Relationship between cognitive function and balance in a community-dwelling population in Japan.
（日本地域住民における認知機能とバランスとの関連性）

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Abstract

Background: There has been no treatment found yet that cure dementia. Hence it is important to establish the evaluation index of cognitive decline before becoming dementia. **Objective**: The purpose of this study was to clarify the effective balance test indicating early cognitive decline by gender. **Methods**: A total of 218 volunteers (60 years of age and above) who participated in the Iwaki promotion health project in 2015 were recruited. We performed three balance tests: one leg standing test, functional reach test and static posturography, and we used mini-mental state examination (MMSE) to investigate cognitive function. **Results**: As a result of analysis of covariance, there was a statistically significant trend in only men that the more the MMSE score declined, the longer became the path length with both eyes opened and closed. In the result of multiple regression analysis, there was a significant negative association with MMSE score and path length with eyes opened or closed in men. There was no significant association with MMSE scores and balance tests in women. **Conclusion**: The study suggests that static posturography might be a useful balance test to assess early cognitive decline in men

Keywords

Iwaki promotion health project, dementia, static posturography, balance ability, mini-mental state examination

Introduction

Recently, the number of elderly people is increasing all over the world, and patients with dementia are also increasing. This trend of an increase of elderly population is remarkable in Japan, where there were 4.62 million dementia patients in 2015 [1]. Dementia causes symptoms such as memory disorder, disorientation, aphasia, apraxia, agnosis, and decrease of activities of daily living (ADL) and quality of life (QOL) [2], and consequently some dementia patients become bedridden. However, there has been no treatment found yet to cure dementia. For the purpose of preventing dementia, it is important to establish an evaluation index of cognitive decline before the development of dementia.

Declines in mobility and balance are both causes and effects of dementia [3]. Especially, there have been some reports pointing out that balance disability can be a higher risk of dementia than declines of mobility and muscle strength [4]. Balance ability is gaining more attention as the evaluation index of dementia. It is reported that dementia patients have low scores of the ability of static balance compared with control subjects [5]. And the mini-mental state examination (MMSE) [6] score which is a cognitive decline test, correlated with dynamic balance in dementia patients. However, there has been no previous study about the association of balance disability and cognitive function before dementia. Therefore, it is unknown whether assessment of balance ability is useful as a predictor of early cognitive decline. Also, it is necessary to determine which balance test is a superior index of decline in cognitive functions, for that reason research done at the same time with the same subjects was necessary.

In the present study, we examined people before onset of dementia (their MMSE scores were more than 23 points and they had no neuropsychiatric disorders) [7]. The people participated in

the Iwaki Health Promotion Project that is performed in the Iwaki region in Hirosaki City, in order to prevent lifestyle-related disease, to maintain or gain better health and to extend life span. In this project, we performed common medical checks including blood pressure, blood test, body measurement and so on. In addition, in this project for the purpose of establishing the relationship between cognitive function and balance ability we performed three balance tests for people aged 60 and above: one leg standing test (OLST), functional reach test (FRT) and static posturography, and we used MMSE to investigate cognitive function.

Subjects and methods

Subjects

Iwaki district is a stable community with a population of 11,260 in 2015. We invited all residents above 20-years-old living in the Iwaki district to the Iwaki promotion health project. As a result, 1113 volunteers participated in 2015. Data collection for the present study and the project was approved by the Ethics Committee of Hirosaki University School of Medicine, and all subjects provided written informed consent before participating in the project.

Lifestyles and physical measurements

We interviewed participants regarding age, sex, education, present medical history, past history, drug information, habits of smoking, drinking and exercise. Also, we advised exercise for once or more in a week as a habit.

We calculated body mass index (BMI) (kg/m2) by measuring their height and weight.

