Original article

Fall prediction accuracy of visual spatial abilities tests in patients with Alzheimer's disease: a retrospective study

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Abstract

Objective: The purpose of the present study was to conduct five visual spatial abilities tests frequently used in Japan (clock drawing test [CDT], overlapping figures test of the Visual Perception Test for Agnosia [overlapping figures test], construction of the Japan version of the Alzheimer's Disease Assessment Scale [constructions], intersecting pentagon copying test [PCT] of the Mini-Mental State Examination, and Yamaguchi fox-pigeon imitation test [YFPIT]) on patients with the same disease, and to compare the fall prediction accuracy of these tests.

Methods: The participants comprised 35 Alzheimer's disease (AD) patients (average age: 80.5 ± 6.5 years old). We compared the results of the five visual spatial abilities tests using the χ^2 and Mann–Whitney *U* tests. We performed a receiver operating characteristic (ROC) analysis using evaluation indicators that showed a significant difference between two groups as independent variables and calculated the area under the curve (AUC) and cutoff value.

Results: Only in CDT (p = .032, effect size: *r* = -.36) and overlapping figures test (*p* = .020, effect size: *r* = -.39) were the results of the fall group worse than those of the non-fall group. For CDT, the AUC of falls was 0.711 (95% confidence interval [CI]: .538–.884, *p* = .033), while the sensitivity and specificity at three cutoff values were 82.4% and 55.6%, respectively. For overlapping figures test, the AUC was 0.699 (95% CI: .524–.875, *p* = .044), while the sensitivity and specificity at one cutoff value were 55.6% and 82.4%, respectively.

Conclusion: The AUC of falls for CDT and overlapping figures test, which both showed between-group differences, indicated that overlapping figures test had low fall prediction accuracy and the CDT had moderate prediction accuracy. Thus, CDT can be considered a simple visual spatial abilities test that can be used for screening and predicting falls in AD patients. Further investigations with a larger sample size are required.

Keywords: Visual spatial abilities, Fall, Clock drawing test

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Introduction

A fall in elderly individuals often leads to a fracture and can shorten their healthy lifespan, which is a period where they are capable of independent activities of daily living. Fractures due to falls are listed as one of the top causes for elderly individuals requiring nursing care needs (Ministry of Health, Labour and Welfare, 2016), and falls are becoming a serious medical/social problem. The fall rate of patients with dementia is extremely high with the annual incidence of patients with dementia living at home about eight times higher than that of healthy elderly individuals (Lousie, 2009). Falling not only reduces motor function but also accelerates the progress of dementia (Yukimasa, 2011) making it difficult for patients with dementia to become self-reliant (Morris, 1987). Therefore, prevention of falls in patients with dementia is an important issue that, if properly addressed, can lead to the prevention of the progression of dementia and increasing burden of nursing care.

Factors associated with falls in dementia patients include age (Peláez, 2015), sex (Erikson, 2007; Peláez, 2015), severity of dementia (Muir, 2012), presence of advanced white matter lesions (Horikawa, 2005), administration of antipsychotic drugs (Horikawa, 2005), hypertension (Morris, 1987; Peláez, 2015), Behavioral and Psychological Symptoms of Dementia (BPSD) (Suzuki, 2012), unstable balance (Sterke, 2010; van Dijk, 1993), and decreased visual spatial abilities (Chen, 2011; Erikson, 2007; Olsson, 2005; Yamada, 2013). Among these related factors, those that rehabilitation professionals, such as occupational therapists and physical therapists, should focus on are unstable balance and decreased visual spatial abilities. There are numerous reports, including studies whose participants were not dementia patients, on the relationship between balance ability and falls (American Geriatrics Society, 2001; An, 2014; Borowicz, 2016; Granacher, 2013; Murphy, 2003; Persad, 2010; Sherrington, 2008; Shumway-Cook, 2000; Sterke, 2010; Teasell, 2002; Tinetti, 2010; van Dijk, 1993). However, the relationship between visual spatial abilities and falls has not been sufficiently studied.

Erikson et al. (2007) and Chen et al (2011) assessed the visual spatial abilities of 204 dementia patients and 338 participants including dementia patients, respectively, using the Mini-Mental State Examination (MMSE) and intersecting pentagon copying test (PCT), and reported that there was an association between impaired visual spatial abilities and falls. Olsson et al (2005) assessed the visual spatial abilities of 364 dementia patients using the Reality Comprehension Clock Test and reported that decreased visual spatial abilities increased the risk of falls by three. Yamada et al. (2013) reported that impaired visual spatial abilities of 31 individuals with mild cognitive impairment assessed by the clock drawing test (CDT) were associated with falls. However, among these studies, only in the study conducted by Yamada et al. (2013) in which individuals with mild cognitive impairment was studied was there consistency in the disease of dementia patients. The characteristics of visual spatial abilities impairment caused by dementia vary depending on whether it is Alzheimer's disease (AD), vascular dementia, or dementia with Lewy bodies (Shimomura, 1998; Nagahama, 2011; Washida, 2015). Preferably, there should be consistency in the disease of the participants studied. Furthermore, although three different tests were used to assess visual spatial abilities in these previous studies, it has yet to be examined which of these tests reflects the risk of falls the most.

