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Direct and indirect effects of nutritional status, physical function and cognitive function on activities of daily living in Japanese older adults requiring long-term care

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Aim: To identify the direct and indirect effects of nutritional status, physical function, and cognitive function on activities of daily living in Japanese older adults requiring long-term care.

Methods: In total, 179 participants aged ≥65 years who were eligible for long-term care insurance (mean age 85.5 ± 7.8 years) were recruited for this study. Nutritional status (Mini Nutritional Assessment, Short Form) and physical function (Short Physical Performance Battery) were examined. Activities of daily living, cognitive function and frailty were assessed using the Barthel Index, Mini-Mental State Examination and Clinical Frailty Scale, respectively. Path analysis was used to determine relationships between these factors and the activities of daily living.

Results: For Japanese older adults requiring long-term care, pathways were modeled for nutritional status, physical function and the activities of daily living. The total effect of nutritional status was 0.516 ($P < 0.001$). The indirect effect of nutritional status through physical function on the activities of daily living was 0.458 ($P < 0.001$). Finally, no significant direct effect of nutritional status on activities of daily living was observed (b = 0.058, $P = 0.258$).

Conclusions: The present study identified the complex pathway from nutritional status to the activities of daily living through physical function in aged Japanese people requiring long-term care. These findings suggest that maintaining good nutritional status and nutritional support might delay physical function decline, and prolong the activities of daily living. **Geriatr Gerontol Int 2014; 14: 799–805.**

Keywords: activities of daily living, frail elderly, nutritional status, path analysis, physical function.

Introduction

In Japan, dramatic reductions in early mortality and declining fertility have resulted in a rapidly aging population. The percentage of the population aged 65 years and older in Japan was 24.3% in 2011.[1] Nursing services are required for support of elderly individuals who require long-term care because of physical disability. Since 2000, these services have been provided in Japan through the social insurance system enacted in the Long-term Care Insurance Act.[2] In this system, applicants for services are classified into six grades (support level and care levels 1, 2, 3, 4, and 5) according to the severity of physical disability, and the required amount of nursing intervention is determined by grade.[3] In 2011, long-term care insurance provided approximately 4 million people with home care services, and approximately 1 million people with care in a long-term facility, such as a nursing home.[3,4] The health status of 29% of elderly Japanese requiring long-term care deteriorated, as measured by the grade of care service required, and 56% of them died within 6 years.[5] Care insurance covers two types of services: in-home (domiciliary) services (e.g. home help, bathing assistance, visiting rehabilitation, day care service, visiting nurse, assistive device leasing, short stays, in-home medical care, care management, and an allowance for the purchase of assistive devices and home renovation) and institutional services. For elderly people receiving nursing care, further deterioration in their ability to carry out activities of daily living (ADL), such as bathing, dressing and walking, is an important concern.

Previous studies have suggested that malnutrition can lead to deterioration in ADL.[6] However, a decline in ADL might have multiple etiologies. Studies have shown associations between decline in this ability and

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low bodyweight, low fat-free mass, and lower biceps and quadriceps strength;[7] poor nutritional status and weak extremity muscles;[8] and weight loss.[9] Nutritional status may influence ADL limitations indirectly through functional or cognitive deterioration.

The ability to carry out ADL is affected by complex direct and indirect interactions among multiple factors. Previous studies have not always considered the indirect effects of various risk factors. They tended to analyze only direct effects between two variables. In order to determine these indirect effects, a statistical method must be provided that identifies several pathways simultaneously in one path analysis. Multiple factors must be incorporated into a comprehensive analysis as independent variables to show their effects on deterioration in ADL. In the present study, the direct and indirect effects of nutritional status, physical function and cognitive function on ADL were examined in Japanese older adults requiring long-term care.

Methods

The study population initially consisted of 195 participants aged 65 years or older who were eligible to receive long-term care insurance, lived in Iwata City and received various home care services from the Iwata City Health Care Service Foundation for Older People. Of these, 16 participants with missing data were excluded. Thus, in total, 179 participants (36 men, 143 women) were included. Before the data collection, oral or written informed consent was obtained from the residents or their relatives or legal guardians in cases in which geriatric residents were incapable of providing such consent.

Anthropometric measurements

Height was measured to the nearest 0.1 cm with participants barefoot and standing, when possible. Height was estimated from knee height for those with severe kyphosis or for whom standing was not possible.[10] Body mass index (BMI; kg/m^2) was calculated from the weight and height. Body circumference was measured with a measuring tape at the mid-arm and calf.

