, participants underwent comprehensive neurocognitive evaluation, including measures of memory, attention, executive function, processing speed and visuospatial function within a week after the first administration of the computerized multidimensional neurocognitive task battery. The neurocognitive assessment had a standardized format, and was administered by licensed and well-trained clinical speech therapists.

Table 1 Summary of participant characteristics

Characteristics	Value
Mean age (years)	71.6 ± 4.6
Male, *n* (%)	11 (55.0)
Mean education (years)	10.8 ± 1.9
Current diseases/conditions, *n* (%)	
Heart disease	4 (20.0)
Diabetes	2 (10.0)
Cancer	3 (15.0)
Hypertension	9 (45.0)
Fractures (after age 60 years)	1 (5.0)
Cognitive status	
General cognitive function	
MMSE (score)	27.5 ± 2.0
Memory	
WMS-R Logical Memory-I, score	20.4 ± 7.4
WMS-R Logical Memory-II, score	15.9 ± 6.8
Attention/executive function	
Written TMT-A (s)	97.9 ± 19.7
Written TMT-B (s)	130.4 ± 29.7
Processing speed	
Digit Symbol-Coding subtest of the WAIS-III, score	62.1 ± 16.3
Visuospatial function	
Block Design subtest of the WAIS-III, score	34.8 ± 8.2

Values are expressed as mean ± SD. MMSE, Mini-Mental State Examination; TMT-A, Trail Making Test-part A; TMT-B, Trail Making Test-part B; WAIS-III, Wechsler Adult Intelligence Scale III; WMS-R, Wechsler Memory Scale-Revised.

Component of the NCGG-FAT

The computerized multidimensional neurocognitive task battery was presented on an i-Pad (Apple, Cupertino, CA, USA) with a 9.7-inch touch display. The task instructions and questions were presented with a letter size of at least 1.0 × 1.0 cm^2 on the display. This battery consists of eight tasks to assess memory (task 1, -2, -3 and -4), attention and executive function (task 5 and -6), processing speed (task 7) and visuospatial function (task 8). The participants were given approximately 20–30 min to complete the battery, which consisted of following eight initial tasks. An operator supported each participant to set up the tablet PC, understand the task protocols and record their data. Participants only needed to touch the display to complete tasks using a digital pen.

Task 1: Story memory-I (immediate recognition) and task 2: story memory-II (delayed recognition)

In task 1 and task 2, the participants heard a short story (approximately 1 min in length) through an auditory system using headphones. They were instructed to remember the details of a story, then immediately select the correct answer that described the details of the story from four choices (Story memory-I), then again after 20–30 min (Story memory-II). All 10 questions in each task were shown and we calculated the total number of correct answers.

Task 3: Word list memory-I (immediate recognition) and task 4: word list memory-II (delayed recall)

Task 3 and task 4 involved immediate recognition and delayed recall of a 10-word target list. In task 3, which tested word list memory, participants were instructed to memorize 10 words that were shown on the tablet PC. In this task, each of 10-target words was shown for 2 s. A total of 30 words, including 10 target and 20 distracter words was then shown, and participants were asked to choose the 10 target words immediately (Word list memory-I). This was repeated for three trials. The average number of correct answers was calculated with a score range of 0 to 10. Additionally, participants were instructed to recall (write down) the 10 target words after approximately 20 min (Word list memory-II). We calculated the total number of recalled target words. One point was given for each correctly recalled word completed within 60 s for a maximum score of 10.

Task 5: The tablet version of the Trail Making Test-part A and task 6: the tablet version of TMT-part B

The tablet version of the Trail Making Test (TMT) consists of part A and B, as well as the original written version of TMT.[12] In the tablet version of TMT-A, participants were required to touch the target numbers shown randomly on the panel as rapidly as possible, in consecutive order (1–15). In the tablet version of TMT-B, participants must touch target numbers or letters alternately between consecutive numbers and letters (Japanese Kana characters). We recorded the time (in seconds) taken to complete each task, within a maximum period of 90 s.