Visual spatial abilities tests used in Japan for dementia patients include the CDT (Wolf-Klein, 1989; Rouleau, 1992; Yoshimura, 2008), overlapping figures test of the Visual Perception Test for Agnosia (VPTA) (overlapping figures test) (Koyanagi, 2016), construction of the Japan version of the Alzheimer's Disease Assessment Scale (ADAS-Jcog), constructions (Sekiya, 2016; Oshima, 2013; Watanabe, 2013), PCT of MMSE (Suzuki, 2017), and Yamaguchi fox-pigeon imitation test (YFPIT) (Yamaguchi, 2010). These tests are well-received by dementia patients, who have a low tolerance for tests, as all of them are simple and can be performed within minutes. As such, these tests have been often used in Japan to assess visual spatial abilities of dementia patients. However, it has yet to be determined which of these visual spatial abilities tests is associated with falls the most.

AD accounts for approximately 70% of dementia cases (Guo, 2017) and is the most important disease leading to dementia. It has been reported that impaired visual spatial abilities is observed at an early stage of the disease (Yamaguchi, 2010). We believe that understanding the association between impaired visual spatial abilities caused by AD and falls and finding the visual spatial abilities test most suitable for understanding this association will help in developing fall prevention strategies for AD patients. The purpose of the present study was to conduct five visual spatial abilities tests frequently used in Japan (CDT, overlapping figures test, constructions, PCT, and YFPIT) on patients with the same disease, and to compare the fall prediction accuracy of these tests.

The present study was conducted with the approval of the Ethics Committees of the Juntendo Tokyo Koto Geriatric Medical Center affiliated with Juntendo University School of Medicine (approval number: 96-4) and Kyorin University Faculty of Health Sciences (approval number: 29-64). The study participants and the family members living with them received an explanation, orally and in writing, about the purpose and method of the present study prior to consenting to participating in the study.

Participants and Methods

1. Participants (Table 1)

The participants comprised 35 AD patients (15 men and 20 women, average age 80.5 ± 6.5 years old). The participants were selected based on the criteria that they were diagnosed by a physician with AD as defined by ICD-10 and that they were able to follow verbal orders. The exclusion criteria included the following six items that could lead to a fall: (1) Inability to walk for ≥ 50 m, or a Functional Independence Measure (FIM) walk/wheelchair score of ≤ 5, (2) motor paralysis, (3) sensory impairment, (4) a history of impaired consciousness/loss of consciousness, (5) marked visual impairment, and (6) patients that were deemed unsuitable as study participants by the authors for other reasons. Those with a history of fracture due to a fall were not excluded. We acquired information on the characteristics of the participants (sex, age, duration of AD, years of education after graduating from elementary school, complications, number of oral drugs utilized) by viewing the medical records from the time of admission.

2. Visual spatial abilities tests

1) Clock drawing test (Figure 1)

CDT comprises tasks where the participants were asked to draw a picture of an analog clock showing the specified time. The CDT is said to be able to assess constructional ability, visual spatial abilities, language comprehension ability to understand commands, visual memory recall, and visual image reproduction (Mendez, 1992; Juby, 2002). In the present study, we instructed the participants to draw an analog clock showing 11:10 on a blank sheet of paper. Scoring was done using the method presented by Rouleau et al. (Rouleau, 1992) (Table 2). The higher the score the better the function with 10 being the highest score.

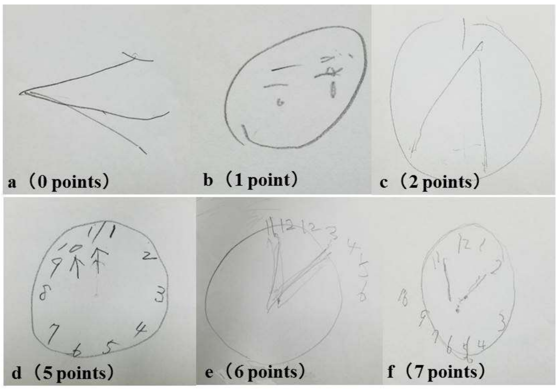

Figure 1: Example of the clock drawing test (CDT)

