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ORIGINAL ARTICLE

Prevalence of depressive symptoms among the elderly: A longitudinal study

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Aim: Depression is a common psychiatric problem in late life. The purpose of the present study was to assess the prevalence of depressive symptoms among community-dwelling elderly, both cross-sectionally and longitudinally.

Methods: This study was a part of the community study in a large cohort of elderly people aged 65 and over in Nangai Village, Japan. Data on depressive symptoms from the fifth survey in 2000 were analyzed cross-sectionally and also combined with data from the first survey in 1992 to assess aging and cohort effects. Depressive symptoms were measured by the short form of Geriatric Depression Scale.

Results: Among 1195 respondents at the fifth survey, the prevalence of depressive symptoms was 22.3%. In 457 subjects who responded at both surveys, mean depression score or prevalence of depressive symptoms tended to be higher at the fifth survey than at the first survey. The difference in prevalence between the first survey and the fifth survey among individuals of the same age groups was significant only in the oldest group (77 years and over).

Conclusion: Among Japanese community-dwelling elderly people, aging effects on depressive symptoms were found, though marked cohort effects were not confirmed.

Keywords: aging effects, cohort effects, depressive symptoms, longitudinal study, prevalence.

Introduction

As depression is a major health and common mental health problem in late life, there are many epidemiological studies of depression and depressive symptoms among the elderly. However, most studies of elderly people have been cross-sectional. Therefore, information on changes in depression over time among elderly people was limited.

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The purpose of the present study was to assess the prevalence of depressive symptoms among community-dwelling elderly, both cross-sectionally and longitudinally. This study is a part of multidisciplinary longitudinal project that is called the Tokyo Metropolitan Institute of Gerontology Longitudinal Interdisciplinary Study on Aging (TMIG-LISA).[1] Data from the first survey in 1992 and from the fifth survey in 2000 were presented in this report.

Methods

The study area was Nangai Village in Akita Prefecture located in the north part of Honshu, the main land of Japan. In 1990, this village has a population of 5136 in an area of 99 km.[2] About 70% of the households were engaged in agriculture.

Table 1 Mean age and gender distribution of respondents

	First survey in 1992		Fifth survey in 2000	
	n	Age (mean ± SD)	n	Age (mean ± SD)
Male	285	71.5 ± 5.5	508	72.2 ± 5.7
Female	429	72.0 ± 5.5	687	73.5 ± 6.4
Total	714	71.8 ± 5.5	1195	72.9 ± 6.2

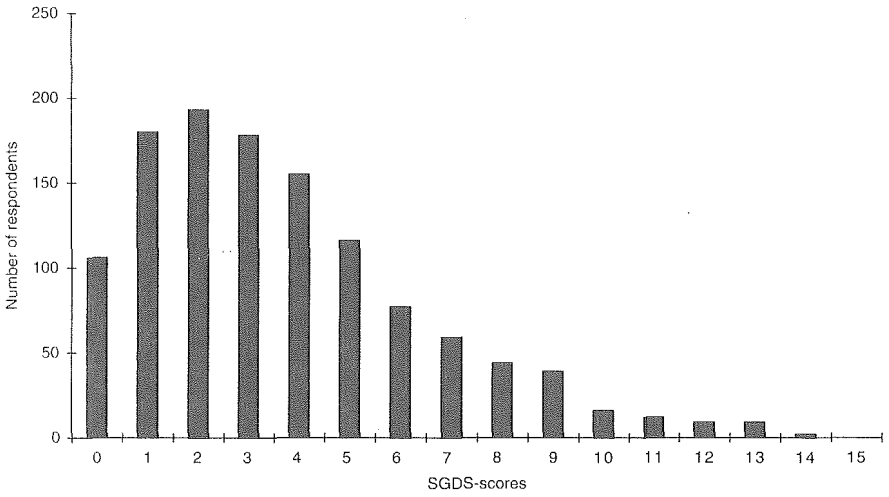

Figure 1 The distribution of Short form of the Geriatric Depression Scale Scores (in 2000). n = 1195, prevalence = 22.3%.

Depressive symptoms were measured among elderly residents aged 65 years and over in Nangai Village every two years from 1992. Data from the first survey in 1992 and from the fifth survey in 2000 were used in this paper. Seven hundred and fourteen persons completely responded to the first survey and 1195 to the fifth (Table 1). Responding rates were over 70% in both surveys. Those who responded completely in both first and fifth survey were 457 people.

Data on depressive symptoms were collected during a structured interview by trained non-medical personnel using the Japanese version of Geriatric Depression Scale (GDS).[2] In the present study, short form of GDS (SGDS) was used. The SGDS is a 15-item questionnaire to which subjects respond by indicating yes or no to questions about depressive symptoms. SGDS-scores of six or higher are regarded as mild or severe depressive symptoms.[3]

Data from the fifth survey were analyzed cross-sectionally and also combined with data from the first survey to examine changes over time.

The sample was split into four age groups: 65–68, 69–72, 73–76, and 77+. Aging effects (following the same individuals over time) were examined by analyzing data at two time points. Cohort effects (comparing individuals of similar age at different time points) were also investigated by comparing different individuals in the same age groups in 1992 and 2000.

Statistical analysis was done by using t-test, χ^2 test, or McNemar test with the SPSS release 6.1 statistical package.[4] Statistical significance was taken at $P < 0.05$.

Results

Cross-sectional data: From the fifth survey

The distribution of SGDS-scores for the fifth survey is shown in Fig. 1. The prevalence of depressive symptoms, which was the proportion of the elderly whose SGDS-scores were six or higher, was 22.3%. Prevalence increased as subjects got older in cross-sectional settings (Fig. 2).

Longitudinal data: Effect of aging in the followed-up cohort

Results from 457 subjects who responded completely at two time points are shown in Table 2. In all age groups, mean SGDS at the fifth survey was significantly higher than that at the first survey. Prevalence of depressive symptoms was also significantly higher at the fifth survey than at the first survey except for the youngest group (65–68 years-old at the initial point) (Table 3).