One leg standing test (OLST)

OLST is one of the measuring methods that assess static balance [8]. Subjects were standing on either leg without any support. OLST got completed when the raised leg touched the other leg or when the supporting leg moved, and the time was measured. Upper limit of OLST was 80 s for men and 70 s for women. When they reached the upper limit, OLST was completed. We performed the test three times and the best time was taken as their result.

Functional reach test (FRT)

FRT is one of the methods for measuring dynamic balance [9]. Subjects stood upright and raised either arm to the height of their shoulder, and the position of the top of the middle finger was marked. After that, they stretched their arm forward as far as possible, with their legs kept fixed. The maximum distance of the position of the top of the middle finger from the first position was recorded. We performed the test three times and the best record was taken as their result.

Static posturography

Posturography is able to detect the center of pressure when subjects are standing upright [10]. We used a Gravicorder GP 31 platform (ANIMA, Tokyo, Japan). During the examination, the subjects maintained static upright posture on the foot plate with their feet together and their arms on the side of the body. And we instructed them not to speak or move during the examination. We conducted the test twice, once with their eyes opened and once with their eyes closed, for 1 min each. When the subjects opened their eyes, we instructed them to gaze at the target placed 150 cm ahead of their eyes. We used path length (cm) for analysis.

Cognitive examination

We used MMSE as the cognitive functioning examination [6]. The examination assesses orientation of time and place, presence or absence of aphasia, apraxia and agnosis, short and long memory, and calculating ability. The full score is 30 points, and if the subjects' cognitive function is declining, the score declines. There is no time limit during the examination. The examination was performed by a clinical psychologist, one-to-one, in a separated space. We selected subjects whose MMSE score was >23 points [7] and who had no neuropsychiatric disorders.

Statistical analysis

Analysis of covariance (ANCOVA) was performed for analyzing relationship by gender between MMSE score and the four balance tests: OLST, FRT, path length with eyes opened and path length with eyes closed. And we performed multiple comparisons by Bonferroni correction. OLST results were categorized into four groups: less than 20 s (Q1), 20 s or more and less than 40 s (Q2), 40 s or more and less than 60 s (Q3), 60 s or more (Q4). FRT results were categorized into four groups: less than 25 cm (Q1), 25 cm or more and less than 30 cm (Q2), 30 cm or more and less than 35cm (Q3), 35 cm or more (Q4). Path length results with eyes opened were categorized into four groups: less than 70 cm (Q1), 70 cm or more and less than 110 cm (Q2), 110 cm or more and less than 150 cm (Q3), 150 cm or more (Q4). Path length results with eyes closed were also categorized into four groups: less than 125 cm (Q1), 125 cm or more and less than 175cm (Q2), 175cm or more and less than 225 cm (Q3), 225 cm or more (Q4). p values less than .05 were considered statistically significant.

Multiple regression analysis was also performed for analyzing relationship by gender between MMSE score and path length with eyes opened, and eyes closed. p values less than .05 were

considered statistically significant. We adjusted covariates: age, BMI, years of education, current smoking, current drinking and habit of exercise. We used SPSS 22.0J (IBM, Armonk, NY) for data analysis.

Results

Characteristics of subjects (Table 1)

We enrolled 314 volunteers who were 60 years of age and above. Eighty-two subjects with history of malignant tumor, cardiovascular disease, stroke, major surgery due to spinal or lower limb problems, vertigo, rheumarthritis, psychiatric disorder, steroid use or sex hormone use were excluded. Ten subjects were also excluded due to deficit of data and there were four subjects who had less than 23 points in MMSE. The remaining total was 218 subjects (men: 79, women: 139).

The mean ages were 67.8 ± 5.8 for men and 67.1 ± 5.7 for women, and there was no statistically significant difference. There was no statistically significant difference concerning education levels either. BMI, habit of smoking and drinking were significantly higher in men than women ($p<.05$), while MMSE scores were significantly higher in women than men ($p<.05$). In the balance tests, OLST, was significantly better in men ($p<.05$). Path length with eyes opened and with eyes closed were significantly better in women ($p<.05$). On the other hand, FRT showed no significant difference by gender.