Table 1: Participants' characteristics and evaluation results

	Total (n = 35)	Fall group (n = 18)	Nonfall group (n = 17)	p value	Effect size
Men/Women (n)	15 / 20	5/13	1	0.064	0.31
Age (years)†	80.5 ± 6.5	82.2 ± 6.0	78.8 ± 6.7	0.119	0.27
Duration of AD (number of months)‡	30 (2-144)	21 (2-132)	36 (3-144)	0.728	-0.06
Years of education (years)‡	6 (0-10)	6 (0-10)	6 (3-10)	0.386	-0.15
Number of complications‡	7 (0-35)	7.5 (0-35)	6 (1-27)	0.53	-0.11
Number of types of oral medicines‡	4 (1-12)	4.5 (1-11)	4 (1-12)	0.947	-0.01
MMSE-J (points)†	17.1 ± 5.5	16.6 ± 5.1	17.6 ± 6.1	0.61	0.09
NPI (points)‡	4 (0-40)	4.5 (0-36)	4 (0-40)	0.88	-0.03
FIM exercise items (points)‡	80 (48-90)	74 (48-85)	81 (55-90)	0.116	-0.02
FIM cognition items (points)†	22.0 ± 5.6	22.1 ± 6.5	22.0 ± 4.7	0.977	-0.01
TUG (seconds)‡	13.1 (5.9-91.7)	13.8 (8-91.7)	10.7 (5.9-23.9)	.018*	-0.4
CDT (points)‡	4 (0-10)	2 (0-10)	5 (1-10)	.032*	-0.36
Overlapping figures test (points)‡	0 (0-5)	1 (0-5)	0 (0-2)	.020*	-0.39
Constructions (points)‡	1 (0-4)	1 (0-4)	1 (0-2)	0.189	-0.22
PCT (success/failure)	24/11	11/8	13/4	0.328	0.17
YFPIT fox (success/failure)	31/4	15/3	16/1	0.316	0.17
YFPIT pigeon (success/failure)	14 / 21	5/13	9/8	0.129	0.26

†: Welch's t test (mean value ± standard deviation), ‡: Mann-Whitney's U test (median [range]), sex, PCT, YFPIT fox, YFPIT pigeon by chi-square test (number of persons)

AD: Alzheimer ' s disease, MMSE-J: Mini-Mental State Examination-Japanese, NPI: Neuropsychiatric Inventory, FIM: Functional Independence Measure, TUG: Time Up and Go test, CDT: clock drawing test, Overlapping figures test: overlapping figures test of the Visual Perception Test for Agnosia, Constructions: constructions of the subtest for cognitive function of the Japanese version of the Alzheimer's Disease Assessment Scale, PCT: Intersecting Pentagon Copying Test, YFPIT: Yamaguchi fox-pigeon imitation test

*p < .05

2) Overlapping figures test of the Visual Perception Test for Agnosia (Japan Society for Higher Brain Dysfunction, 2003) (Figure 2, Table 3)

VPTA is a test battery created with the aim of clinically and comprehensively understanding higher-order visual perception impairments such as visual spatial abilities, control impairment, and topographical disorientation. In the present study, we conducted the overlapping figures test, which is a sub-item of the basic function of visual perception.

Overlapping figures test comprised the following three tasks: (1) The participant was presented with a figure (Figure 2a) in which overlapping objects are drawn, and he/she was asked to name the things drawn on it. If the participant had difficulties naming the objects, he/she was asked to trace the contour of the objects with a finger. If the participant was able to name the objects or trace them with a finger, it was considered to be a correct answer. (2) The participant was presented with an illustration (Figure 2b) in which four geometric figures were drawn, and he/she was asked to speak out the number of geometric figures. (3) The participant was presented with an illustration (Figure 2c) in which six figures were drawn, while Figure 2b continued to be presented to him/her, and he/she was asked to point out with their fingers the figures in Figure 2c that also appear in Figure 2b.

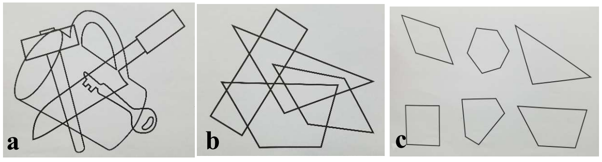

Figure 2: Overlapping figures test of the Visual Perception Test for Agnosia (VPTA)
(Source: Japan Society for Higher Brain Dysfunction, 2003)

The time limit for (1), (2), and (3) was 60 seconds each. Scoring was done based on the number of correct answers given (on a 7-point scale of 0 to 6), where a low score indicated good function.