Handgrip strength

Handgrip strength was measured using a Smedley-type hand dynamometer (model TKK5001; Takei Scientific Instruments, Niigata, Japan). Participants were seated on a straight-backed chair without armrests with shoulders adducted, elbows flexed at 90°, forearms in neutral position and wrists slightly extended. Two measures were taken from the dominant hand, and the highest measure was recorded (kg of force).

Cognitive function

Cognitive function was assessed using the Mini-Mental State Examination (MMSE).[11] MMSE scores range from 0 to 30, with lower scores indicating more severe cognitive impairment in the domains of orientation, memory, attention and executive functions. Scores between 0 and 21 are typical for subjects with cognitive impairment (sensitivity 87.0%, specificity 82.0%).[12]

Nutritional status

Nutritional status was assessed using the Mini Nutritional Assessment, Short Form (MNA-SF).[13] The MNA-SF has the option of using calf circumference when BMI measurement is not possible for bedridden and immobile subjects. MNA-SF was developed and validated to allow a two-step screening process in low-risk populations; this version of the instrument retains the validity and accuracy of the full MNA.[14] The MNA-SF can be completed in less than 10 min.[15] Each answer has a numerical value, and contributes to the final maximum score of 14. Threshold values have been established for Japanese frail elderly populations as follows: scores of ≥12 indicate that subjects are well-nourished; scores of 8–11 indicate risk of malnutrition; and scores of <8 indicate malnourishment. The sensitivity, specificity and positive predictive value of the MNA-SF in Japanese frail elderly populations have been established as 86.0%, 84.0%, and 95.0%, respectively.[16]

Physical function

Physical function was assessed using the Short Physical Performance Battery (SPPB). SPPB is a well-established, reliable and valid measure of functional status.[17,18] Testing involves assessment of standing balance, a timed 4-m walking test, and a timed test of five repetitions of rising from a chair and sitting down. All times are measured to the nearest 0.01 s using a stopwatch. Each test is scored between 0 and 4, and the scores are summed for a maximum score of 12. Higher scores represent better functioning. Scores on SPPB have been observed to predict disability within 1–6 years in several older populations.[17,18]

ADL

Activities of daily living was assessed using the Barthel Index (BI), which covers all aspects of self-care independence in ADL, such as transfer, walking, use of stairs, toilet use, dressing, feeding and bathing.[19] A total score of 100 points indicates complete self-sufficiency, whereas a score of zero indicates complete dependence.[19]

Frailty

Frailty was assessed using the Canadian Study of Health and Aging Clinical Frailty Scale (CSHA-CFS). CSHA-CFS was introduced in the second version of the CSHA assessment tool to provide increased emphasis on frailty, and as a means of stratifying elderly patients according to the relative degree of vulnerability.[20] It uses simple clinical descriptors to stratify seven grades of fitness/frailty. Higher scores are associated with a greater risk of mortality.

Statistical analysis

The SPSS software version 19.0 for Windows (IBM SPSS Japan, Tokyo, Japan) was used for data analyses. One-way analysis of variance was used to determine differences among the three groups. Age was utilized as covariates when a factor was found to have a significant relationship with the independent variable. The post-hoc multiple comparisons least significant differences test was used to identify pairwise differences. The χ^2-test and Student's *t*-test were used to assess differences in categorical variables and continuous variables, respectively. A significance level of $P < 0.05$ was set for the regression coefficients.

To determine the relationships among nutritional status, physical function, cognitive function, ADL and frailty, a path analysis was carried out using AMOS 16 structural equation modeling. The mediating effects of the variables were evaluated in a specified model with path diagrams. Path analysis can be used instead of several separate regressions to examine mediating effects within a single model.[21] In addition, path analysis allows testing of causal relationships among a set of observed variables.[22]

The degree of correspondence between the hypothesized models and the actual data was assessed with a goodness-of-fit test. Criteria for the goodness-of-fit test included a comparative fit index (CFI), a Tucker–Lewis index (TLI) and root mean square error of approximation (RMSEA). Values of >0.95 for the CFI, >0.95 for the TLI and <0.06 for the RMSEA are considered to indicate a good fit of the data to the model.[23,24] Statistical power was considered for this analysis. In a path analysis, sample sizes of approximately 150–200 are desirable.[25] Standardized path coefficients were used to estimate effect size (range –1.0 to 1.0). The size of the effect of these coefficients was determined using the following classification: <0.10 = a small effect, 0.11–0.30 = a medium effect and 0.31–0.50 = a large effect. These values are recommendations. Effect sizes can be reasonably estimated in combination with tests of significance, which also take into account sample size and correlations between variables.[26]

