Characteristic of process analysis on instrumental activities of daily living according to the severity of cognitive impairment in community-dwelling older adults with Alzheimer's disease

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ABSTRACT

Objectives: To clarify the characteristic of impaired and unimpaired Instrumental Activities of daily living (IADL) processes with the severity of cognitive impairment in community-dwelling older adults with Alzheimer's disease (AD) using the Process Analysis of Daily Activity for Dementia (PADA-D).

Design: Cross-sectional study.

Setting: 13 medical and care centers in Japan.

Participants: 115 community-dwelling older adults with AD.

Methods: The severity of cognitive impairment was classified by Mini-Mental State Examination ($20 \geq$ mild group, $20 <$ moderate group ≥ 10, $10 <$ severe group), and IADL scores and eight IADL items in PADA-D were compared among three groups after adjusting for covariates. Rate of five feasible processes included in each IADL of PADA-D was compared.

Results: IADL score showed a decrease in independence with the severity of AD except for Use modes of transportation and Managing finances, which was especially pronounced in Shopping (F = 25.58), Ability to use the telephone (F = 16.75), and Managing medication (F = 13.1). However, when the PADA-D was examined by process, some processes that were impaired and unimpaired with the severity of cognitive impairment were clear. For example, Plan a meal was impaired (ES = 0.29) with the severity, but Prepare the food was not in Cooking performance.

Conclusions: We suggested that detailed process analysis in IADLs can clarify the characteristic of processes that are impaired and unimpaired with the severity of cognitive impairment in older adults with AD living in the community. Our findings may be useful for rehabilitation and care in IADL to continue living at home.

Key words activities of daily living, cognitive impairment, Alzheimer's disease, occupational therapy

Introduction

Alzheimer's disease (AD) is the most frequent cause of dementia in the older population. Activities of daily living (ADL) disability progress with the severity of cognitive impairment in patients with AD (Kamiya *et al.*, 2014; Tanaka *et al.*, 2014;

Andersen *et al.*, 2004). IADL disabilities appear from the stage of subjective memory complaints and mild cognitive impairment (MCI) and transfer to basic ADL (BADL) disabilities with cognitive declines (Ikeda *et al.*, 2019; Barberger-Gateau *et al.*, 2002). Complex IADLs, such as medication management, money management, and shopping, are known to be impaired at early stage (Kim *et al.*, 2009; Hesseberg *et al.*, 2013). According to the Diagnostic and Statistical Manual of Mental Disorders, Fifth Edition (DSM-5) (American Psychiatric Association, 2013), mild neurocognitive disorder is defined by impairments in complex IADLs such as bill payment and medication management while ADLs are independent. Therefore, it is necessary to understand the different ADL disability depending on the severity of AD and to provide rehabilitation and care to them.

The Ministry of Health, Labor, and Welfare (MHLW) in Japan announced the New Orange Plan in 2015, which aims to enable people to continue to live as they like in the community (Ministry of Health, Labor and Welfare, 2015). It is recommended in the rehabilitation of dementia in New Orange Plan to identify the cognitive function and related ability, to make the best of the ability, and to intervene and care in ADLs. It is necessary to understand which processes of ADLs are impaired and remain in order to make the best use of abilities. We have developed the Process Analysis of Daily Activity for Dementia (PADA-D), which can specifically present ADL impairments related to cognitive function, and this was reported to be both reliable and valid (Tabira *et al.*, 2019; Ikeda *et al.*, 2019). PADA-D is characterized by identifying processes of impaired and remaining of ADLs. Most of the previous ADL scales such as Functional Independence Measure (Muir-Hunter, 2016), Barthel Index (Bouwstra *et al.*, 2018), and Geriatric Rating scale for ADLs (Kobayashi *et al.*, 1988) judged ADL disability based on the amount of assistance; practitioners may have difficulty interpreting the clinical meaning of summary scores or changes in scores (Yayan *et al.*, 2020). The process of using the PADA-D for IADLs of community-dwelling AD patients may be useful for interventions by utilizing their detailed disabilities and residual abilities. Therefore, it is necessary to identify the characteristics of IADL disabilities and hard-to-be impaired processes by the severity of AD.

The aim of this study was to clarify characteristic of impaired and hard-to-be impaired IADL processes with the severity of cognitive impairment in community-dwelling older adults with AD using PADA-D and to provide basic data for rehabilitation and care in IADLs at home.

Materials and method

Study design
The study applied a cross-sectional design.

Participants
Participants were recruited from 13 medical and care centers in Japan such as medical centers for dementia, outpatient clinics specializing in dementia, day care and rehabilitation centers, and visiting nurse station between 2016 and 2020. The selection criteria were as follows: (1) major neurocognitive disorder caused by AD diagnosed by a dementia specialist based on DSM-5 diagnostic criteria, (2) age 65 years or older, (3) living at home, and (4) having family members familiar with the living situation. The exclusion criteria consisted of patients with moderate-to-severe physical impairment that affected IADL independence such as wheelchair mobility because of musculoskeletal disease. A total of 115 participants were included in the analysis, except five missing data.