3) Constructions of the Subtest for cognitive function of the Japanese version of the Alzheimer's Disease Assessment Scale (Homma, 1992) (Figure 3, Table 4)

ADAS is a cognitive function test with a focus on the evaluation of memory, language, and behavior. It is aimed at assessing changes in cognitive function. The Japanese version (ADAS-Jcog) was created by Homma et al. (1992) and its reliability and validity have been verified. Of the tasks comprising the ADAS, we conducted the constructions in the present study.

The participant was presented with four figures (a circle, two overlapping rectangles, a rhombus, and a cube), one at a time, and he/she was asked to copy them. The participant was instructed to "take their time to draw the exact same figure as them" and to copy them again if his/her response was quick and crude. The participant was considered to have given the correct answer if he/she was able to reproduce all essential features of the original figure. The participant was also considered to have given the correct answer even if there were differences in size and small gaps between lines. Scoring was done on a 6-point scale of 0 to 5. A low score indicated good function.

4) Intersecting pentagon copying test of the Mini-Mental State Examination-Japanese (Figure 4)

MMSE has been widely used as a screening test for cognitive function. In the present study, the PCT, which evaluates the subset of visual closure, was subjected to analysis. The participant was presented with a sheet where intersecting pentagons were drawn, and he/she was asked to copy them. The participant was considered to have given the correct answer if two pentagons intersected in one area. Scoring was done based on whether the participant succeeded or not (0/1).

5) Yamaguchi fox-pigeon imitation test (Figure 5)

YFPIT is an imitation task using the hands. It is also used as a screening test for AD accompanied by visual spatial abilities impairment. In the task, one hand was used to imitate a fox or both hands were used to imitate a pigeon. The participant was seated in a chair and the examiner sat in a chair in front of the participant. The examiner first formed a fox using his/her left hand and asked the participant to "make the same shape using his/her hand." This procedure was subsequently repeated for the pigeon. When forming a pigeon, it was not relevant which hand was over the other. The time limit was 10 seconds for both the fox and pigeon. Scoring was done based on whether the participant successfully performed the imitation (0/1).

3 . Cognitive function, BPSD, activities of daily living, and test for balance ability

In order to understand the functions and abilities of the participants other than their visual spatial abilities, we used the MMSE-Japanese (MMSE-J), Neuropsychiatric Inventory (NPI), Functional

Table 2 Revised scale used for scoring the clock drawings

(Rouleau, 1992)

Integrity of the clockface (maximum: 2 points)
2: Present without gross distortion
1: Incomplete or some distortion
0: Absent or totally inappropriate
Presence and sequencing of the numbers (maximum: 4 points)
4: All present in the right order and at most minimal error in the spatial arrangement
3: All present but errors in spatial arrangement
2: Numbers missing or added but no gross distortions of the remaining numbers
Numbers placed in counterclockwise direction
Numbers all present but gross distortion in spatial layout (i.e., hemineglect, numbers outside the clock)
1: Missing or added numbers and gross spatial distortions
0: Absence or poor representation of numbers
Presence and placement of the hands (maximum: 4 points)
4: Hands are in correct position and the size difference is respected.
3: Slight errors in the placement of the hands or no representation of size difference between the hands.
2: Major errors in the placement of the hands (significantly out of course including 10 to 11)
1: Only one hand or poor representation of two hands
0: No hands or perseveration on hands

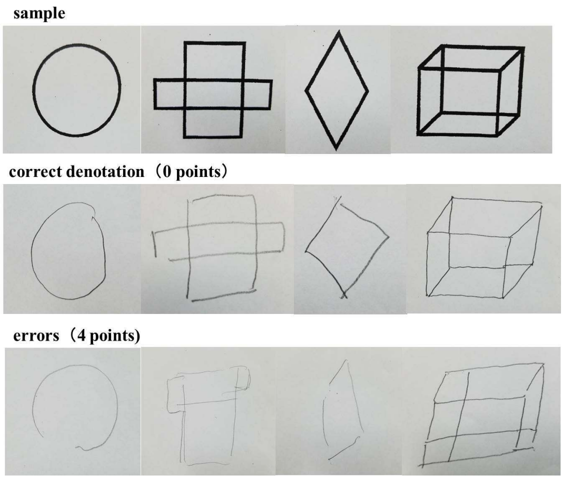

Figure 3: Constructions task of the Alzheimer's Disease Assessment Scale (Japan Version) Circle, two overlapping rectangles, trapezoid, cube (from left to right)