Longitudinal data: Cohort effects in individuals of the same age groups

Data on depressive symptoms is summarized in Tables 4 and 5. The difference between the first survey

and the fifth survey was significant only in the oldest group (77 years and over). No significant difference was found between two time points in younger three age categories.

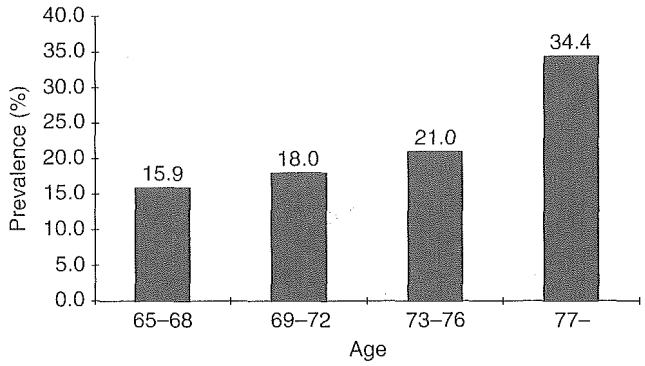

Figure 2 Prevalence of depressive symptoms by age group (in 2000). Prevalence increased as subjects get older (P-trend < 0.05 by Mantel-Haenszel test). Prevalence: the proportion of the elderly whose Short form of the Geriatric Depression Scale scores were 6 or higher.

Discussion

The prevalence of depressive symptoms was 22.3% from our cross-sectional data. A number of investigators have estimated the prevalence of depressive symptoms among community-dwelling elderly people to be between 8% and 44%.[5–13] Since the measurements of depressive symptoms were different, we can make no conclusion as to the similarity of these results. However, some studies reported similar prevalence rates to our own.[11–13]

Snapshot prevalence studies do not adequately represent late-life depression. Changes over time may be studied by means of longitudinal or cohort approaches. In the present study, longitudinal data were analyzed in two ways. First, by examining those who had participated in both first and fifth survey, it was possible to investigate the effects of aging in the survivors of a followed-up cohort. As a result, mean depression score or prevalence of depressive symptoms was significantly higher at the fifth survey than at the first survey in most cases. Though the 20-year follow-up of the Midtown

Table 2 Mean Depressive scores from the first and the fifth survey for the follow-up cohort (n = 457)

Age in 1992 (n)	First survey in 1992	Fifth survey in 2000	Significance[a]
65–68 (179)	2.9 ± 2.6	3.7 ± 3.0	**
69–72 (146)	3.4 ± 2.4	4.4 ± 3.0	**
73–76 (72)	2.9 ± 2.3	4.7 ± 3.0	**
77– (60)	3.4 ± 2.0	4.4 ± 2.6	*

[a]Using t-tests for paired samples; $^{**}P < 0.01$; $^{*}P < 0.05$.

Table 3 Prevalence of depressive symptoms from the first and the fifth survey for the follow-up cohort (n = 457)

Age in 1992 (n)	First survey in 1992	Fifth survey in 2000	Significance[a]
65–68 (179)	16.8%	20.1%	ns
69–72 (146)	20.5%	34.2%	**
73–76 (72)	11.1%	34.7%	**
77– (60)	11.7%	31.7%	*

[a]Using McNemar test for paired samples; $^{**}P < 0.01$; $^{*}P < 0.05$; ns, not significant.

Table 4 Mean Depressive scores from the first and the fifth survey for individuals of the same age groups

Age groups	First survey in 1992 (n)	Fifth survey in 2000 (n)	Significance[a]
65–68	3.1 ± 2.7 (238)	3.2 ± 2.5 (339)	ns
69–72	3.5 ± 2.5 (208)	3.3 ± 2.6 (323)	ns
73–76	3.4 ± 2.5 (125)	3.8 ± 3.0 (210)	ns
77–	4.6 ± 3.0 (323)	3.9 ± 2.2 (142)	**

[a]Using t-tests; $^{**}P < 0.01$; $^{*}P < 0.05$; ns, not significant.

Table 5 Prevalence of depressive symptoms from the first and the fifth survey for individuals of the same age groups

Age groups	First survey in 1992 (*n*)	Fifth survey in 2000 (*n*)	Significance[a]
65–68	16.4% (238)	15.9% (339)	ns
69–72	19.7% (208)	18.0% (323)	ns
73–76	17.6% (125)	21.0% (210)	ns
77–	34.4% (323)	20.4% (142)	**

[a]Using χ^2 test; $^{**}P < 0.01$; $^{*}P < 0.05$; ns, not significant.

Manhattan study whose subjects included young or middle-aged people reported that the prevalence of mental health impairment did not increase longitudinally with age[14] the 6-year follow-up study of a large cohort of elderly people showed a significant increase in depression scores with aging.[15] Thus, there appeared to be an aging effect for depressive symptoms among the elderly. However, it is unclear whether the increase in symptoms was really due to depression. The increase in depression score may reflect not increasing depression but some other change in physical function or simply to the process of aging. This possibility would be worthy of further investigation.

Second, we examined for cohort effects at two different time points by comparing individuals in the same age group at first and fifth survey. In our results, the evidence for cohort effects was not found. As the relatively higher prevalence of depression in younger cohorts found in the Epidemiologic Catchment Area studies or Psychobiology of Depression Study, it is said that Western society has entered an age of melancholy.[16] In our study, however, these trends were not confirmed at least among the Japanese elderly generation.

Our sample is notable because of its size and the length of follow-up, which enables examination of longitudinal aging and cohort effects, as well as cross-sectional results. However, the longer the initial sample is followed up, the more deaths occur so that those available for re-examination may be healthy survivors. This will tend for the results to introduce a bias in the direction of good health. Interpretation of the results must take these considerations into account.