Task 7: The tablet version of the Symbol Digit Substitution Task

In the tablet version of the Symbol Digit Substitution Task (SDST), nine pairs of numbers and symbols were provided at the top of the display. A target symbol was shown at the center of the display. Participants then chose a number corresponding to a target symbol at the bottom of the display as rapidly as possible (Fig. 1). The score was the number of correct numbers chosen within 90 s. One point was given for each correctly chosen number completed within the time limit.

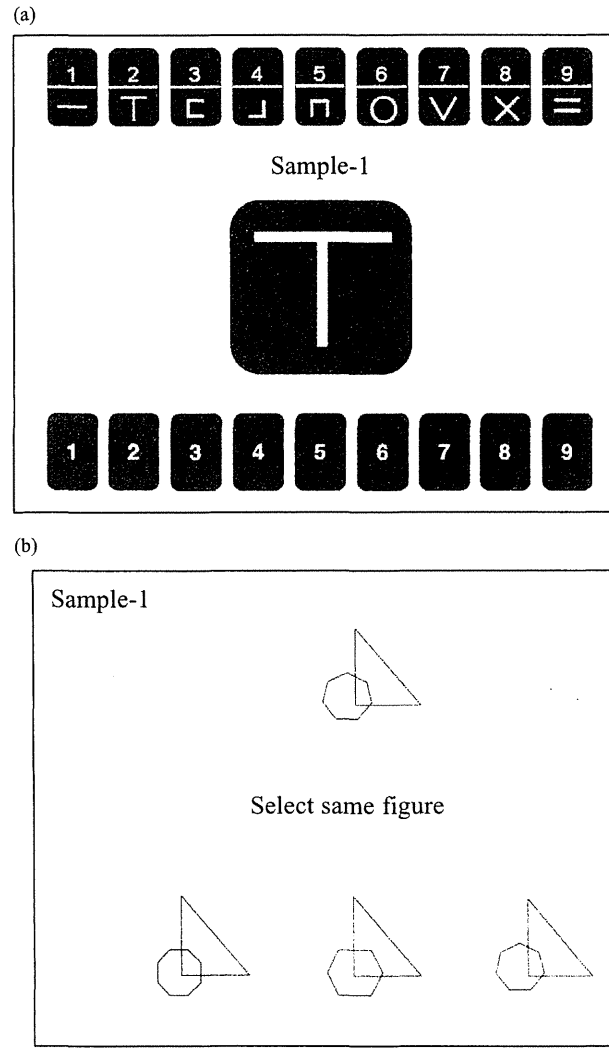

Figure 1 Samples of the representative tests on the tablet personal computer. (a) Task 7, the tablet version of the Symbol Digit Substitution Task. (b) Task 8, figure selection. The task instructions and questions in the original version of the National Center for Geriatrics and Gerontology functional assessment tool were presented in Japanese.

Task 8: Figure selection

In the figure selection task, participants were required to select the same figure from three choices shown at the bottom of the display. This task consists of nine questions and one point is given for each correctly selected figure (Fig. 1). The time limit for each question was within 15 s. We calculated the total number of correct answers (0–9).

Assessment instruments for validity

The conventional neurocognitive tests included the WMS-R Logical Memory, the Word Recognition subtest of the Alzheimer's Disease Assessment Scale-cognitive subscale (ADAS-cog), the TMT, the Digit Symbol-Coding subtest of the Wechsler Adult Intelligence Scale (WAIS) III and the Block Design subtest of the WAIS-III to examine the validity of the NSGG-FAT. These neurocognitive tests were administered by licensed and well-trained clinical speech therapists.