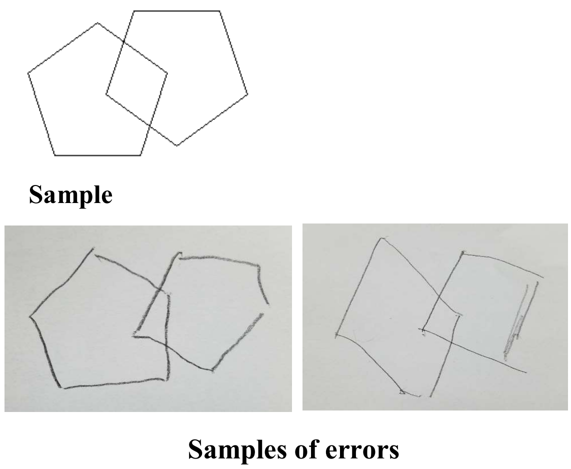

Figure 4: Intersecting pentagon copying test (PCT) of the Mini-Mental State Examination-Japanese (MMSE-J)
Example of a correct answer (left) and an incorrect answer (right)

Table 3: Overlapping figures test of the Visual Perception Test for agnosia (Japan Society for Higher Brain Dysfunction, 2003)

Figs. a, b
0: All correct responses
1: 2–3 correct responses
2: 0–1 correct response
Fig. c
0: 3 correct responses
1: 2 correct responses
2: 0–1 correct response

Independence Measure (FIM), and Timed Up and Go test (TUG) to test cognitive function, BPSD, activities of daily living, and balance ability, respectively.

TUG was conducted according to the method proposed by Okaji et al. (2005). The participant was seated in a chair with the body in contact with the back and sitting surface of the chair in the starting position. The participant was instructed to "walk around the pole that can be seen over there and sit on this chair as fast as he/she can." The time required to stand up from the seated position in the chair, walk to and from the pole 3 m ahead, and sit in the same chair was measured in the order of 1/10 second using a digital stopwatch.

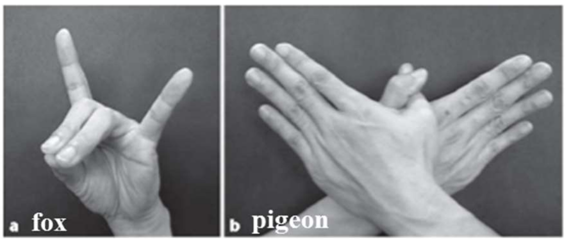

Figure 5: Yamaguchi fox-pigeon imitation test (YFPIT) (source: Yamaguchi, 2010)

4. Survey methods

All tests were conducted on all the participants by physical therapists or occupational therapists. Due consideration was given to the participants' fatigue.

A fall was defined as "a part of the body other than the sole coming into contact involuntarily with the ground or a surface lower than the ground" (Kondo, 1999), and falling down the stairs, off the stands or bikes was considered as a fall. Those that fell more than once within a year prior to the investigation date were grouped in the fall group, while those that did not were grouped into the non-fall group. This information was obtained from the main nursing caregivers that understood the living situation of the participants right up until they were hospitalized.

Table 4: Constructions of the subtest for cognitive function of the Japanese version of the Alzheimer's Disease Assessment Scale (Homma, 1992)

Point	Number of correct responses
0	All 4 figures are correct
1	1 figure is incorrect
2	2 figures are incorrect
3	3 figures are incorrect
4	4 figures are incorrect
5	No figures drawn, scribbling, only part of the figures drawn, or characters written instead of figures

5. Statistical methods

We compared the participant characteristics and the results of the visual spatial abilities tests between the fall group and the non-fall group. The Mann–Whitney *U* test was used for the CDT, overlapping figures test, and constructions, while the $\chi 2$ test was used for sex, PCT, and YFPIT (fox, pigeon). The normality of other variables was examined using the Shapiro-Wilk test, and age, MMSE-J, and FIM cognitive were normally distributed. Therefore, Welch's *t*-test was used for age and MMSE-J. The Mann–Whitney *U* test was used for disease duration of AD, years of education, number of complications, number of oral drugs utilized, FIM motor, and TUG as these variables were not normally distributed. In order to examine the relationship between visual spatial abilities and balance ability, linguistic function, and social cognitive function, we used Spearman's rank correlation coefficient and acquired the correlation coefficient of visual spatial abilities tests, which showed significant differences between the two groups, with regard to the TUG, FIM communica-

Table 5 Relationship between visual spatial abilities, balance ability, and FIM cognition items (communication and social cognition)

	FIM cognition items		TUG
	Communication	Social cognition	
CDT (points)‡	.549*	0.315	-0.271
Overlapping figures test (points)‡	-.408*	-0.235	.370*

FIM: Functional Independence Measure, TUG: Time Up and Go test, CDT: clock drawing test, Overlapping figures test: overlapping figures test of the Visual Perception Test for Agnosia

Spearman's *rs* $^{*}p < .05$

tion, and FIM social cognition.