In conclusion, the prevalence of depressive symptoms among community-dwelling elderly was investigated, both cross-sectionally and longitudinally. The prevalence in cross-sectional data in 2000 was 22.3%. There was an aging effect on depressive symptoms in the followed-up cohort. However, marked cohort effects were not confirmed in individuals of the same age groups.

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ORIGINAL ARTICLE

Predictors for the onset of functional decline among initially non-disabled older people living in a community during a 6-year follow-up

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Background: Predictors for functional decline in basic activities of daily living (BADL) among older people have been extensively studied. However, relatively little is known about predictors for decline in instrumental activities of daily living (IADL).

Objectives: To identify predictors for functional decline in IADL as well as predictors for decline in BADL among initially non-disabled older people living in a community by a longitudinal epidemiological study.

Methods: Out of 748 older persons aged 65 years and over who participated in the interview survey and medical examination at baseline in 1992, 601 persons were identified as being independent in both BADL and IADL, and were followed-up yearly for 6 years until 1998. Outcome events were the onset of IADL disability prior to the onset of BADL disability as well as the onset of BADL disability. A wide range of variables obtained in the baseline survey was entered into the model predicting functional decline in BADL and IADL during the follow-up period.

Results: Common predictors for BADL and IADL disability included: (1) advanced age; (2) lower levels in performance-based measures; (3) a history of hospitalization in the past year; and (4) poor chewing ability. Longer sleep-hours, poor intellectual activities, and poor self-rated health were identified as significant predictors for only IADL disability. Not having an occupation, a history of heart disease, and higher blood β_2-microglobulin level were identified as a significant predictors of BADL disability.

Conclusions: Good intellectual activities, good self-rated health, good chewing ability, and good physical performance are closely associated with remaining independent in IADL for non-disabled older people. Significance of blood β_2-microglobulin in predicting the onset of functional decline merits further study.

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Keywords: community-dwelling older people, functional dependence, longitudinal study, predictors

Introduction

Good functional capacity is a crucial component for successful aging. Thus, many previous studies have examined what factors contribute to functional decline with advancing age.[1] According to Lawton's model,[2] functional capacity in humans comprises seven different kinds of capacity in terms of exerted function and complexity. Among those, basic activities of daily living (BADL)[3] composing of self-care tasks such as bathing and dressing, have attracted much attention from gerontologists because older persons with functional decline in BADL need care from someone else as well as their lowered quality of life. To date, contributors to decline in BADL have been extensively reported elsewhere.[4–7]

In contrast, relatively little is known about contributors to decline in instrumental activities of daily living (IADL),[8,9] though IADL are the most relevant capacities for living independently in a community;[10] IADL include activities such as using transportation, going shopping, preparing meals, paying bills, and handling one's own banking. Functional decline in IADL has been reported to predict the future onset of decline in BADL and mortality.[11–13] To examine factors contributing to functional decline in IADL is thus important not only to help find ways for older people to remain independent in a community, but also to prevent subsequent functional decline in BADL and premature mortality.

We thus investigated predictors for functional decline in IADL in comparison with those for BADL decline, using data from our longitudinal study on aging[14] among community-dwelling older people. Our earlier study[15] has reported that having a high-level hand grip-strength, good intellectual activities, and good social roles are strongly associated with remaining independence in IADL for the non-disabled persons aged 65 years and over. In this study, we extended the observation period of the cohort from previous the 3 years to 6 years, and intended to extract predictors for functional decline from a wider range of health-related variables.

Methods

Study area and subjects

We obtained the data for this study from the Tokyo Metropolitan Institute of Gerontology Longitudinal Interdisciplinary Study on Aging (TMIG-LISA). Details of this project have been described elsewhere.[14] The present study area was Nangai Village, a rural and mainly agricultural area of Akita Prefecture in Japan. In 1992, 940 people aged 65 years and older were registered as residents in the village. Of these, 88 were living in institutions, homebound due mainly to mobility difficulty or long-term absent. The remaining 852 were invited to participate in the baseline survey held at community halls in 1992. After signing informed consent forms, which had been approved by the ethics committee of the Institute, 748 took part in the survey.

Baseline survey

Interview survey and medical examinations were administered to the participants in the baseline survey. Questionnaires used in the interview survey comprised a wide range of health-related variables (i.e. demographic, lifestyle-related, and psychosocial variables, variables regarding functional capacity, use of outpatient care, history of hospitalization, medication use and history of chronic medical conditions). Medical examinations included measurements of body build, blood pressure, and blood profiles. Blood samples were collected when the subjects were in non-fasting state and sitting. Separated serum samples were transported via air to a laboratory (Special Reference Laboratories, Inc., Tokyo, Japan), and were determined by a sequential auto-analyzer.

The participants also underwent tests of hand grip-strength, length of time standing on one leg, and usual and maximum walking speed. We evaluated hand grip-strength by a mechanical dynamometer in the dominant hand and used the higher of two trials in the analysis. For the one-leg standing test, we asked subjects to look straight ahead at a dot 1 meter in front of them. We then asked them to stand on the preferred leg with their eyes open and hands down alongside the trunk. The time until balance was lost (or maximum 60 s) was recorded. We used the better of two trials in the analysis. To test walking speed, we asked subjects to walk on a straight walkway 11 m in length on a flat floor once at their usual speed and then, again at their maximum speed. Walking speed was measured over a 5-m distance between marks 3 m and 8 m from the start of the walkway. For maximum walking speed, we used the faster results in the analysis. The good reproducibility of these walking tests has been reported previously.[16]

Assessment of functional status

We asked the subjects about their dependence in five basic ADLs: bathing, dressing, walking, eating, and

continence. Dependence in an ADL was defined as the subject needing help from someone else or being unable to perform the activity. The IADL was measured using the five-item subscale of Instrumental Self-Maintenance of the TMIG Index of Competence,[17] which was a multidimensional 13-item index, developed to assess functional competence higher than BADL in community-dwelling older people. The response to each item in the index was designed as 'yes' or 'no', and the total score was designed as the sum total of the 13 items. The dimensions of their level of competence, as measured by the index, consisted of three factors: (1) Instrumental Self-Maintenance; (2) Intellectual Activity; and (3) Social Role. Therefore, the score of each factor was designed as the sum total of items in each subscale. We defined functional decline in BADL and IADL as a loss of independence in one or more items of BADL and IADL, respectively.