WMS-R Logical Memory

WMS-R Logical Memory was used to assess the validity of story memory tasks (task 1 and 2) in the tablet PC version of multidimensional neurocognitive tests. In the WMS-R Logical Memory, two short stories (story A and B) were read aloud to the participant, who was instructed to recall details of the stories immediately (Logical Memory I) and after 30 min (Logical Memory II).[11] We calculated the total score (i.e. sum score of story A and B) of WMS-R in the Logical Memory I and II tasks.

Word recognition subtest of ADAS-cog

ADAS-cog consists of 11 tasks including the assessment of memory, comprehension, orientation in time and place, praxis, and attention.[13] We used the Word Recognition subtest of ADAS-cog as assessment measures for validity of word list memory tasks (task 3 and 4) in the tablet PC version of multidimensional neurocognitive tests. In the Word Recognition subtest of ADAS-cog, participants read out 12 words. They were then asked to identify 12 target words that were mixed with 12 distracter words. This process was repeated for three trials, with new distracters for each trial. The average error score was calculated with an error score range of 0–12. In addition, participants were instructed to recall the 12 target words after 30 min. We calculated the total number of recalled target words. One point was given for each correctly recalled word completed within 90 s for a maximum score of 12.

TMT

We used the TMT[12] to assess attention and executive function. The TMT consists of two parts, A and B. Part A requires the participant to draw a line as rapidly as possible, joining consecutive numbers (1–25). In Part B, the participant was required to draw a line alternately between consecutive numbers and letters (1-A-2-B-12-L). In the Japanese version of the TMT-B, letters from the Roman alphabet are exchanged for Kana characters. We recorded the amount of time (in seconds) it took to complete each task. These tests evaluated the validity of the tablet version of TMT-A and -B (task 5 and 6).

Digit Symbol-Coding subtest of the WAIS-III

Participants were measured processing speed by the Digit Symbol-Coding subtest of the WAIS-III.[14] In the Digit Symbol-Coding subtest, participants copy symbols that are paired with numbers. Using the key provided at the top of the exercise form, the participant draws the symbol under the corresponding number. The score, which has been found to decline with old age,[15] is the number of correct symbols drawn within 120 s. One point is given for each correctly drawn symbol completed within the time limit for a maximum score of 133. Higher scores indicate better processing speed. This test evaluated the validity of the tablet version of the SDST (task 7).

Block Design subtest of the WAIS-III

The Block Design subtest of the WAIS-III[16] was used to assess visuospatial function and examine the validity of the figure selection test using a tablet PC (task 8). In the Block Design task, participants were presented with increasingly difficult patterns consisting of blocks with red, white, and red and white sides, then asked to arrange the same pattern using blocks that had all white sides, all red sides, and red and white sides. The number of correctly arranged blocks was used as a performance variable. The maximum score for this subtest was 68. A previous study in Sweden showed the reliability of impaired glucose metabolism and a cognitive measure of visuospatial function in predicting progression from MCI to AD.[17]

Data analysis

Means, standard deviations and proportions were calculated to describe the samples, and provide summary information of the measures used. A P-value of <0.05 was considered to show statistical significance. All data entry and analysis were carried out using SPSS Windows 19.0 (SPSS, Chicago, IL, USA). The test–retest reliability of each component of the NCGG-FAT was assessed by intraclass correlation coefficient (ICC) with a 95% confidence interval (CI). For the validity of each neurocognitive task of the NCGG-FAT, we used Pearson's correlation coefficients to test relationships between each score of the NCGG-FAT items and each score of the conventional neurocognitive tests.