Ethics
This study was approved by the Ethical Review Committee of the Kagoshima University Faculty of Medicine (Ref. No.170377). Informed consent was obtained from all study participants, and consent was obtained from family members where it was impossible to obtain from the individual because of a decline in cognitive function or other reasons, and the study was conducted with the informed assent of the individual.

Outcome measure
PADA-D (Tabira et al., 2019; Ikeda et al., 2019)

Purpose and characteristics The purpose of the PADA-D was to analyze the impairments in daily activities associated with cognitive decline along the process and to clarify specific interventions for rehabilitation and care. The characteristics of PADA-D were as follows: (1) impairment and remaining of processes related to cognitive function could be clarified, (2) activities of performances were arranged in a time series from the beginning to the end of an action, and (3) the number of processes and items was the same for all activities.

Development and survey method The processes and items of the PADA-D were developed in consultation with five occupational therapists and two dementia specialists, referring to the Physical Self-Maintenance Scale (PSMS) (Lawton *et al.*, 1969; Hokoishi *et al.*, 2001) and the Lawton IADL Scale (Lawton IADL) (Lawton *et al.*, 1969; Hokoishi

et al., 2001) recommended for ADL scale in the Clinical Practice Guideline for Dementia 2017 in Japan (Japanese Society of Neurology, 2017). The PADA-D consisted of a total of 14 activities: 6 BADL activities (Eating, Bathing, Dressing, Grooming, Mobility, and Toileting) and 8 IADL performance (Cooking, Housework, Shopping, Ability to use the telephone, Use modes of transportation, Laundry, Managing medication, and Managing finances). Each performance was divided into five processes (Table 1), and each process was further divided into three actions that make up the process (Supplementary Tables 1–8). The evaluation was based on observation at home by medical staff such as occupational therapists, but interviews with family members familiar with the living situation well were also possible. Each subitem was judged on the basis of whether the patient was actually "doing" or "not," and one point was given for "doing" (yes). If there was no habit to perform the procedure before the onset of AD, check "no habit" and "not doing" (no). Three points were available for one process, 15 points for one performance, and a total of 210 points for the 14 performances. The final scale with the items selected had high internal consistency (Cronbach $\alpha = 0.96$) and criterion validity (Tabira *et al.*, 2019). Previous studies showed that older adults with MCI and very mild AD experienced an early decline in IADLs (Schmitter-Edgecombe *et al.*, 2012; Tabira *et al.*, 2020), so this study investigated IADL-8 performance in PADA-D. This survey was conducted by an occupational therapist visiting the participant's home for observation or by interviewing the family members.

OTHER OUTCOMES

Basic information such as age, gender, living situation, and medication was examined. The Mini-Mental State Examination (MMSE), PSMS, Lawton IADL Scale, Hyogo Activities of Daily Living Scale (HADLS) (Nobutsugu *et al.*, 1997), and Degree of Independence in Daily Living of older adults with Disabilities (DIDLD) (Sagari *et al.*, 2020; Ministry of Health, Labour and Welfare, 2017) were administered by occupational therapists with adequate experience in caring for and rehabilitation of patients with dementia. The MMSE is one of the most frequently used cognitive screening questionnaires (Folstein, 1975). The PSMS is used to evaluate patients' ability to perform BADL (Lawton *et al.*, 1969; Hokoishi *et al.*, 2001). It contains six items, assessing independence in toileting, feeding, dressing, grooming, physical ambulation, and bathing. Scores range from 0 to 6; higher scores indicate better functioning. The Lawton IADL Scale evaluates eight domains of function:

Table 1. IADL performance and process in PADA-D

PERFORMANCE	PROCESS
Cooking	1 Plan a meal
	2 Prepare the food (wash, cut, and cook the ingredients)
	3 Season the ingredients (choose seasoning, etc)
	4 Plate the food
	5 Set the table
Housekeeping	1 Clean up after a meal
	2 Managing daily necessities
	3 Management of bedding
	4 Clean the house
	5 Garbage dumping
Shopping	1 Enter the store
	2 Go to the section
	3 Find a product
	4 Pay for the product
	5 Take home the product
Ability to use the telephone	1 Call others
	2 Talk on the phone
	3 Hang up the phone
	4 Notice the phone ring
	5 Answer and talk on the phone
Laundry	1 Put the laundry in the washing machine
	2 Start the washing machine
	3 Operate the dryer or find another effective means to dry the laundry
	4 Take in and fold the laundry
	5 Put the clothes in the chest/closet
Use modes of transportation	1 Take a taxi
	2 Take a bus or train
	3 Ride a bicycle
	4 Drive a mobility scooter
	5 Choose an appropriate mode of transportation
Managing medication	1 Keep the regular time to take medicate
	2 Taking out the prescribed medicine
	3 Check the correct quantity of medicine
	4 Take medicine correctly
	5 Keep track of leftover medicine
Managing finances	1 Handle cash
	2 Use cash in daily life
	3 Understand household express
	4 Use the bank and the post office
	5 Use electronic money