Furthermore, in order to examine the fall prediction ability of each visual spatial abilities test, we generated a Receiver Operating Characteristic (ROC) curve with test results that showed a significant difference between the two groups as an independent variable and whether or not the participants fell as a dependent variable, and calculated the cutoff value, sensitivity, specificity, and the area under the curve (AUC). In an ROC curve, sensitivity is plotted on the y-axis while specificity is plotted on the x-axis. It is said that the closer the area under the ROC curve is to 1, the higher its discriminatory power (Kihara, 2009). Here, the cutoff value is an index that shows the fall prediction ability useful for screening for patients at high fall risk. The AUC varies between 0.5 and 1. An AUC equal to or higher than 0.9 indicates high accuracy, an AUC between 0.7 and 0.9 indicates medium accuracy, and an AUC between 0.5 and 0.7 indicates low accuracy (Anthony, 2007). Furthermore, we calculated the effect size (*r*) because the present study was conducted as a preliminary study and the small number of participants could affect the detection ability. Based on the index proposed by Cohen (1992), an effect size between 0.1 to 0.29 was interpreted as low, between 0.3 and 0.49 as moderate, and 0.5 or higher as high. SPSS Statistics software (Ver.21.0, IBM Corporation, Armonk, USA) was used for statistical analysis and the significance level was set to less than 5%.

Results

1. Characteristics of the participants (Table 1)

Participant characteristics and test results are shown in Table 1. Of the 35 participants, 18 of them (51.4%) had fallen in the previous year. With regard to complications, 25 participants suffered from cranial nerve disease, 31 participants suffered from internal medicine disease, 16 suffered from orthopedic disease (including one participant with a history of patellar fracture due to a fall within the past one year), and 16 were diagnosed with other diseases (ophthalmologic disease such as postoperative complications of cataract and dermatological disease). None of the 35 participants was using walking aids.

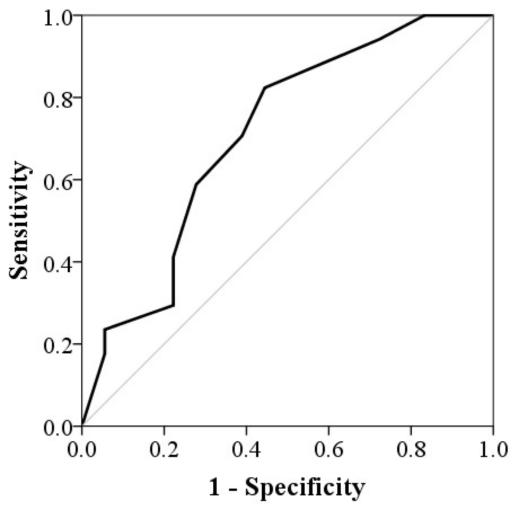

Figure 6: ROC curve of the CDT, which determines whether an AD patient will fall
For the CDT, the AUC regarding falls was 0.711 (95% confidence interval (95% CI): .538–.884, $p = .033$), while the sensitivity and specificity at three cutoff values were 82.4% and 55.6%, respectively.
ACU: area under the receiver operating curve, AD: Alzheimer's disease, CDT: clock drawing test, ROC: Receiver operation characteristic

There was no significant difference in age, sex, disease duration of AD, years of education, number of complications, number of oral drugs, MMSE-J, NPI, motor FIM, or cognitive FIM, between the fall and non-fall groups. The non-fall group scored significantly higher (p = .018) on the TUG, which was conducted to evaluate balance, than the fall group.

2. Comparison of visual spatial abilities tests between the fall group and non-fall group (Table 1)

A comparison of each index between the two groups is shown in Table 1. The fall group showed significantly lower scores ($p < .05$) for the CDT as well as the overlapping figures test than those of the non-fall group. The effect size of all the items that showed significant differences was moderate (effect size: r = -.36 to -.39). On the other hand, there was no significant difference in constructions, PCT or YFPIT (fox/pigeon).

Furthermore, ceiling effects were observed in 22 out of 35 participants (62.9%) scoring the highest score in the overlapping figures test, 10 out of 35 participants (28.6%) scoring the highest score in constructions (0 point), 24 out of 35 (68.6%) participants giving the correct answer in the PCT, and 31 out of 35 participants (88.6%) giving the correct answer in the YFPIT (fox), while a floor effect was noted in 21 of 35 participants (60.0%) giving the wrong answer in the YFPIT (pigeon). Meanwhile, the CDT did not show a ceiling effect/floor effect with 3 out of 35 participants (8.6%) scoring the highest score in the CDT and 3 participants (8.6%) scoring the lowest score.