Results

The score of each component of the NCGG-FAT for the entire sample are presented in Table 2. Table 3

Table 2 Each content score for the entire sample ($n = 20$)

Contents	First administration				Second administration		
	Scale range	Mean	SD	Observed range	Mean	SD	Observed range
Memory							
Story memory-I (immediately) score	0–10	7.50	1.47	5–10	7.95	1.36	5–10
Story memory-II (delay) score	0–10	7.35	1.63	4–10	7.85	1.50	4–10
Word recognition (immediately) score	0–10	7.72	1.01	5.7–9.0	8.22	0.97	6.3–9.7
Word recall (delay) score	0–10	3.85	1.60	1–6	4.70	1.81	1–7
Attention/Executive function							
Tablet version of TMT-A (s)	0–90	19.80	5.48	13–32	19.25	3.96	12–27
Tablet version of TMT-B (s)	0–90	40.40	16.30	19–81	37.50	15.08	17–80
Processing speed							
Tablet version of SDST score	0–90	40.60	9.23	23–55	43.45	8.11	27–57
Visuospatial function							
Figure selection score	0–9	6.35	1.35	4–9	5.90	1.21	4–9

SDST, Symbol Digit Substitution Task; TMT, Trail Making Test.

Table 3 Pearson's correlation coefficients between each component and assessment instruments for validity and intraclass correlation coefficients of each measurement

Contents	Validity		Test-retest reliability		
	r	P value	ICC	95%IC	P value
Memory					
Story memory-I (immediately)	0.583	0.007	0.764	0.415, 0.906	0.001
Story memory-II (delay)	0.496	0.026	0.809	0.526, 0.924	<0.001
Word recognition (immediately)	0.550	0.012	0.793	0.486, 0.917	<0.001
Word recall (delay)	0.565	0.009	0.788	0.475, 0.916	0.001
Attention/executive function					
Tablet version of TMT-A	0.611	0.004	0.837	0.596, 0.935	<0.001
Tablet version of TMT-B	0.550	0.012	0.850	0.628, 0.940	<0.001
Processing speed					
Tablet version of SDST	0.842	<0.001	0.942	0.857, 0.977	<0.001
Visuospatial function					
Figure selection	0.723	<0.001	0.815	0.540, 0.926	<0.001

The following assessment instruments were used to test validity: the Wechsler Memory Scale-Revised (WMS-R) Logical Memory-I for the tablet version of story memory-I (immediately), the WMS–R Logical Memory-II for the tablet version of story memory-II (delay), the subtest of ADAS-cog (immediately recognition) for the tablet version of word recognition (immediately), the subtest of Alzheimer's Disease Assessment Scale-cognitive (ADAS-cog; delay recall, modified) for the tablet version of Word recall (delay), the written Trail Making Test-part A (TMT-A) for the tablet version of TMT-A, the written Trail Making Test-part B (TMT-B) for the tablet version of TMT-B, the Digit Symbol-Coding subtest of the Wechsler Adult Intelligence (WAIS)-III for the tablet version of SDST, and the Block Design subtest of the WAIS-III for the tablet version of Figure selection.

shows the test–retest reliability and validity of each component of the NCGG-FAT. For the test–retest reliability, all of the ICC for each task component were higher than 0.750, and those of eight task components (story memory-I, story memory-II, word recognition, word recall, tablet version of TMT-A, TMT-B, SDST, and figure selection) were 0.764, 0.809, 0.793, 0.788, 0.837, 0.850, 0.942 and 0.815, respectively. Thus, the test–retest reliability of each component of the developed multidimensional neurocognitive task battery were in an acceptable range.[18] Pearson's correlation coefficients were calculated to examine the validity of each component of the NCGG-FAT. In the validity assessment, we examined the WMS-R Logical Memory-I and -II, the Word Recognition subtest of the ADAS-cog, the TMT-A and -B, and the Digit Symbol-Coding subtest and the Block Design sub-test of the WAIS-III, which are used widely in clinical settings internationally.