Follow-up survey

Study participants in the baseline survey were followed up for the next 6 years on a yearly basis using a method similar to the baseline survey. Each survey has been carried out in municipal community halls in Nangai Village. When a subject could no longer walk, the follow-up survey was conducted by a home visit. Death or institutionalization was ascertained from death certificate or interview with family proxy. The outcome event in this study was the onset of BADL or IADL disability. In this study, BADL disability was defined as the onset of decline in BADL, institutionalization, or death of persons who had shown no decline in BADL at the follow-up in the past year.

Decline in IADL mostly occurred prior to the onset of decline in BADL (Fig. 1). Partly because of yearly based-follow up, it sometimes happened simultaneously with decline in BADL or after the onset of BADL decline. On the assumption of hierarchical relationship between BADL and IADL, and considering the purpose of this study to identify and compare predictors for functional decline in BADL and IADL, we selected only the cases showing decline in IADL prior to the onset of BADL decline for the analysis, and denoted as IADL disability.

Potential predictors of functional decline

Four demographic variables, four lifestyle-related variables, four psychosocial variables, four performance-based measures, and 18 physiological and medical variables were used as independent variables for this study (Table 1).

At the time of interview, we asked participants to rate their own health status. Possible responses were excellent, good, fair, and poor. Responses were dichotomized into good (excellent and good) and poor (fair and poor)

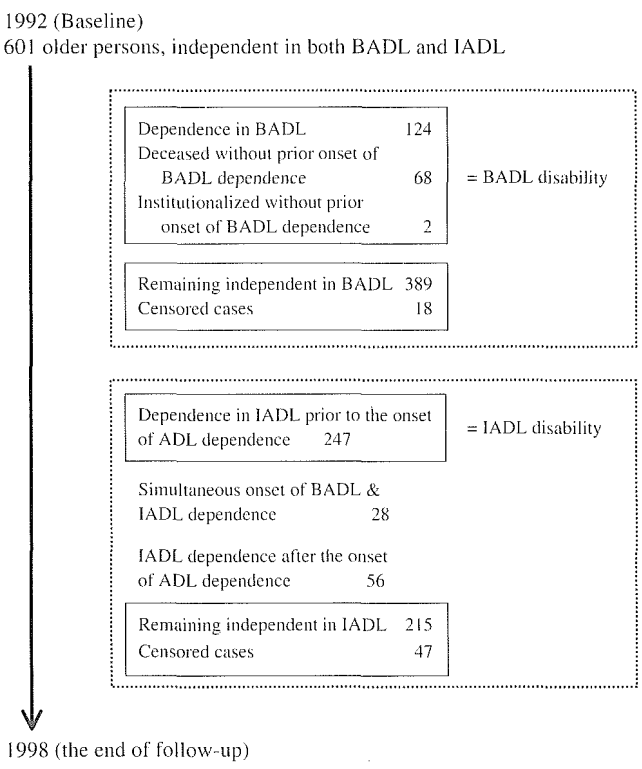

Figure 1 Outcome events during 6 years of follow-up among non-disabled older persons in both BADL and IADL at the time of baseline.

for the analysis. Depressive symptomatology was measured using the Japanese version of the Geriatric Depression Scale (GDS).[18] We determined depressive symptomatology in subjects who had GDS scores of ≥ 11 points. Intellectual activity and social role were assessed using the subscales of the TMIG Index for Competence. Each subscale consists of four dichotomized items. We defined 'poor intellectual activities' and 'poor social roles' as scores below four full marks in Intellectual Activity subscale and in Social Roles subscale of the Index, respectively.

The subjects were also asked about hearing and visual impairment (present or absent), chewing ability, history of fall and hospitalization in the past year (present or absent), use of outpatient care in the past month (yes or no), history of physician-diagnosed chronic medical conditions (present or absent for each of stroke, heart disease, diabetes mellitus, and hypertension). Chewing ability was assessed by questions about ability to chew or bite in hard food items: (1) without difficulty; (2) with some difficulty; (3) with much difficulty; and (4) not able. In the analysis we defined persons who reported (3) or (4) as having impaired chewing ability.

Statistical methods

We limited the subjects of this particular study to those who were independent in both BADL and IADL at the

Table 1 Baseline characteristics among subjects who were independent in both BADL and IADL at the time of baseline survey in 1992 (n = 601)