Results

The general characteristics of the participants are shown in Table 1. The participants included 90 community-dwelling elderly people and 89 institutionalized elderly people. Their mean age was 85.5 ± 7.8 years (range 65–102 years). The mean BMI was 19.5 ± 3.3 (range 12.4–31.9).

Results for the analysis of ADL, physical function and cognitive function according to the three categories of nutritional status (well-nourished, at risk of malnutrition, malnourished) are presented in Table 2. According to the original cut-off point system in MNA-SF, 25.7% of those assessed were malnourished, 54.7% were at risk of malnutrition and 19.6% were well nourished.

Table 1 Basic characteristics of the study population

	Community (n = 90)	Nursing home (n = 89)	Total (n = 179)	$P^†$
Male (n)	25	11	36	<0.05
Female (n)	65	78	143	
Age (years)	84.3 ± 8.2	86.7 ± 7.2	85.5 ± 7.8	<0.05
Height (cm)	151.6 ± 6.2	148.8 ± 5.8	150.2 ± 6.2	<0.01
Weight (kg)	47.1 ± 9.7	41.2 ± 6.9	44.2 ± 8.9	<0.001
BMI (kg/m^2)	20.4 ± 3.7	18.6 ± 2.5	19.5 ± 3.3	<0.001
Midarm circumference (cm)	23.4 ± 3.5	21.6 ± 2.7	22.5 ± 3.3	<0.001
Calf circumference (cm)	30.5 ± 3.8	27.3 ± 3.2	28.9 ± 3.3	<0.001
MMSE score	20.5 ± 5.9	13.0 ± 8.9	16.8 ± 8.4	<0.001
SPPB score	4.9 ± 3.5	2.0 ± 2.9	3.5 ± 3.5	<0.001
BI	81.9 ± 20.1	45.8 ± 33.6	64.0 ± 33.0	<0.001
Grip strength (kg)	15.9 ± 7.5	8.8 ± 7.6	12.4 ± 8.3	<0.001
Clinical Frailty Scale	4.7 ± 1.5	6.4 ± 0.9	5.5 ± 1.5	<0.001

$^†P$ = comparison between community and nursing home. Data are presented as mean ± SD. BI, Barthel Index; BMI, body mass index; MMSE, Mini-Mental State Examination; SPPB, Short Physical Performance Battery.

Table 2 Participants' characteristics according to nutritional status

	Well nourished (n = 35)	At risk (n = 98)	Malnourished (n = 46)	P
Male (n)	7	24	5	NS
Female (n)	28	74	41	
Age (years)	83.6 ± 6.5	84.7 ± 8.5*	88.5 ± 6.4*	<0.05
Height (cm)	151.5 ± 5.7	150.7 ± 6.5	148.2 ± 5.4	<0.05
Weight (kg)	53.3 ± 6.8	43.7 ± 8.0*	38.4 ± 6.4**	<0.001
BMI (kg/m^2)	23.2 ± 2.5	19.2 ± 2.9*	17.4 ± 2.4**	<0.001
Midarm circumference (cm)	25.7 ± 2.8	22.3 ± 2.9*	20.5 ± 2.4**	<0.001
Calf circumference (cm)	33.1 ± 2.9	28.7 ± 3.1*	26.2 ± 3.3**	<0.001
MMSE score	22.0 ± 4.1	17.7 ± 7.6*	10.9 ± 9.1**	<0.001
SPPB score	6.7 ± 3.6	3.3 ± 3.2*	1.3 ± 1.9**	<0.001
BI	90.0 ± 17.6	67.0 ± 27.1*	37.7 ± 35.1**	<0.001
Grip strength (kg)	17.2 ± 6.4	13.4 ± 8.2*	6.6 ± 6.5**	<0.001
Clinical Frailty Scale	4.0 ± 1.5	5.6 ± 1.3*	6.5 ± 0.9**	<0.001

Data are presented as mean ± SD. *Significantly different from well-nourished participants. **Significantly different from well-nourished participants and those at risk of malnutrition (P < 0.05 by least squared differences post-hoc test). BI, Barthel Index; BMI, body mass index; MMSE, Mini-Mental State Examination; SPPB, Short Physical Performance Battery.