Pearson's correlation coefficients between those widely used clinical neurocognitive tests and each task component of the NCGG-FAT ranged from 0.496 to 0.842, and the following relationships were statistically significant: story memory-I and the WMS-R Logical Memory-I ($r = 0.583$, $P = 0.007$), story memory-II and the WMS-R Logical Memory-II ($r = 0.496$, $P = 0.026$), word recognition and the Word Recognition subtest of the ADAS-cog ($r = 0.550$, $P = 0.012$), and word recall and the recall version of the Word Recognition subtest of the ADAS-cog ($r = 0.565$, $P = 0.009$), the tablet version of TMT-A and the original version of TMT-A ($r = 0.611$, $P = 0.004$), the tablet version of TMT-B and the original version of TMT-B ($r = 0.550$, $P = 0.012$), the tablet version of SDST and the Digit Symbol-Coding subtest ($r = 0.842$, $P < 0.001$), and figure selection and the Block Design subtest ($r = 0.723$, $P < 0.001$).

Discussion

The current study investigated the test–retest reliability and validity of our newly multidimensional neurocognitive task battery using a tablet PC. High test–retest reliability was found for each task component of the NCGG-FAT (the ICC ranged from 0.764 to 0.942). The results showed moderate and high validity values for all task components of the NCGG-FAT.

Older adults with memory impairment are at an increased risk for progression to dementia. Previous community-based longitudinal studies have shown that amnestic MCI is likely to convert to AD.[19,20] In contrast, non-amnestic MCI patients without memory impairment but with cognitive decline in other domains are expected to represent the early stages of non-AD dementia.[21] Therefore, measures for multidimensional neurocognitive function were required to examine the risk of developing dementia earlier among older populations. The NCGG-FAT consists of multiple tasks including memory, attention, executive function, processing speed and visuospatial function. We evaluated the validity of each task component using measurements that are commonly used in clinical settings. In the results of the present study, moderate to high correlations were shown between the NCGG-FAT items and conventional neurocognitive measures ($r = 0.496$ to 0.842), and the results support the external validity of the NCGG-FAT.

The Japanese public long-term care insurance system was launched in April 2000 in response to the growing elderly population.[22] The rapid aging of the population has also increased the demand for formal long-term care services in Japan, and it is important to prevent conditions related to age-related physical and cognitive decline, such as frailty and MCI. The current results confirmed that the NCGG-FAT, which includes multidimensional cognitive domains, showed good test–retest reliability (ICC = 0.764 to 0.942), and moderate to high external validity ($r = 0.496$ to 0.842). The NCGG-FAT has several advantages over conventional neurocognitive assessments. First, the NCGG-FAT is easily administered using a tablet PC with instructions shown on the display. Therefore, it is not necessary for assessors to have a thorough knowledge of neurocognitive measures, and the particular assessor des not strongly affect the results. The simplicity and portability of the application permits assessment in the community and non-clinical settings by non-specialized persons. Participants were able to complete the NCGG-FAT battery in approximately 20–30 min. Administering an equivalent range of traditional psychiatric tests, including measures of memory, attention and executive function, processing speed, and visuospatial function using the original version would require twice this amount of time. The NCGG-FAT might be useful for cognitive screening in a population-based sample to assess the risk of cognitive decline on multidimensional functions. In addition, data collected from a large population using tablet PCs can be aggregated quickly, as the data is digital rather than paper-based.

A number of limitations were identified in the present study. Although the tablet version of the neurocognitive task battery was found to show good test–retest reliability and validity, it was not found to show predictive validity. This suggests that an operator might be required to support older participants in using a tablet PC, especially those showing cognitive decline. Importantly, our sample included community-dwelling older adults without cognitive impairment and did not include participants meeting the criteria for dementia and MCI. In addition, although story memory scores in the NCGG-FAT were significantly correlated with WMS-R Logical Memory scores, these two tasks differ in the terms of retrieval. The story memory scale in the NCGG-FAT is a recognition task, whereas WMS-R Logical Memory is a recall task. Therefore, studies using the NCGG-FAT require experimental design and cautious interpreting of results. Despite these limitations and the need for further research, our tool for assessing multidimensional neurocognitive function using a tablet PC appears to be helpful in evaluating cognitive decline among older adults in clinical settings.