Eight performances, five processes.

ability to use the telephone, shopping, food preparation, housekeeping, laundry, mode of transportation, responsibility for own medication, and ability to handle finances (Lawton *et al.*, 1969; Hokoishi *et al.*, 2001). HADLS (Nobutsugu *et al.*, 1997)

assesses the level of independence with basic and IADLs. It consists of 18 items, including toileting, eating, dressing, grooming, personal hygiene, brushing, bathing, mobility, telephoning, shopping, preparing meals, cleaning, making one's bed, cleaning up after meals, doing laundry, managing fire, handling switches, and Managing finances. Total scores range from 8 to 100; higher scores indicate lower independence. DIDLD (Ministry of Health, Labour and Welfare, 2017) was classified based on the severity of physical impairment according to nine stages defined by MHLW 15 (independent; 0, patient is bedridden and requires care for excretion, eating, and dressing; 8). These ADL scales were completed visiting the participant's home for observation or using information provided by the family members.

Classification of the severity of cognitive impairment

Following a previous study according to the MMSE score, 20 points or more was classified as the mild group, 10 points or more and less than 20 points as the moderate group, and less than 10 points as the severe group (Perneczky *et al.*, 2006).

Statistical analysis

Comparisons of basic information were done based on the normality of the values. Analysis of variance and analysis of covariance (ANCOVA) were performed for PSMS, HADLS, total of PADA-D (sum of IADL and BADL), IADL score of PADA-D, and process of IADL (Cooking, Housework, Shopping, Ability to use the telephone, Use modes of transportation, Laundry, Managing medication, and Managing finances) for each severity stage of cognitive impairment. The covariates were age, gender, living situation, and medication. Chi-square test or Fisher exact test, residual analysis, and effect size (ES) calculation were conducted for the rate of feasible IADL process (independence: three perfect score) by the severity stage of cognitive impairment in PADA-D. Cramer's V was used as an ES to examine the strength of coherence among the three groups (Ferguson, 2009). ES was small (ES < 0.1), medium ($0.1 \leq ES < 0.5$), and large ($0.5 \leq ES$) (Cohen, 1988). The significance level was $P < 0.05$, and Holm correction (Holm, 1979) was performed. Residual analysis was performed using adjusted residuals for the three groups: mild, moderate, and severe. Adjusted residuals were calculated to test which group has significant difference in the chi-square test (Shelby, 1973) Adjusted residuals with an absolute value of 2.56 or higher were considered $p < 0.01$ (Agresti, 2002). The significance level was $p < 0.01$. All statistical analyses were performed

using the IBM SPSS Statistic version 27.0 (IBM Corp., Armonk, NY). 95% confidence intervals for the ES measure (Cramer's V) were calculated using R version 4.0.3.

Results

Characteristics of the study participants

Table 2 summarizes the characteristics of study participants. A total of 115 participants were included in the analysis of the survey items obtained from 120 participants, excluding those 5 participants with missing information. Among the 115 participants, 85 (74%) were female, 24 (21%) were living alone, and 109 (95%) were taking medication. No significant differences in age, gender, living status, or medication were observed according to the severity of cognitive impairment.

IADL independence by the severity of cognitive impairment

Table 3 shows the comparison of IADL assessment by the severity of cognitive impairment. Lawton IADL, HADLS, and total and IADL of PADA-D significantly decreased in independence with the severity of cognitive impairment.

In each performance of IADL in the PADA-D, the following results were obtained using the ANCOVA model after adjusting for covariates (adjust model): significant main effects were found for Cooking ($F = 4.06$, $p = 0.012$), Housework ($F = 6.54$, $p = 0.016$), Shopping ($F = 25.58$, $p < 0.001$), Ability to use the telephone ($F = 16.75$, $p < 0.001$), Laundry ($F = 5.03$, $p < 0.01$), and Managing medication ($F = 13.1$, $p < 0.001$). There was no main effect for Use modes of transportation and Managing finances. In the multiple comparisons, Shopping, Ability to use the telephone, and Managing medication, which had high F values, showed significant decrease in independence with the severity.

IADL processes of PADA-D according to severity of cognitive impairment

Table 4 shows the IADL processes of PADA-D, and Figure 1 visualizes them. Significant differences were observed in the rate of independence according to the severity of cognitive impairment in the following processes: Plan a meal (ES = 0.29) in Cooking, Clean up after a meal (ES = 0.32) in Housekeeping, all processes in Shopping and Ability to use telephone, Put the laundry in the washing machine (ES = 0.33), Start the washing machine (ES = 0.38), Put the clothes in the chest/closet (ES = 0.35) in Laundry, Ride a bicycle (ES = 0.35) in Use modes of transportation, Keep regular time to take medicine (ES = 0.33), Taking