Lower values for ADL, more severe cognitive impairment, lower physical function and higher malnutrition incidence were observed for residents in the nursing home than for participants living in the community. Significant associations were found between nutrition class and age, height, BMI, MMSE score, BI score, mid-arm circumference (MAC), calf circumference (CC), SPPB score, CSHA-CFS score, and grip strength (Table 2). There were no significant differences in MMSE, SPPB, BI, and MNA-SF between men and women.

The initial model was estimated with all hypothesized pathways corresponding to the selected variables directly or indirectly affecting ADL. Insignificant paths were then eliminated, and other significant bivariate correlations were added to fulfil the model-fit indices. A final model was then estimated with only statistically significant paths retained. The final model was a fairly good fit (χ^2 = 1.973; P = 0.758; CFI = 0.999; TLI = 1.000; RMSEA < 0.001).

Figure 1 shows parameter estimates for the final path model. The following significant direct paths were identified: (i) from age to nutritional status, cognitive function as indicated by the fact that age decreased the MNA-SF score and the MMSE score (b = –0.22, and –0.17, respectively); (ii) from nutritional status to physical function and cognitive function, meaning that malnutrition led to physical function decline (b = 0.51 and 0.24, respectively); (iii) from physical function and cognitive function to frailty, indicating that physical function and cognitive function had a direct relationship with frailty (b = – 0.49 and –0.23, respectively); (iv) from physical function, cognitive function and frailty to ADL, indicating that maintaining physical and cognitive function delayed the decline in ADL (b = 0.40, 0.45, and –0.15, respectively).

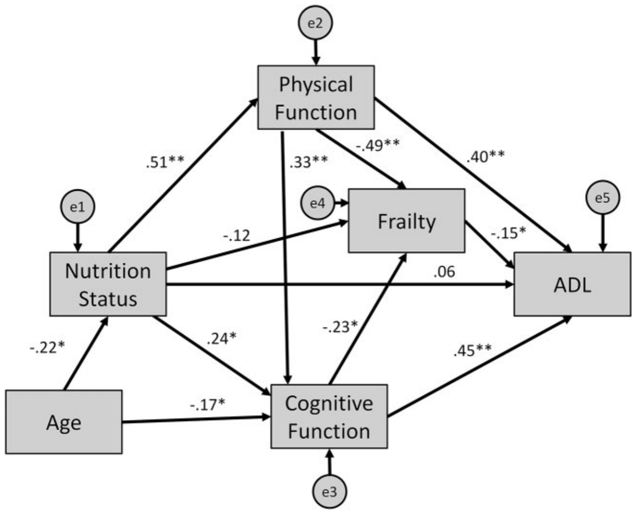

Figure 1 Hypothesized model of relationships between nutritional status, functional function, cognitive function, frailty and activities of daily living (ADL). Continuous variables included nutritional status (Mini Nutritional Assessment, Short Form), physical function (Short Physical Performance Battery), cognitive function (Mini-Mental State Examination) and ADL (Barthel Index). Frailty was the categorical variable (0 = not frail, 1 = frail). *P < 0.01, **P < 0.001.

Table 3 shows the direct, indirect and total effects of nutritional status on the endogenous variables used in the path analysis. The final model showed that nutritional status had a relatively large effect on ADL.

Table 3 Direct, indirect, and total effects of nutritional status on endogenous variables

Variables	Direct effect		Indirect effect		Total effect	
	Coeff	*P*	Coeff	*P*	Coeff	*P*
Physical function	0.514	<0.001	–		0.514	<0.001
Cognitive function	0.242	<0.001	0.169	<0.001	0.411	<0.001
Frailty	–0.115	0.065	–.342	<0.001	–0.457	<0.001
ADL	0.058	0.278	0.458	<0.001	0.516	<0.001

Standardized path coefficients used to estimate effect size (range –1.0 to 1.0): <0.10 = a small effect, 0.11–0.30 = a medium effect and 0.31–0.50 = a large effect. ADL, activities of daily living; Coeff, path coefficient.

The total effect of nutritional status on ADL was 0.516 ($P < 0.001$). The indirect effect of nutritional status through physical function on ADL was 0.458 ($P < 0.001$). Finally, no significant direct effect of nutritional status on frailty and ADL was observed (b = –0.115 and 0.058, respectively).