Relationship between balance and cognitive function

As a result of ANCOVA, in OLST and FRT, there was no significant difference in the MMSE score between any groups in both genders (Table 2). Also, in path length with eyes both opened

and closed, there was no significant difference in the MMSE score between any groups in both genders. But there was a statistically significant trend in only men that the more the MMSE score declined, the longer became the path length with both eyes opened and closed (Table 2).
In the result of multiple regression analysis, there was a significant negative association with MMSE score and path length with eyes opened or closed in men. However, there was no statistically significant association in women (Table 3). These indicated that the longer path length with eyes opened and closed were, the lower MMSE score was in men.

Discussion

This study was, to the best of our knowledge, the first to investigate the association between balance ability and early cognitive decline before dementia in a general population. In this study, the longer the path length, the lower the score of MMSE in men. Previous studies reported that the patients with dementia or mild cognitive impairment (MCI) have a decline in their balance ability [5]. Shin et al. [11] showed that path length in MCI patients was longer than in controls either with eyes opened or with eyes closed. Center of pressure velocity had significant correlation with cognitive decline measured by MMSE score, but path length had no correlation with cognitive decline, which caused the aging of the subjects [5]. The principal reason for this relationship between cognitive function and balance function might be the structural or functional change of the brain. It was reported that hippocampal volume is associated with maintaining upright posture and balance [12]. Lower gray matter volume has been found to be related not only to cognitive decline, but also to postural instability [13]. Makizako et al. [14] reported that lower gray matter densities in the middle frontal gyrus and superior frontal gyrus were associated with falls in older adults with MCI.

Balance ability is maintained by processing information from vestibular function, visual sense and somatosensory sense in the central nervous system and outputting to the vestibule-ocular reflex and musculoskeletal system [15]. There are two methods for testing balance ability, dynamic balance and static balance. Dynamic balance tests include FRT and Timed Up and Go test (TUG) and more [16]. TUG is indicated to include influence of gait except for balance function [16]. Hence there is a possibility that TUG has not measured pure balance function. OLST is one of the measuring methods that assess static balance. OLST has an upper limit and does not have normal distribution [8]. In addition, balance decline of the subjects was not so large in our study. Static posturography is also one of the methods of assessing static balance, and the test can assess balance ability with eyes opened and eyes closed quantitatively if the subjects can stand alone. Because static posturography is measured by a computer, the record and analysis are easy and accurate. Furthermore, posturography is reported as an index of risk for falls in elderly people because posturography was previously proved to have a relationship with falls [17]. From the above, static posturography is considered as one of the best measurements in the balance tests. In the present study, there was no significant relationship between OLST, FRT and cognitive function in either gender. Therefore, we conclude that static posturography might be the most appropriate method as a marker to detect cognitive decline.

In our study, there was no relationship between path length and MMSE score in women. Johanne et al. [18] reported that decline of balance function with aging is earlier in men, and decline of muscle supporting balance function is different by gender. Especially, it was reported that muscle strength declined significantly earlier for men than women [18]. Brain atrophy is earlier in men [19], so cognitive function might be more declined in men. As the past reports, in our study, the MMSE score was significantly lower and path length was significantly longer for men

than women. Thus, it could be speculated that declines of both balance function and cognitive function are larger in men than women. And therefore, it is thought that the tendency occurs in men because the balance and cognitive abilities decrease greatly. On the contrary, it is thought that the tendency did not occur in women because the balance and cognitive abilities decrease still slight in the same generation.

In this study, we examined the relationship between cognitive function and balance function by gender. The current findings suggest that static posturography might be a useful balance test to assess early cognitive decline in men. Prevention of dementia becomes increasingly important, so it is considered significant to assess early cognitive decline with no subjective symptoms.