Table 2. Characteristics of study participants

CHARACTERISTIC	OVERALL N = 115	MILD N = 41	MODERATE N = 56	SEVERE N = 18	P-VALUE[1]
Age, Mean (SD)	80.95 (8.05)	79.6 (8.79)	81.75 (7.34)	81.72 (8.51)	0.76[a]
Gender, N (%)					0.60[b]
Male	30 (26%)	11 (27%)	16 (29%)	3 (17%)	
Female	85 (74%)	30 (73%)	40 (71%)	15 (83%)	
MMSE, Mean (SD)	17.38 (5.98)	23.12 (2.74)	16.32 (2.17)	7.00 (3.01)	<0.01[a]
Living status, N (%)					0.23[b]
Living alone	24 (21%)	10 (24%)	13 (23%)	1(6%)	
Living with someone	91 (79%)	31 (76%)	43 (77%)	17 (94%)	
Medication, N (%)					0.58[c]
Yes	109 (95%)	40 (97%)	52 (93%)	17 (94%)	
No	6 (5%)	1 (3%)	4 (7%)	1 (6%)	
DIDLD					0.32[d]
Median (Min-Max)	2 (0–6)	2 (0–4)	3 (0–5)	3 (1–6)	

[1] Statistical tests performed: a one-way ANOVA; b chi-square test of independence; c Fisher's exact test; d Kruskal–Wallis test.
MMSE; Mini-Mental State Examination, DIDLD; Degree of Independence in Daily Living of older adults with Disabilities.

out the prescribed medicine (ES = 0.42), Check the correct quantity of medicine (ES = 0.29) in Managing medication, and Handle cash (ES = 0.49) in Managing finances. In addition, high ESs were found for the following processes: Shopping (Find a product; ES = 0.50, Pay for the product; ES = 0.51) and Ability to use the telephone (Call others; ES = 0.53, Talk on the phone; ES = 0.55).

No significant differences were found in the following processes: Prepare the food, Season the ingredients, plate the food and Set the table in Cooking, Managing daily necessities and Management of bedding and Clean the house in Housekeeping, Operate the dryer, or Find another effective means to dry the laundry and Take in and fold the laundry in Laundry, four processes other than Ride a bicycle in Use modes of transportation, Take medicine correctly and Keep track of leftover medicine in Managing medication, and four processes other than Handle cash in Managing finances.

Discussion

In this study, we examined processes of IADL disability and remaining with the severity of cognitive impairment in community-dwelling older adults with AD using the PADA-D. The IADL score showed a decrease in independence with the severity of AD except for Use modes of transportation and Managing finances, which was especially pronounced in Shopping, Ability to use the telephone, and Managing medication. However, when the PADA-D was examined by process, some processes, impaired and unimpaired with the severity of cognitive impairment, were clear. For example, Plan a meal was impaired with the severity, but Prepare the

food was not in Cooking performance. The findings of this study may be useful for support and rehabilitation of IADL in AD patients by analyzing IADL processes in detail, which is impaired in each stage of cognitive impairment.

IADL independence by the severity of cognitive impairment

The independence of IADLs other than Use modes of transportation and Managing finances decreased with the severity of AD, especially significant differences were large in Shopping, Ability to use the telephone, and Managing medication. These findings coincide with those of past studies, wherein independence in using the telephone, medication management, using home appliances, and transport was significantly lower among patients with MCI and mild AD than healthy older adults (Reppermund *et al.*, 2011; Rodakowski *et al.*, 2014). In cohort study in patients with mild-to-moderate AD, shopping, medication management, and meal preparation also decreased in frequency in that order (Mlinac, 2016). Shopping, ability to use the telephone, and managing medication are complex IADL requiring cognitive functions such as executive function (Saari *et al.*, 2018; Putcha *et al.*, 2016) and self-management for life over time (Mariani *et al.*, 2008). Independence in complex IADL was decreased by progressing cognitive impairment because of deterioration in various cognitive functions necessary for daily life performance and management, including executive function, space perception (Han *et al.*, 2020), and time orientation (Dubois *et al.*, 2014) in AD patients. We considered that independence of Use of transportation may not change with the progression of cognitive impairment

Table 3. IADL independence by the severity of cognitive impairment[4]