	Mean ± SD or %	Range
Demographic variables		
Age (years)	70.9 ± 4.9	65–89
Gender (% female)	56.1	
Living with spouse (% yes)	65.1	
Occupation (% being engaged in work)	63.9	
Lifestyle-related variables		
Sleeping hours per day (% ≥ 8 h)	40.9	
Alcohol drinking status (% current drinker)	40.3	
Smoking status (% current smoker)	17.8	
Walking/Calisthenic habit (% present)	46.9	
TMIG-Index of Competence		
Intellectual Activity (% 4 full mark)	55.6	
Social Roles (% 4 full mark)	77.9	
Psychological variables		
Self-rated health (% ≥ good)	76.2	
GDS (% < 11 points)	81.0	
Fitness variables		
Hand-grip strength (kg)	24.5 ± 7.9	8–48
One-leg standing (s)	35 ± 23	1–60
Usual walking speed (m/s)	1.15 ± 0.26	0.41–2.03
Maximal walking speed (m/s)	1.86 ± 0.44	0.65–3.29
Physical and medical variables		
Hearing impairment (% present)	11.0	
Visual impairment (% present)	4.2	
Use of outpatient in the past month (% yes)	75.5	
History of hospitalization in the past year (% present)	9.5	
History of stroke (% present)	4.0	
History of heart disease (% present)	21.3	
History of diabetes (% present)	7.3	
History of hypertention (% present)	43.1	
History of fall in the past year (% present)	13.8	
Chewing status (% limited)	9.5	
Body Mass Index (kg/m^2)	22.8 ± 3.2	15.7–35.1
Serum albumin (g/dL)	4.1 ± 0.3	3.0–4.8
Total cholesterol (mg/dL)	190 ± 36	105–353
HDL-cholesterol (mg/dL)	50 ± 13	24–94
Uric acid (mg/dL)	4.5 ± 1.4	0.4–10.6
HbA1c (%)	5.0 ± 0.7	4–13.4
β_2-microglobulin (mg/L)	1.7 ± 0.5	0.8–5.90
Systolic blood pressure (mmHg)	144 ± 22	98–216

Continuous data were presented as mean ± SD and range.
BADL, basic activities of daily living; IADL, instrumental activities of daily living.

time of the baseline survey. Baseline variables were used to characterize the subjects. The previous reports[4,19,20] have identified age, gender, and chronic medical conditions as significant factors affecting functional status in old ages. Thus, we first analyzed the relationship between these potential confounding factors at baseline and the onset of functional dependence during the 6-year follow-up period among the initially non-disabled subjects. Second, using the Cox proportional hazard model, we determined factors associated significantly with the onset of functional decline even after controlling for the potential confounding factors.

Third, the Cox proportional hazard analysis with stepwise procedure was used to help identify the best model for predicting the onset of functional decline. All of the independent variables were dichotomized except

Table 2 Relationships between potential confounding factors at baseline and the onset of functional dependence during the 6-year follow-up period among community-dwelling older people

Variables	Categories for comparison	BADL disability	*P*-value	IADL disability	*P*-value
Demographic variables					
Age	an increase by 5 years	1.48 (1.31–1.69)	0.000	1.85 (1.63–2.10)	0.000
Gender	female/male	0.86 (0.65–1.15)	0.308	1.54 (1.16–2.05)	0.003
Chronic medical conditions					
History of stroke	yes/no	1.31 (0.66–2.61)	0.437	1.57 (0.79–3.12)	0.195
History of heart disease	yes/no	1.61 (1.18–2.19)	0.003	1.57 (1.14–2.15)	0.005
History of diabetes	yes/no	1.87 (1.19–2.92)	0.006	1.32 (0.79–2.20)	0.297
History of hypertension	yes/no	1.16 (0.88–1.55)	0.298	1.05 (0.79–1.38)	0.752

Hazard ratios and their 95% confidence intervals (in the parenthesis) determined by the proportional hazard analysis.

that performance-based measures, BMI, systolic blood pressure, and blood parameters were made into quartiles. *P*-values of 0.05 and 0.10 were used for variable entry and retention for stepwise procedure, respectively. The association between possible predictors and functional decline was described by hazard ratio and 95% confidence interval. We performed the likelihood ratio test on the final model to measure how well the model fit the data. Potential collinearity among performance-based measures forced us to enter each of four measures into models, of which we selected the fittest one. All reported *P*-values were two-tailed, and the level of significance was set at $P < 0.05$.

Results

Table 1 shows the characteristics of the subjects who were independent in both BADL and IADL at the time of baseline in 1992 ($n = 601$). Figure 1 summarizes the functional change among them during the 6-year follow-up period. One hundred and twenty-four persons exhibited the decline in BADL, 68 persons died, and two persons were institutionalized without showing decline in BADL in the previous year; those were all defined as BADL disability. During the same period, 247 persons exhibited the decline in IADL prior to the onset of BADL dependence; those were defined as IADL disability. The cases that showed simultaneous onset of decline in BADL and IADL ($n = 28$), or decline in IADL after the onset of decline in BADL ($n = 56$) were excluded from the analysis.

Table 2 indicates the relationships between potential confounding factors at baseline and the onset of functional dependence during the follow-up period among initially non-disabled older persons. Advanced ages and a history of heart disease increased a risk for both BADL and IADL disability. Female gender showed an increased risk for only the onset of IADL disability, while a history of diabetes for only the onset of BADL disability.

Table 3 lists the adjusted hazard ratios for baseline variables against the onset of functional dependence during the follow-up period after controlling for potential confounding factors. Many baseline variables were found to be associated significantly with both the onset of BADL and IADL disability; longer sleep hours (≥ 8 h), poor social roles, poor self-rated health, lower levels of all four performance-based measures, impaired chewing ability, a history of hospitalization in the past year, and higher level of blood β_2-microglobulin were identified as common risks against the onset of both BADL and IADL disability. Poor intellectual activity, depressive symptomatology, presence of hearing impairment, and use of outpatient care in the past month increased the risk for only IADL disability.

For identifying significant predictors for functional decline, we applied the Cox-proportional hazards method with stepwise procedure (Table 4). Common variables selected into the fittest models for predicting BADL and IADL disability were age, usual walking speed, a history of hospitalization during the past year, and chewing status; advanced ages, slower usual walking speed, presence of a history of hospitalization, and impaired chewing ability were identified as common predictors for both functional decline. In addition, longer sleep hours, poor intellectual activities, and poor self-rated health were identified as significant predictors for only IADL disability. On the other hand, not having an occupation, a history of heart disease, and higher blood β_2-microglobulin level were identified as significant predictors of only BADL disability during the 6-year follow-up period.