With respect to the relationship between balance ability and visual spatial abilities (Table 5), the overlapping figures test showed a significant correlation with the TUG (r = .370, p < .05), but no significant relationship was observed between the CDT and the TUG (r = -.271, p = .114).

With respect to the relationship between linguistic function, social cognitive function, and visual spatial abilities (Table 5), the CDT showed a significant correlation with FIM communication (r = .549, $p < .05$) but not with FIM social cognition (r = .315, p = .066). The overlapping figures test showed a significant correlation with FIM communication (r = -.408, $p < .05$) but not with FIM social cognition (r = -.235, p = .170).

3. Prediction accuracy of visual spatial abilities tests in determining whether an AD patient will fall

We generated ROC curves for the CDT and overlapping figures test, which showed significant differences between the fall group and non-fall group, and examined the sensitivity, specificity, and cutoff values. For the CDT, the AUC regarding falls was 0.711 (95% confidence intervals (CI): .538–.884, p = .033), indicating a moderate prediction accuracy based on the classification by Anthony (2007). The sensitivity and specificity of the CDT at three cutoff values were 82.4% and 55.6%, respectively (Figure 6).

For the overlapping figures test, the AUC was 0.699 (95% CI: .524–.875, p = .044), indicating only a low prediction accuracy based on the classification by Anthony (2007). The sensitivity and specificity of the overlapping figures test at one cutoff value were 55.6% and 82.4%, respectively (Figure 7).

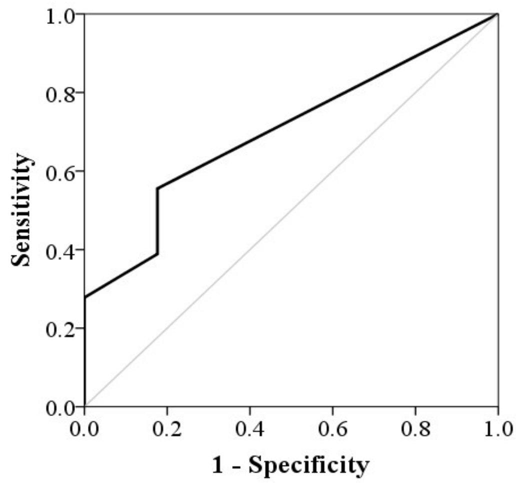

Figure 7: ROC curve of the overlapping figures test, which determines whether an AD patient will fall
For the overlapping figures, the AUC was 0.699 (95% confidence interval (95% CI): .524 – .875, p = .044), while the sensitivity and specificity at one cutoff value was 55.6% and 82.4%, respectively.
ACU: area under the receiver operating curve, AD: Alzheimer's disease, Overlapping figures test: Overlapping figures test of standard perceptual visual examination (Visual Perception Test for Agnosia; VPTA), ROC: Receiver operating characteristic

Discussion

In the present study, we divided AD patients into a fall group and non-fall group to examine the between-group differences in the test results of the CDT, overlapping figures test, constructions, PCT and YEPIT (fox/pigeon), which are visual spatial abilities tests frequently used in Japan. The results showed that the fall group performed worse than the non-fall group only in the CDT and overlapping figures test. Furthermore, for the CDT and overlapping figures test, which showed between-group differences, the AUC regarding falls was 0.771 and 0.699 for the CDT and overlapping figures test, respectively, indicating that the overlapping figures test had a low fall prediction accuracy, while the CDT had a moderate fall prediction accuracy.

The CDT and overlapping figures test were the two tests that showed significant differences between the two groups into which the participants were divided based on whether they had a history of a fall, while there was no significant difference in the other three tests (constructions, PCT, YEPIT (fox/pigeon)). Ceiling effects were observed in the constructions, PCT, and YEPIT (fox/pigeon), and a floor effect was observed in the YEPIT, while the CDT showed no ceiling effect/floor effect. In general, a test showing no ceiling effect/floor effect is considered to accurately understand the participant's function (Domen, 2010). However, because the CDT evaluation results are expressed on an 11-point scale of 0 to 10, the visual spatial abilities of the participants can be subdivided and analyzed. We believe the significant difference detected in the CDT between the two groups was due to this test characteristic.

On the other hand, the overlapping figures test showed a ceiling effect despite its use of a 7-point scale for evaluation. While the constructions only requires copying four figures, the overlapping figures test requires attentional function and linguistic function in addition to visual spatial abilities because it is a more complex task that requires the participant to (1) speak out the name of the objects or trace them with his/her finger, (2) speak out the number of geometric shapes, and (3) point out with a finger the shapes in Figure 2c that also appear in Figure 2b (Koyanagi, 2016). Therefore, it is possible that the overlapping figures test detects overall differences in cognitive function between the two groups, while also showing a ceiling effect.