Discussion

In the present cross-sectional study, the relationships among nutritional status, physical function, cognitive function and ADL were examined in Japanese older adults requiring long-term care. Using path analysis, this study traced the complex pathway from nutritional status to ADL through physical function in aged Japanese people living in the community and a nursing home. This is the first study to utilize path analysis as a statistical method to determine multidirectional associations and potential causal pathways in the complex etiology of decline in ADL. The indirect effect of nutritional status on decline in ADL was tested through analysis of physical and cognitive function. The direct effect of nutritional status on physical function was determined, which in turn was observed to be associated with decline in ADL. There were significant differences between category (community *vs* nursing home) with to sex distribution, MAC, CC, MMSE, SPPB, BI and grip strength. As expected, nursing home residents showed lower MMSE, SPPB, grip strength and BI. However, it is necessary to consider the influence of sex. Previous studies have suggested that grip strength was substantially higher in men than women.[27,28] In addition, there were no significant differences in cognitive function, physical function, nutritional status, and ADL between men and women.[29] These results suggest that grip strength difference might involves gender distribution rather than differences between community and nursing home).

Possible pathways leading to decline in ADL based on the findings of the present study and those of previous studies are as follows. Cappola *et al*. reported that poor nutritional status in conjunction with comorbid illness reduces insulin-like growth factor production, which leads to a reduction in muscle strength.[30] This reduction in muscle strength resulting from malnutrition can lead to reduced physical performance. Reduced physical performance impairs the ability of elderly people to bathe or dress themselves, leading to decline in ADL and ultimately to frailty. In the present study, cognitive function and nutritional status had direct effects on ADL. This finding agrees with those of other previous studies in elderly people.[6,31] Malnutrition and cognitive impairment have been associated poor muscle strength and reduced physical performance,[32] which lead to disability, reducing the basic ADL. In addition, age is associated with variables in the model. For example, as one would expect, older adults had poorer physical function performance. Older adults with more chronic health conditions were less efficacious in relation to their gait and balance, and capability to be physically active. The age-associated loss of muscle strength is highly associated with both mortality and physical disability.[33–37] Understanding various factors related to deterioration in ADL in this population encourages a multifocal approach for maintaining ADL in older adults who require long-term care.

Path analysis has been used in other fields, such as genetic epidemiology and psychology,[38,39] but has been very rarely used in medical research. Path analysis is an appropriate method to assess the causal contributions of one variable to another.[40] This method assumes that causality is not a one-to-one correspondence between cause and effect, but that each dependent variable has an unexplained variance. However, to determine causal relationships with certainty, the analysis must be carried out over time.[26] The results of the present study, in which path analysis was applied in clinical research, might motivate the use of path analysis in determining the complex origins of decline in ADL and assessing causal relationships.

In the present study, the total score on MNA-SF represents the direct and indirect effects of nutritional status on ADL, or 0.058 + 0.458 = 0.516. In the final model, the indirect effects were greater than the direct effects. This finding conflicts with those of previous studies.[6–9] The path model in the current study included two factors related to ADL: physical function and cognitive function. Previous studies that showed an association between nutritional status and ADL failed to incorporate these factors into their analyses.[6,9] Though factors other than nutritional status might affect ADL more strongly, these relationships might be less obvious in the present study.

The current study had some limitations. Using path analysis, causal inferences were made about relationships among various factors related to ADL; however, its cross-sectional design means that reverse causation cannot be ruled out. Further longitudinal study is required to examine temporal relationships among the variables included in the present study. Other social and cognitive factors, such as affective status and social support, which might also serve as mediators, were not included in this study. Several studies have reported relationships between sociological factors and physical function, ADL, cognitive function, and nutritional status.[31,40] ADL has also been associated with psychosocial factors.[41] Because sociological and psychosocial factors might have more indirect than direct effects on ADL than physical function, cognitive function, and nutritional status, these factors were not included in the present study.

Despite these limitations, to our knowledge, this is the first study to examine the relationships among nutritional status, physical function, cognitive function and ADL decline in Japanese older adults requiring long-term care. Little is known about the effects of nutritional status, physical function and cognitive function on decline in ADL. The findings of the present study suggest that maintaining high nutritional status and providing nutritional support could indirectly cause a decline of physical function, resulting in a decline in the ADL in this population.

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