In conclusion, the current results showed that the NCGG-FAT assessment for multidimensional neurocognitive function using a tablet PC was reliable and valid for a sample of community-dwelling older adults. The NCGG-FAT might be useful for cognitive screening in population-based samples and outcomes to assess intervention effects on multidimensional cognitive function among older adults.

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Disclosure statement

There are no financial and personal relationships with other people or organizations that may lead to a conflict of interest.

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Original Research Article

Cognitive Activities and Instrumental Activity of Daily Living in Older Adults with Mild Cognitive Impairment

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Key Words
Cognitive impairment · Dementia · Alzheimer's disease · Cognitive reserve

Abstract
Aims: This study aimed to identify differences in the implementation of cognitive activities and instrumental activities of daily living (IADLs) between healthy individuals and subjects with mild cognitive impairment (MCI). ***Methods:*** The study included 2,498 cognitively healthy subjects (mean age, 71.2 ± 5.1 years) and 809 MCI subjects (mean age, 71.8 ± 5.4 years). The subjects were interviewed regarding their participation in cognitive activities and the implementation of IADLs. ***Results:*** We found a significant association between participation in any cognitive activities ($p < 0.001$), using a bus or a train ($p < 0.001$), and MCI. After adjusting for covariates, cognitive activity of any type remained significantly associated with MCI ($p < 0.005$) but not with the implementation of IADLs. ***Conclusions:*** Our study revealed that greater participation in cognitive activity was associated with lower odds of MCI. Participation in cognitive activities may reflect differences between healthy and MCI subjects. To clarify the causal relationship between cognitive activities and MCI, further studies are required.

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Introduction

Alzheimer's disease (AD) is the most common cause of dementia. An estimated 33.9 million individuals worldwide have AD, and the prevalence is predicted to triple over the next 40 years [1, 2]. There is a lack of available treatments; therefore, research has focused on establishing strategies to prevent AD [1]. Mild cognitive impairment (MCI) is an early indication of cognitive disease and a crucial target for the prevention of AD [3, 4]. Focused modifiable risk factors for dementia and an active lifestyle, e.g., greater participation in a leisure activity involving physical and cognitive activity, play a potentially protective role against the progression from MCI to AD [1, 5].

A growing body of evidence suggests that participation in cognitive activities leads to a slower cognitive decline [6, 7] and reduces the risk of incident AD [6, 8] and dementia [9]. Engagement in cognitive activity, even in mid-life adults, is associated with a reduced risk of AD [10, 11]. Cognitive activity is generally regarded as a leisure activity [9] and contributes to an enhanced cognitive reserve, restricting cognitive decline and progression to dementia [12]. The cognitive reserve is thought to withstand the burden of the neuropathologic condition of AD and to maintain cognitive function [12]. In fact, a low degree of participation in cognitive activities is associated with the risk of amnestic MCI [13], while more frequent participation in leisure activities, especially intellectual ones, accelerates cognitive decline in patients with AD [14]. The role of these activities against the progression of AD may be varied and dependent on the disease course. Although cognitive activities have the potential to be related to MCI, few population-based studies with small samples have investigated the association between cognitive activities and MCI [13, 15]. As a result, our current understanding of the association between cognitive activity and MCI is insufficient.

Elderly activities range from activity in daily living (ADL) in order to live independently to complex activity such as instrumental activity of daily living (IADL). IADL is associated with the development of dementia [16, 17] as well as cognitive inactivity. Furthermore, deficits in IADL are characteristic of older adults with MCI [18–21]. However, the results are dependent on the measurement of IADL and therefore vary between different studies. Based on the Lawton and Brody IADL scales [22], MCI subjects were similar to subjects without MCI in the implementation of conventional IADL [18, 23]. However, the deficits in the other IADLs were more likely in subjects with MCI [19–21]. There is insufficient evidence regarding the specific activities associated with MCI.