Discussion

Predictors for functional decline in only IADL included specific lifestyle-related and psychosocial variables (sleep hours, self-rated health, and intellectual activity) as well as demographic, physical and medical variables (age, physical performance, history of hospitalization

Table 3 Adjusted hazard ratios for baseline variables against the onset of functional dependence during the 6-year follow-up period among community-dwelling older people

Variables	Categories for comparison	BADL disability	IADL disability
Demographic variables			
Living with spouse	no/yes	ns	ns
Occupation	not being engaged in/being engaged in work	1.42 (1.05–1.92)	ns
Lifestyle-related variables			
Sleeping time	≥ 8 h/ < 8 h	1.46 (1.09–1.96)	1.75 (1.31–2.32)
Alcohol drinking status	ex-drinker/present drinker, no-drinker	1.85 (1.18–2.90)	ns
Smoking status	present smoker/ex-smoker, non-smoker	ns	ns
Walking/Calisthenic habit	no/yes	ns	ns
TMIG-Index of Competence			
Intellectual Activity	≤ 3 scores/4 full scores	ns	1.68 (1.26–2.24)
Social Roles	≤ 3 scores/4 full scores	1.44 (1.05–1.97)	1.52 (1.12–2.07)
Psychological variables			
Self-rated health	fair, poor/very, good	1.56 (1.15–2.13)	2.22 (1.66–2.98)
GDS	≥ 11 points/< 11 points	ns	1.06 (1.03–1.09)
Fitness variables			
Hand grip strength	an decrease by a quartile	1.22 (1.07–1.39)	1.33 (1.17–1.52)
One-leg standing	an decrease by a quartile	1.41 (1.22–1.62)	1.30 (1.14–1.49)
Usual walking speed	an decrease by a quartile	1.31 (1.14–1.50)	1.47 (1.28–1.68)
Maximal walking speed	an decrease by a quartile	1.40 (1.22–1.61)	1.49 (1.30–1.72)
Physical variables			
Hearing impairment	yes/no	ns	1.53 (1.03–2.29)
Visual impairment	yes/no	ns	ns
History of fall	yes/no	ns	ns
Use of outpatient	yes/no	ns	1.55 (1.02–2.35)
History of hospitalization	yes/no	1.91 (1.30–2.80)	2.40 (1.63–3.53)
Chewing status	limited/not limited	1.88 (1.26–2.82)	2.22 (1.50–3.27)
Medical examination			
Body Mass Index	an increase by a quartile	ns	ns
Serum albumin	1st quartile/2nd, 3rd quartiles	ns	ns
Total cholesterol	1st quartile/4th quartile	ns	ns
HDL-cholesterol	an increase by a quartile	ns	ns
Uric acid	an increase by a quartile	ns	ns
HbA1c	an increase by a quartile	ns	ns
β_2-microglobulin	4th quartile/1st quartile	1.23 (1.08–1.42)	1.14 (1.00–1.29)
Systolic blood pressure	an increase by a quartile	ns	ns

Hazard ratios adjusted for age, gender and history of each chronic condition.
95% confidence intervals of hazard ratio are presented in the parenthesis.

and chewing ability) common to predictors for BADL decline. This would be plausible considering that IADL are more adaptive tasks than BADL that depend primarily on bodily functions.

Ishizaki *et al.*[15] reported in the earlier study that poor intellectual activities and poor social roles are significantly associated with decline in IADL among the same cohort during the 3-year follow-up period. Although social roles variable was not included in the fittest model for predicting IADL disability in this study, the risk ratio of poor to good social roles against functional decline remained significant even after controlling for age, gender, and history of chronic medical conditions. Among older people living in an urban community (Koganei City, a suburb of Tokyo), Fujiwara *et al.*[21] demonstrated that baseline level of social roles and intellectual activities significantly predict the new onset of IADL disability during the 8-year follow-up period. Taken together, it can be concluded that older persons with good higher-level functional capacity above IADL (intellectual activity and social roles) are likely to remain independent in IADL.

The association between intellectual activities and IADL would be complex. The Intellectual Activity sub-

Table 4 Predictors for functional dependence during the 6-year follow-up period among community-dwelling older people

Variables	Categories for comparison	BADL disability	IADL disability
Demographic variable			
Age	an increase by 5 years	1.29 (1.16–1.44)	1.67 (1.46–1.92)
Occupation	not being engaged in/being engaged in work	1.31 (0.97–1.77)	–
Lifestyle-related variable			
Sleeping hours	≥ 8 h/< 8 h	–	1.43 (1.06–1.94)
TMIG-Index of Competence			
Intellectual Activity	≤ 3 scores/4 full scores	–	1.54 (1.15–2.06)
Psychological variable			
Self-rated health	fair, poor/very, good	–	1.91 (1.41–2.59)
Fitness variable			
Usual walking speed	an decrease by a quartile	1.23 (1.08–1.41)	1.36 (1.19–1.57)
Physical variables			
History of hospitalization	yes/no	1.64 (1.09–2.47)	1.66 (1.08–2.56)
History of heart disease	yes/no	1.50 (1.09–2.06)	–
Chewing status	limited/not limited	1.52 (1.01–2.29)	1.45 (0.96–2.19)
Medical examination			
β_2-microglobulin	4th quartile/1st quartile	1.20 (1.05–1.38)	–

Variables selected by the proportional hazard model with backward stepwise method.
Data are presented as hazard ratio and its 95% confidence interval in the parenthesis.

scale of TMIG Index of Competence consists of four tasks, which can be categorized as cognitive stimulating activities; filling out forms for pension, reading the newspaper, reading books or magazines, and interest in news stories or programs dealing with health. Wilson *et al.*[22] reported that frequent participation in cognitive stimulating activities was associated with reduced risk of Alzheimer disease. At the same time, Intellectual Activity subscale is considered to enable to detect a low grade of cognitive function. Fujiwara *et al.*[23] noted that a community-dwelling older person with mild cognitive decline assessed by Mini-Mental State Examination had a lower level of Intellectual Activity than did a cognitively intact older person. Greiner and colleagues[24] reported that low normal cognitive function predicted a loss of functional independence in an older population. Thus, we suppose that poor intellectual activities have an increased risk for future cognitive impairment and concomitant IADL disability.