CHARACTERISTIC	OVERALL N = 115[1]	MILD (A) N = 41[1]	MODERATE (B) N = 56[1]	SEVERE (C) N = 18[1]	CRUDE MODEL[2] F	p	ADJUSTED MODEL[3] F	p	POST HOC[5]
Lawton IADL (Max 6)	3.17 (2.26)	4.77 (20.3)	2.68 (1.86)	0.89 (0.96)	32.56	<0.001	30.59	<0.001	a>b>c
HADLS-total (Max 100)	34.23(19.46)	23.28 (15.05)	36.29 (17.53)	54.07 (17.12)	22.65	<0.001	20.73	<0.001	a<b<c
PADA-D total (Max 210)	124.85 (40.44)	148.35 (31.08)	121.32 (35.79)	79.67 (32.08)	27.13	<0.001	25.15	<0.001	a>b>c
PADA-D IADL-total (Max 120)	46.54 (31.30)	64.58 (25.5)	41.93 (29.70)	17.78 (21.36)	20.51	<0.001	18.85	<0.001	a>b>c
Performance of PADA-D IADL									
Cooking (Max 15)	6.60 (6.26)	7.95 (6.48)	6.46 (6.30)	3.59 (4.52)	3.09	0.011	4.06	0.012	a,b>c
Housekeeping (Max 15)	5.42 (4.71)	7.21 (4.76)	4.96 (4.62)	2.56 (2.97)	7.42	0.008	6.54	0.016	a>c
Shopping (Max 15)	8.09 (6.34)	12.05 (4.54)	7.02 (6.38)	1.94 (2.87)	24.95	<0.001	25.58	<0.001	a>b>c
Ability to use the telephone (Max 15)	8.81 (6.44)	12.67 (4.47)	7.75 (6.43)	1.94 (2.87)	21.88	<0.001	16.75	<0.001	a>b>c
Laundry (Max 15)	7.72 (6.20)	9.26 (6.26)	7.58 (6.26)	4.29 (4.42)	4.14	0.006	5.03	0.008	a,b>c
Use modes of transportation (Max 15)	1.93 (3.15)	2.57 (3.34)	1.33 (2.21)	1.67 (3.00)	1.45	0.246	1.48	0.234	
Managing medication (Max 15)	6.12 (4.48)	8.47 (4.49)	5.78 (4.58)	1.56 (2.70)	16.53	0.002	13.01	<0.001	a>b>c
Managing finances (Max 15)	2.89 (3.77)	4.77 (3.79)	2.20 (3.51)	0.56 (2.35)	11.45	0.009	8.41	0.031	

[1] Mean (SD).
[2] Analysis of Variance.
[3] Analysis of covariance; adjusted with age, gender, medication, living status, degree of independence in daily living of older adults with disabilities.
[4] The significance level was $P < 0.05$, and Holm correction was performed to avoid type I error.
[5] Post hoc test used Bonferroni method, adjust model.
HADLS; Hyogo Activities of Daily Living Scale, PADA-D; Process Analysis of Daily Activities for Dementia, PSMS; Physical Self-Maintenance Scale.

Table 4. IADL processes of PADA-D according to severity of cognitive impairment

PROCESSES IN PADA-D IADL	OVERALL N = 115[1]	MILD N = 41[1]	D[1]	MODERATE N = 56[1]	D[1]	SEVERE N = 18[1]	D[1]	ES	95% CI[2]	P-VALUE[3]
Cooking										
independence, n (%)										
1. Plan a meal	36 (31)	17 (41)	1.7	19 (34)	0.7	0 (0)	− 3.1*	0.29	0.16–0.49	0.007†
2. Prepare the food	44 (38)	18 (43)	0.8	21 (38)	− 0.1	5 (28)	− 1.0	0.16	0.13–0.30	0.542
3. Season the ingredients	32 (28)	17 (41)	2.3	15 (27)	− 0.2	0 (0)	− 2.8	0.30	0.16–0.50	0.038
4. Plate the food	45 (39)	22 (52)	2.3	19 (34)	− 1.0	4 (22)	− 1.6	0.23	0.13–0.43	0.051
5. Set the table	62 (53)	26 (62)	1.4	31 (55)	0.4	5 (28)	− 2.4	0.23	0.13–0.43	0.048
Housekeeping										
independence, n (%)										
1. Clean up after a meal	55 (47)	27 (64)	2.7*	25 (45)	− 0.6	3 (17)	− 2.8*	0.32	0.18–0.52	0.003†
2.Managing daily necessities	11 (10)	7 (17)	2.0	3 (5)	− 1.5	1 (6)	− 0.6	0.19	0.13–0.38	0.138
3. Management of bedding	22 (19)	10 (24)	1.0	12 (21)	0.7	0 (0)	− 2.2	0.21	0.13–0.40	0.079
4. Clean the house	37 (32)	17 (41)	1.5	17 (30)	− 0.3	3 (17)	− 1.5	0.17	0.13–0.37	0.182
5. Garbage dumping	24 (21)	13 (31)	2.1	11 (20)	− 0.3	0 (0)	− 2.4	0.25	0.13–0.45	0.024
Shopping										
independence, n (%)										
1. Enter the store	58 (50)	30 (71)	3.5*	27 (48)	− 0.4	1 (6)	− 4.1*	0.44	0.29–0.65	<0.001††
2. Go to the section	57 (49)	30 (71)	3.6*	27 (48)	− 0.2	0 (0)	− 4.5*	0.47	0.32–0.67	<0.001††
3. Find a product	50 (43)	30 (71)	4.6*	20 (36)	− 1.6	0 (0)	− 4.0*	0.50	0.34–0.70	<0.001††
4. Pay for the product	39 (34)	27 (64)	5.3*	12 (21)	− 2.7*	0 (0)	− 3.3*	0.51	0.36–0.71	<0.001††
5. Take home the product	68 (59)	35 (83)	4.1*	31 (55)	− 0.7	2 (11)	− 4.5*	0.49	0.34–0.69	<0.001††
Ability to use the telephone										
independence, n (%)										
1. Call others	54 (47)	33 (79)	5.2*	20 (36)	− 2.3	1 (6)	− 3.8*	0.53	0.37–0.73	<0.001††
2. Talk on the phone	59 (51)	35 (83)	2.2	23 (41)	0.1	1 (6)	− 3.3*	0.55	0.39–0.75	<0.001††
3. Hang up the phone	68 (59)	35 (83)	4.1*	29 (52)	− 1.4	4 (22)	− 3.4*	0.43	0.28–0.64	<0.001††
4. Notice the phone ring	63 (54)	30 (71)	2.8*	29 (52)	− 0.5	4 (22)	− 3.0*	0.33	0.19–0.53	0.002†
5. Answer and talk on the phone	68 (59)	34 (81)	3.7*	30 (54)	− 1.1	4 (22)	− 3.4*	0.41	0.26–0.61	<0.001††
Laundry										
independence, n (%)										
1. Put the laundry in the washing machine	48 (41)	23 (55)	2.2	24 (43)	0.3	1 (6)	− 3.4*	0.33	0.19–0.53	0.002†
2. Start the washing machine	48 (41)	26 (62)	3.4*	21 (38)	− 0.8	1 (6)	− 3.4*	0.38	0.24–0.58	<0.001††
3. Operate the dryer or find another effective means to dry the laundry	57 (49)	23 (55)	0.9	27 (48)	− 0.2	7 (39)	− 0.9	0.11	0.03–0.30	0.520
4. Take in and fold the laundry	58 (50)	23 (55)	0.8	30 (54)	0.7	5 (28)	− 2.1	0.19	0.13–0.39	0.121
5. Put the clothes in the chest/closet	46 (40)	24 (57)	2.9*	21 (38)	− 0.5	1 (6)	− 3.2*	0.35	0.21–0.55	0.001†
Use modes of transportation										
independence, n (%)										
1. Take a taxi	16 (14)	9 (21)	1.8	6 (11)	− 0.9	1 (6)	− 1.1	0.23	0.03–0.28	0.337