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Declaration of interest

The authors report no conflicts of interest. The authors alone are responsible for the content and writing of the paper.

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Table 1. Characteristics of Subjects

	Men (n=79)	Women (n=139)	p-value
Age (years)	67.8 ± 5.8	67.1 ± 5.8	0.402
Height (m)	1.65 ± 0.06	1.52 ± 0.05	0.000
Weight (kg)	64.3 ± 8.6	52.0 ± 7.3	0.000
BMI (kg/m²)	23.7 ± 2.7	22.4 ± 3.0	0.003
Education (years)	11.8 ± 2.3	11.4 ± 1.8	0.151
Current smoking, %	17.7	4.3	0.001
Current drinking, %	70.9	22.3	0.000
Habit of exercise (1≦week, %)	38.0	37.4	0.934
MMSE (Score)	28.5 ± 1.9	29.0 ± 1.3	0.024
OLST (s)	62.2 ± 25.1	53.4 ± 23.1	0.010
FRT (cm)	30.4 ± 5.5	30.1 ± 4.6	0.685
Posturography			
Eye open			
Path length (cm)	117.5 ± 39.0	95.1 ± 28.8	0.000
Eye closed			
Path length (cm)	177.3 ± 64.3	134.9 ± 47.9	0.000

Values are mean ± standard deviation.

BMI: body mass index, MMSE: mini mental state examination, OLST: one leg standing time,FRT: functional reach test

Table 2. Association between MMSE score and balance tests by four groups

	MMSE score	
	Men	Women
	mean ± SD	mean ± SD
OLST, (s)		
Q1: <20	27.7 ± 2.5	28.3 ± 1.9
Q2: <40	27.4 ± 2.4	28.6 ± 1.8
Q3: <60	28.1 ± 2.1	29.0 ± 1.2
Q4: 60≦	28.8 ± 1.5	29.3 ± 1.0
p for trend	0.105	0.064
FRT, (cm)		
Q1: <25	27.6 ± 2.2	28.5 ± 1.5
Q2: <30	28.4 ± 1.8	28.8 ± 1.4
Q3: <35	28.5 ± 2.0	29.2 ± 1.3
Q4: 35≦	29.2 ± 1.1	29.6 ± 0.5
p for trend	0.204	0.157
eye open path length, (cm)		
Q1: <70	29.7 ± 0.5	29.2 ± 1.0
Q2: <110	28.5 ± 1.6	29.0 ± 1.3
Q3: <150	28.8 ± 1.6	28.7 ± 1.7
Q4: 150≦	27.4 ± 2.7	29.1 ± 1.1
p for trend	0.022	0.237
eye closed path length, (cm)		
Q1: <125	29.2 ± 1.4	29.2 ± 1.0
Q2: <175	28.6 ± 1.6	28.9 ± 1.5
Q3: <225	28.5 ± 1.7	28.7 ± 1.8
Q4: 225≦	27.4 ± 2.5	28.7 ± 1.1
p for trend	0.045	0.845

In every balance test, there was no significant difference in the MMSE score between any groups in both genders. But there was a statistically significant trend in only men that the more the MMSE score declined, the more the path length became longer with both eyes opened and closed. Values are adjusted for age, BMI, education, current smoking, current drinking, exercise habit. MMSE: mini mental state examination, SD: standard deviation, OLST: one leg standing time, FRT: functional reach test

Table 3. Multiple regression with MMSE as a dependent variable

		Men			Women		
		β -coefficient	p-value	R^2	β - coefficient	p-value	R^2
Path length	eye open	-0.244	0.025	0.278	0.041	0.650	0.122
	eye closed	-0.251	0.018	0.283	0.018	0.839	0.121

There is significant negative association with MMSE score and path length with eyes opened and closed in men. However there is no statistically significant association in women.

Values are adjusted for age, BMI, education, current smoking, current drinking, exercise habit.

MMSE: mini mental state examination