To date, many previous studies have documented that poor self-rated health is significantly associated with functional decline,[7,25] hospitalization,[26] and mortality[27–29] among older people. In this study, poor self-rated health was reported by 33.8% out of initially non-disabled older people at baseline; they had 2.22 times higher risk than did older persons with good self-rated health for developing the onset of IADL disability during the follow-up period even after controlling for potential confounders. Poor self-rated health remained as a significant variable in the model predicting for IADL disability. This result largely coincides with the previous report. Together with a history of hospitalization in the past year, self-rated health may be useful items for identifying older persons vulnerable to functional decline.

Impaired chewing ability was strongly associated with the future onset of functional dependence among initially non-disabled older adults. Several cross-sectional studies[30] have documented that disabled older persons have poor oral health relative to non-disabled peers. Physical disability may affect their ability to maintain good oral hygiene and restrict their access to necessary dental treatment, leading to poor oral health. However, the present result implies that an alternative direction may exist for linking physical disability and oral health; poor oral health may lead to functional decline among non-disabled older people. To date, only a few studies have examined the relationship between oral health in older persons and changes in functional ability.[31] We assessed oral health status of participants roughly by self-reported chewing ability. However, this self-assessment method is considered a useful tool in dental research. We have yet confirmed the validity of self-report on chewing ability with the objective assessment method using jelly of varying hardness.[32] Using similar self-assessment methods, Avlund *et al.*[31] have recently shown that poor oral health (having no or few teeth, and chewing problems) predicted mobility-related functional decline during 5 years from age 75 to age 80. Nutritional problems[33] and low physical function[32] associated with poor oral health may be potential underlying causes that link poor oral health and func-

tional limitation. However, precise mechanisms remain unsolved, and merit further study.

The present results stress the importance of physical performance for remaining functionally independent in later life, coinciding with previous reports.[15,34–36] For this study we adopted the hand grip-strength, one-leg standing, and walking speed tests for assessments of the physical performance of older subjects. Nagasaki *et al.*[37] proposed a physical fitness model for the older person, in which strength, walking, balance, and manual speed comprise basic motor ability for older adult. They suggest hand grip-strength, walking speed, standing balance on one foot, and finger tapping for examining the level of each component. Only finger tapping was not included in the present analysis, the three other measures were closely associated with the onset of functional decline in older subjects, among which walking speed was the most sensitive in predicting the functional dependence. Increasing numbers of study have shown that older persons with difficulty in mobility have an increased risk for the onset of functional dependence and mortality.[34,36,38] Obviously mobility as assessed by walking speed can be regarded as fundamental component for independent living in the community.

The one-leg standing and hand grip-strength tests were also shown to be useful for detecting older people at increased risk of future functional dependence. This result largely confirmed previous reports.[15,39,40] Using the Tokyo Metropolitan Institute of Gerontology Index of Competence, we had demonstrated that lower performance in these two physical tests was independently associated with decline in each of three subscales (Instrumental Self-Maintenance, Intellectual Activity and Social Role) in an older population.[41] Taken together, performance-based measures of physical function is very useful for identifying older persons at an increased risk for functional decline. Programs or strategies targeting to improve physical performance, especially walking ability, among community-dwelling elderly are urgently needed.

Among the blood parameters examined, only β_2-microglobulin was found to be significantly associated with the future onset of functional decline even after controlling for potential confounders. It was also selected as a predictor for BADL disability among non-disabled older people. β_2-microglobulin is a chaperon of major histocompatibility complex class I molecule that is expressed on plasma membrane of all nucleated cells in human body.[42] The blood level of β_2-microglobulin has been reported to increase in inflammation[43] and cancer[44] as well as in renal dysfunction.[45] Clinically, it has been used as a marker of renal glomerular function.[41] At present it is unclear how potential inflammation and/or impaired renal function as suggested by higher-level β_2-microglobulin increased the risk for the onset of functional decline among non-disabled older people. On the other hand our recent longitudinal analysis has shown that blood level of β_2-microglobulin is a potent marker for biological aging; it increased linearly with advancing age without showing gender and regional differences, and did not exhibit cohort effect among non-disabled older people living in communities (unpubl. data). Thus, we assume that the aging process *per se* may contribute at least in part to functional decline in older people.

In conclusion, this longitudinal study showed that good intellectual activities, good self-rated health, good chewing ability, and good physical performance are closely associated with remaining independent in IADL for non-disabled older people. Significance of blood β_2-microglobulin in predicting the onset of functional decline merits further study.

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ORIGINAL ARTICLE

Factorial invariance of the physical performance measures in longitudinal study of aging: A simultaneous analysis approach

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In this study, we examined the factorial structure of the physical performance measures and the longitudinal invariance of elderly people in the community. The subjects were investigated in Akita as part of TMG-LISA. Data used in this study were from 463 older adults who participated in all the physical performance tests, both in the baseline (1992) and the 4-year follow-up (1996) investigation. The test battery consisted of six items (hand power, walking, and balance). There were longitudinal aging changes in gender and age in all of the measurements between the baseline research and the follow-up research, except for the one-leg standing with eyes closed test. The factorial invariance of the structure in these measures taken in 1992 and 1996 was confirmed through the confirmatory factor analysis (CFA) of the structural equation modeling, controlled for gender and age. As a preliminary step for analysis of factorial invariance, we analyzed the fitting *basic motor ability* model to cross-sectional data of the baseline and follow-up. As a result of the analysis, the fitness levels of each data of the models were good. Then, we applied simultaneous analysis and analyzed longitudinal changes in the factorial structure of measurements. The results were that there were the same factors in the factorial structure model of physical performance measured in both the baseline and follow-up investigation, and that their arrangements were identical. Furthermore, we find that there was no difference in all factor-loading in both models being investigated. These results statistically indicated that there were no signs of aging changes in factorial structure of the measures between the baseline investigations and the follow-up 4 years later in spite of the longitudinal decline of the values of physical performance tests. Moreover, it was indicated that the simultaneous analysis, which this research used, was applicable for statistical analysis procedure of factorial invariance of various repeated measures on studies of aging, as a longitudinal study.