Table 4. Continued

PROCESSES IN PADA-D IADL	OVERALL N = 115[1]	MILD N = 41[1]	D[1]	MODERATE N = 56[1]	D[1]	SEVERE N = 18[1]	D[1]	ES	95% CI[2]	P-VALUE[3]
2. Take a bus or train	12 (10)	6 (14)	1.0	5 (9)	− 0.5	1 (6)	− 0.7	0.23	0.13–0.30	0.530
3. Ride a bicycle	10 (9)	9 (21)	3.2*	0 (0)	− 3.2*	1 (6)	− 0.5	0.35	0.20–0.55	0.001†
4. Drive a mobility scooter	4 (3)	1 (2)	− 0.5	2 (4)	0.1	1 (6)	0.5	0.06	0.04–0.32	0.824
5. Choose an appropriate mode of transportation	13 (11)	8 (19)	2.0	4 (7)	0.8	1 (6)	− 0.8	0.19	0.13–0.38	0.129
Managing medication independence, n (%)										
1. Keep the regular time to take medicate	26 (22)	17 (41)	3.5*	8 (14)	− 2.0	1 (6)	− 1.9	0.33	0.19–0.53	0.002†
2. Taking out the prescribed medicine	51 (44)	28 (38)	3.7*	22 (39)	− 1.0	1 (6)	− 3.6*	0.42	0.27–0.62	<0.001††
3. Check the correct quantity of medicine	38 (33)	20 (48)	2.6*	17 (30)	− 0.5	1 (6)	− 2.7*	0.29	0.17–0.50	0.006†
4. Take medicine correctly	38 (33)	15 (36)	0.5	22 (40)	1.4	1 (6)	− 2.7	0.25	0.13–0.44	0.026
5. Keep track of leftover medicine	21 (18)	11 (26)	1.7	9 (16)	− 0.5	1 (6)	− 1.5	0.18	0.13–0.38	0.141
Managing finances independence, n (%)										
1. Handle cash	47 (41)	29 (69)	4.7*	18 (32)	− 1.8	0 (0)	− 3.8*	0.49	0.34–0.69	<0.001††
2. Use cash on a daily life	11(10)	6 (14)	1.3	5 (9)	− 0.2	0 (0)	− 1.5	0.16	0.13–0.35	0.219
3. Understand household express	11(10)	6 (14)	1.3	4 (7)	− 0.8	1 (6)	− 0.6	0.13	0.13–0.32	0.405
4. Use the bank and the post office	13 (11)	7 (17)	1.4	5 (9)	− 0.8	1 (6)	− 0.8	0.14	0.13–0.33	0.345
5. Use electronic money	2 (2)	1 (2)	0.4	1 (2)	0.0	0 (0)	− 0.6	0.06	0.05–0.22	0.809

[1] Represents adjusted residuals, * $p < 0.01$ represent the results of residual analysis, adjusted residuals with an absolute value of 2.56 or higher were considered $p < 0.01$.
[2] CI; Confidence intervals.
[3] Statistical tests performed: chi-square test of independence and Fisher's exact test. The significance level was $p < 0.01$ to avoid type I error whenever possible. †$p < 0.01$, ††$p < 0.001$. ES; effect size, PADA-D; Process Analysis of Daily Activities for Dementia.