The purpose of this study was to examine whether the implementation of cognitive activity and/or IADL was different between healthy and MCI subjects. We hypothesized that participation in cognitive activities and IADLs is lower in MCI subjects as compared to healthy older adults. To confirm this hypothesis, we conducted a cross-sectional study to examine differential associations of MCI with specific cognitive activities and IADL tasks.

Methods

Participants

Subjects eligible for this study were participants of a population-based cohort study (Obu Study of Health Promotion for the Elderly; OSHPE) that was conducted from August 2011 to February 2012. Participants aged ≥65 years at the time of examination and who lived in Obu were eligible for the OSHPE (n = 15,974). Prior to recruitment, 1,661 subjects were excluded because (a) they had participated in another study; (b) they were hospitalized or in residential care, or (c) they were certified as grade 3–5 cases and required support or care by the Japanese public long-term care insurance system. Recruitment was conducted via a mail sent

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to 14,313 individuals, and 5,104 of these individuals underwent a health check. In addition, to be included in our study, participants had to be independent with basic ADL, could not be certified as any grade needing support or care by the Japanese public long-term care insurance system and had to be cognitively healthy (i.e., without subjective and objective cognitive impairment) or have MCI. In total, 3,307 participants (cognitively healthy: n = 2,498, MCI: n = 809) were eligible for inclusion and participated in all assessments.

MCI was classified according to Petersen's criteria [3]. The criteria involve the following: (a) subjective memory complaint; (b) objective cognitive decline; (c) general cognitive health (Mini-Mental State Examination score >23 [24]); (d) independence in ADL, and (e) absence of clinical criteria for dementia. Objective cognitive decline was defined as a cognitive function 1.5 standard deviations below the reference threshold of any of the tests. Cognitive function was comprehensively assessed using the National Center for Geriatrics and Gerontology functional assessment tool (NCGG-FAT). NCGG-FAT contains cognitive tests, and measurement has been described in detail in a previous study [25]. The test consists of tasks to assess memory (story memory, word recognition, and word recall), attention, processing speed (symbol digit substitution task), and visuospatial cognition (figure selection). Cognitively healthy participants were defined as not having both subjective memory complaints and objective cognitive impairment. Informed consent was obtained from all participants before their inclusion in the study. The Ethics Committee of the NCGG approved the study protocol.

Cognitive Activities and IADL

Subjects were interviewed regarding participation in cognitive activities such as reading books or newspapers, using a personal computer, going to an unknown location with a map, and operating a video or DVD player. IADL was assessed using the following items: using a bus or a train, grocery shopping, management of finances, housekeeping, and telephone use. The items of cognitive activities were selected according to previous studies [6, 9, 26], and the domains of IADL were based on the Lawton and Brody IADL scales [22]. Subjects were asked whether they had performed each activity during the past month; responses were 'yes (did)' or 'no (did not)'. In addition, we totaled the number of activities for which each participant answered 'yes' for both cognitive activities and IADL.

Other Measures

Participants completed a questionnaire on medical conditions, current medications, and lifestyle habits. The medical questionnaire captured information on various diseases (hypertension, stroke, heart disease, diabetes mellitus, respiratory disease, and others) and medication use. Weight and height were measured, and BMI was calculated. The questionnaire also inquired about age, gender, educational history, smoking status, and alcohol consumption, and the Geriatric Depression Scale (GDS) score was measured [27]. Walking speed was measured as an indicator of physical performance. Participants were asked to walk on a straight, flat walkway 6.6 m in length 5 times faster than their usual walking speed. Walking time was measured over a 2.4-meter distance between marks at 2.1 and 4.5 m from the start of the walkway, and the mean walking speed (m/s) was calculated. The total amount of time spent walking in a day was assessed using a subscale of the International Physical Activity Questionnaire [28, 29].

Statistical Analysis

Medical history, lifestyle habits, and cognitive function measures were compared between healthy controls and MCI subjects using t tests and χ^2 tests where appropriate. Multiple logistic regression analysis was performed to explore independent associations between participation in cognitive activity or IADL ability and MCI, while controlling for potential

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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.