With regard to the relationship of the CDT and the overlapping figures test to FIM communication and FIM social cognition, both the CDT and the overlapping figures test showed a significant correlation with FIM communication. The CDT is said to be less affected by linguistic function than the MMSE (Shulman, 2000), and visuospatial cognitive ability and execution function are said to primarily affect the CDT results (Shulman, 2000). However, in the present study, it was shown that there was a correlation with the FIM communication score, a score that measures comprehension and expression of auditory and visual communication. There are a number of studies that report the correlation of the CDT with the MMSE (Heinik, 2002; Seigerschmidt, 2002; Bozikas, 2008; Lee, 2009). In studies that qualitatively analyzed errors made in the CDT, it was reported that there were errors due to conceptual impairment where the participants were unable to understand the concept of a clock or the meaning of time (Lee, 2009; Lee, 2011). It has also been reported that the CDT score declines with the progression of AD and that the decrease in general cognitive function is especially marked when there is conceptual impairment at an early stage (Rouleau, 1996). These studies suggest that not only individual cognitive function such as visuospatial cognitive ability and execution function but also general cognitive function affects the CDT results. We believe this to be the reason for a correlation between the CDT and FIM communication in the present study. Furthermore, we believe there was a significant correlation between the overlapping figures test and the FIM communication score because the overlapping figures test requires linguistic function as well due to its complexity (Koyanagi, 2016). In contrast, both the CDT and overlapping figures test showed no correlation with FIM social cognition. A wide range of factors including cognitive function, the environmental settings of the facility (Hisano, 2008), and the patient's personality prior to developing the disease (Horimoto, 2011) are thought to affect the results of social interaction and problem solving, sub-categories of FIM social cognition. We believe this to be the reason there was no correlation.

The AUC regarding falls for the CDT and the overlapping figures test, which showed between-group differences, showed that the overlapping figures test had a low fall prediction accuracy, while the CDT showed a moderate prediction accuracy. Yamada et al. (2013) studied participants with mild cognitive impairment and reported that visual spatial abilities impairment as evaluated by the CDT was associated with falls. The present study was in agreement with their study. Based on these results, the CDT is considered to be a simple visual spatial abilities test that can be used for screening and predicting falls in AD patients. In addition, the sensitivity and specificity were 82.4% and 55.6%, respectively, at 3 points cutoff values. In a drawing of a clock that is accorded 3 points in the CDT, the numbers on the dial face are drawn close to each other creating a mild arrangement imbalance, or the time is obviously incorrect. We believe it is necessary to give warning against falls and propose post-discharge environment adjustment that takes into account the high fall risk to AD patients that draw a clock that scores fewer than 3 points. On the other hand, the prediction accuracy is only moderate when using the CDT alone. Further investigation is required into more reliable methods of predicting a fall by combining other motor function tests.

The TUG also showed a between-group difference. The results suggested that the fall group was slower than the non-fall group and that the fall group had poorer balance ability than the non-fall group. A number of studies have reported that there is a relationship between falls and the TUG (Borowicz, 2016; Granacher, 2013; Shumway-Cook, 2000), and the present study supported these results. Also, it was presumed that the visual spatial abilities of the participants might affect the TUG results. We, therefore, calculated the correlation coefficient of the TUG with the CDT and overlapping figures test using Spearman's rank correlation coefficient. The results showed that there was a significant correlation between the overlapping figures test and the TUG (r = .370, p < .05) but there was no significant correlation between the CDT and the TUG (r = -.271, p = .114). This suggests that balance ability indicated by the TUG results and visual spatial abilities indicated by the CDT results independently affected falling in the participants. Persad et al. (2010) emphasize the importance of evaluating factors that possibly influence fall risk in addition to conducting balance tests including the TUG. We, therefore, believe that both balance ability, which is evaluated by the TUG, and visual spatial abilities, which is evaluated by the CDT, are required to predict falls.

The limitations of the present study include the small sample size. The sample size in the present study was small because it was conducted as a preliminary study. Further investigations with a larger sample size are required. Furthermore, the present retrospectively studied the history of past falls. Future studies should focus on prospectively investigating whether the participants experienced a fall during a certain period of time after evaluating their visual spatial abilities to more accurately understand fall prediction accuracy. The fact that it was a retrospective study is also a limitation of the present study. In addition, the method used to investigate whether the participants experienced a fall is a limitation of the present study as it was based on the memory of main nursing caregivers. Because the present study was a retrospective study, we had to use the recall method, and because the participants were affected by memory impairment, we had to rely on the memory of the main nursing caregivers. Thus, it is possible that the investigation results regarding whether the participants experienced a fall lack sufficient reliability.

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