Cooking

Housekeeping

Laundry
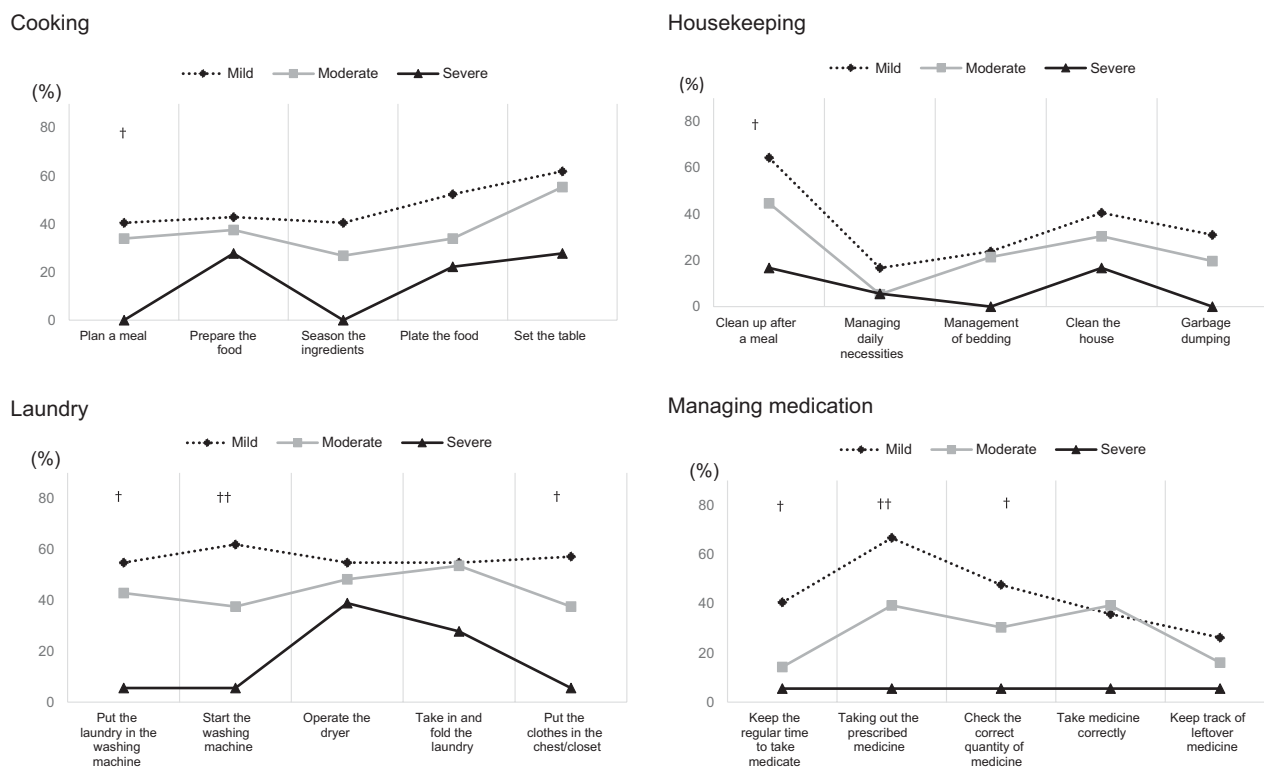

Managing medication

Figure 1. IADL processes of PADA-D according to severity of cognitive impairment. Cooking, Housekeeping, Laundry, Managing medication. Chi-square test or Fisher exact test, residual analysis was conducted for the rate of feasible IADL process by the severity stage of cognitive impairment in PADA-D. $^{\dagger}p < 0.01$, $^{\dagger\dagger}p < 0.001$. Mild; mild group ($n = 41$), Moderate; moderate group ($n = 56$), Severe; severe group ($n = 18$). PADA-D; Process Analysis of Daily Activity for Dementia.

because the use of taxi, buses, trains, bicycles, and mobility scooter may differ depending on individual habits and environments. However, compared to other IADLs, the rate of independence was lower for mild and moderate groups, and Use modes of transportation may be impaired from the early stages of AD.

IADL processes of PADA-D according to severity of cognitive impairment

In processes of Cooking, Plan a meal was significantly lower in the severe group, while Prepare the food, Plate the food, Season the ingredients and Set the table were not significantly different. According to the study in IADL profile of cooking, planning was the most difficult among setting goals, planning, executing, and checking, and required more assistance (Bier *et al.*, 2016). Plan a meal consists of Search for and understand the steps for cooking, Prepare the ingredients and Prepare the cooking utensils and requires memory to recall the menu, necessary ingredients, and steps. As cognitive function declines, support for Plan a meal may become necessary. On the other hand, Prepare the food, which includes wash, cut, and cook the ingredients, was less likely to be defected. This may indicate that AD patients are able to utilize procedural

memory, which is less likely to be impaired in cognitive functions (Wit *et al.*, 2018). We considered that need to encouraging AD patients continue to perform these remaining (hard-to-be impaired) processes without excessive assistance of caregiver.