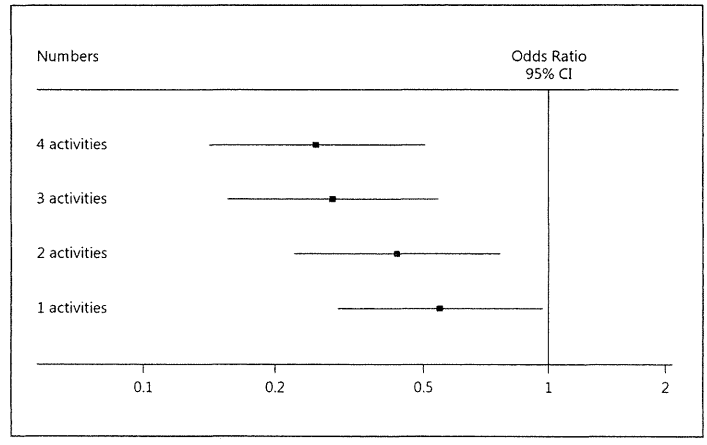

Fig. 1. OR of the number of cognitive activities and MCI. No participation was the reference category for any cognitive activity.

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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RESEARCH ARTICLE Open Access

Poor balance and lower gray matter volume predict falls in older adults with mild cognitive impairment

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Abstract

Background: The risk of falling is associated with cognitive dysfunction. Older adults with mild cognitive impairment (MCI) exhibit an accelerated reduction of brain volume, and face an increased risk of falling. The current study examined the relationship between baseline physical performance, baseline gray matter volume and falls during a 12-month follow-up period among community-dwelling older adults with MCI.

Methods: Forty-two older adults with MCI (75.6 years, 43% women) underwent structural magnetic resonance imaging and baseline physical performance assessment, including knee-extension strength, one-legged standing time, and walking speed with normal pace. 'Fallers' were defined as people who had one or more falls during the 12-month follow-up period.

Results: Of the 42 participants, 26.2% (n = 11) experienced at least one fall during the 12-month follow-up period. Fallers exhibited slower walking speed and shorter one-legged standing time compared with non-fallers (both $p < .01$). One-legged standing time (sec) (standardized odds ratio [95% confidence interval]: 0.89 [0.81, 0.98], $p = .02$) was associated with a significantly lower rate of falls during the 12-month follow-up after adjusting for age, sex, body mass index, and history of falling in the past year at baseline. Voxel-based morphometry was used to examine differences in baseline gray matter volume between fallers and non-fallers, revealing that fallers exhibited a significantly greater reduction in the bilateral middle frontal gyrus and superior frontal gyrus.

Conclusions: Poor balance predicts falls over 12 months, and baseline lower gray matter densities in the middle frontal gyrus and superior frontal gyrus were associated with falls in older adults with MCI. Maintaining physical function, especially balance, and brain structural changes through many sorts of prevention strategies in the early stage of cognitive decline may contribute to decreasing the risk of falls in older adults with MCI.

Background

Falls and fall-related injuries are a common healthcare problem, and represent important causes of morbidity and mortality in older populations. One-third of all community-dwelling adults age 65 years and older experience at least one fall annually [1]. Many distinct causes for falls in older people have been reported by a large number of studies [1-4]. Impaired physical function, particularly muscle weakness and problems with gait and balance, are the most important contributors to the risk of falling [5]. The ageing of the worldwide population in recent decades has resulted in an increasing number of older adults with cognitive decline [6], and cognitive impairment has also been found to increase the risk of falling [7-10]. As such, correctly identifying the risk factors for falling among older adults with cognitive impairment is an important research question. In addition, people with cognitive impairment recover less well after a fall than those without cognitive impairment [11]. Therefore, the falling may have negative impact on health in older people with cognitive

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