In Laundry, processes of Put the laundry in the washing machine and Start the washing machine were impaired according to the severity. Recent washing machines are highly functional and have many buttons in Japan, so operation errors are expected in older adults with cognitive decline (Ikeda *et al.*, 2021). Supportive guide such as landmarks may be necessary in this case (Graff, 2006). In addition, independence of Operate the dryer and Take in and fold the laundry did not decrease with the severity. Operate the dryer includes Stretch the wrinkle on the laundry and Hang the laundry, Take in and fold the laundry includes Fold the laundry according to the shape of clothes. These processes are highly habitual among older Japanese women and may be considered as unique culture in Japan. In addition, it may be to utilize procedural memory, which is one of the less cognitive declines in AD patients (Wit *et al.*, 2018). Since each 39 and 28% in the severe group were able to perform these processes independently, continuous performance of these processes may prevent the severity of laundry disability. Caregivers assisting only those

impaired processes may lead to independence of Laundry in AD patients.

In Housekeeping, processes of Clean up after a meal was impaired with increasing severity. Clean up after a meal includes Put the dishes back where they belong, which requires memory of the original place. This may also be improved by environmental adjustments such as markers and color on the cupboard to supplement in cognitive impairment such as memory and space perception (Motzek *et al.*, 2016; Chard *et al.*, 2009).

In Managing medication, processes of Keep the regular time to take medicate, Taking out the prescribed medicine, and Check the correct quantity of medicine were impaired with increasing severity. Medication management is a complex IADL and is impaired early stage in AD patients (Kim *et al.*, 2009; Hesseberg *et al.*, 2013). Defects of time and place orientation (Dubois *et al.*, 2014) and space perception (Han *et al.*, 2020) may affect these processes. Environmental cues such as color may be adaptive for errors in Check the correct quantity of medicine, and assistive technologies such as electronic calendars and automatic medication dispenser may be adaptive for errors in Keep the regular time to take medicate and Taking out the prescribed medicine (Motzek *et al.*, 2015; Chard *et al.*, 2009; Kamimura, 2019; Nishiura *et al.*, 2021).

According to the Occupational Therapy Guidelines for adults with AD and Related Major Cognitive Disorder (Piersol & Lou, 2018), Occupation-Based Interventions such as ADL training and activity modification, Interventions that address perception, Interventions that address caregiver strategies, Errorless learning and Prompting strategies, Environment-based interventions are recommended rehabilitation for ADL. Understanding the impaired and hard-to-be impaired IADL processes by using PADA-D may help clarify intervention points and assist in these recommended rehabilitations.

The strength of this study is that specific impairments and hard-to-be impaired processes in IADL were clarified by analyzing the IADL processes in community-dwelling older adults with AD and comparing them with severity of cognitive impairment. This finding is novel and can contribute to the care and rehabilitation for IADL.

Several limitations should be noted. First, the recruiting facilities are multicenter. We recruited 13 medical and care centers (medical centers for dementia, outpatient clinics specializing in dementia, etc.), but there is possibility of selection bias because of the functional characteristics of each facility. On the other hand, it is also the strength of multifacility study. Second, this study was cross-sectional. Longitudinal follow-up is necessary to examine the effect of cognitive decline on IADL independence. However, our findings are informative in that we investigated IADL process with severity of cognitive impairment in older adults with AD. Third limitation is the bias of the sample size. The severe AD group (18 participants) was less than half as large as the mild and moderate groups. Older adults with severe dementia often have difficulty living in home, and high percentage of hospitalization and admission (Alzheimer's Association, 2013). However, sample size needs to be increased, and random fluctuations should be considered in the future research. In addition, Tables 3 and 4 consider type I errors whenever possible, but does not completely avoid them. Future study should pay close attention to type I error. Fourth limitation is behavioral and psychological symptoms of dementia (BPSD). BPSD may also affect ADL (Hsieh *et al.*, 2021), but we could not evaluate them. BPSD should be considered as confounders in the future research.

Conclusion

We examined which IADL processes were impaired or not as cognitive impairment progressed in 115 community-dwelling older adults with AD using PADA-D. Degree of independence was observed to be decreased in most IADL performances as cognitive impairment progressed. In particular, Plan a meal in Cooking, Clean up after a meal in Housework, and Start the washing machine in Laundry were found to be impaired with increasing severity; however, Prepare the food in Cooking and Operate the dryer or find another effective means to dry the laundry were maintained. Process analysis in the IADL in detail was considered important not only for supporting the older adults with AD living in the community to continue living at home but also for a very early diagnosis of AD.

Conflict of interest

None.

Description of authors' roles

T. Tabira and M. Hotta designed the study and wrote the initial draft of the manuscript. S. Shimokihara, M. Maruta, G. Han, Y. Ikeda,

Supplementary material

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