Keywords: confirmatory factor analysis, elderly, factorial invariance, longitudinal study, physical performance.

Introduction

The elderly need to maintain their physical strength for their daily activities in order to lead independent and healthy lives. Motor abilities greatly affect their daily activities. Physical performance tests have thus far been

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taken in research and for geriatric assessments.[1–3] The performance measurements are related to their health status; histories of heart disease, stroke, and diabetes, self-rated health, and leisure activities.[4] Theoretically, physical performance measures could be considered functional limitations.[5–8] The functional status level of persons who are not disabled and even who are high functioning can be measured through physical performance measures.[4,9,10] Furthermore, measures of physical performances and measures of walking ability alone are predictive of crucial outcomes such as subsequent disability, functional dependence, nursing home admission, and mortality.[11–17]

We also carried out a short battery test on the community-dwelling elderly by measuring their physical performances.[9,18] These indicated the relationship between the summary score of those measured and their current health status; hospitalization experience, histories of diseases, as well as their level of sports participation.[9] We suggested the predictability of the decline of the level of instrumental activities of daily living (IADL) and mortality in the future by using the sum of the scores of physical performance tests and value of gait speed alone.[19,20]

Physical performance tests conducted on elderly persons have required safety restrictions and the items in the measurements for them are different from those for young adults and the middle aged. The factorial structure of those measures for the elderly people was specific. The decrease of the specificity of motor ability[21] and the increase of the correlation among their factors[3,18,22,23] were also recognized. Contribution of general motor ability[24] factors to those motor ability factors relatively increased. It is important to comprehend the motor abilities estimates by the physical performance tests and their structures, as it is statistically required for validation.

In our previous studies, we clarified the factorial structure in the performance measurement tests taken on older adults.[22,23] We hypothesized a model of those measured, and examined the fitness of the model data by using confirmatory factor analysis (CFA) of equation modeling. CFA was the method used to analyze the factorial structures on the elderly. The supposed model was a hierarchical second-order factorial structure model, called *basic motor ability* (BMA) model (Fig. 1). In the model, the performance tests were assumed to assess motor abilities that are first-order factors. Further, these abilities had loading on a single higher-order factor labeled 'Basic motor ability'. A factor of the upper level was conceptualized as a common determinant of motor skills, or general motor ability. This analysis model successfully accounts for the data in the performance measurement tests.[22] This model gave a further indication that the goodness-of-fit was high in the data of the short battery test of our physical performance measures investigated for the baseline research on the sample of elderly residents in the community from the Tokyo Metropolitan Institute of Gerontology Longitudinal Interdisciplinary Study on Aging (TMIG-LISA).[23,25] These brought out the confirmation of the factorial structure in the physical performance measurements for the elderly with the indication of general motor ability common in motor abilities.[22,23]

The TMIG-LISA was a longitudinal investigation in which the samples, which had been examined in reference to a BMA model in the previous study, were

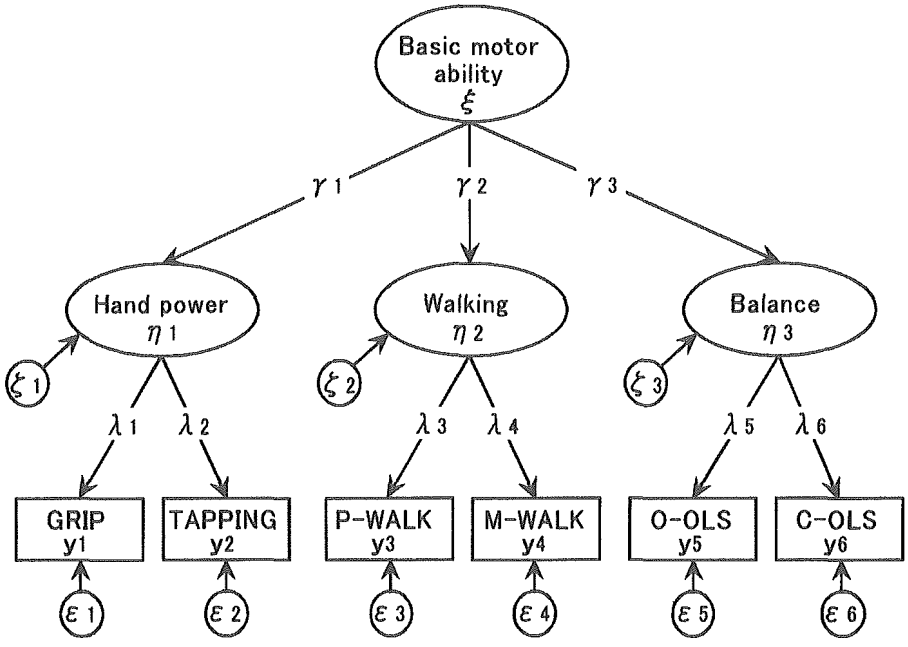

Figure 1 The second order factorial structure for physical performance measures; *basic motor ability* model;[23] GRIP, grip strength with handedness; TAPPING, maximum finger tapping rate; PV-WALK, preferred walking velocity; MV-WALK, maximum walking velocity; O-OLS, one-leg standing with eyes opened; C-OLS, one-leg standing with eyes closed.

given a follow-up examination later. The various values of the performance measurements indicated the longitudinal decline.[19,20] Can the factorial structure of the BMA model be kept longitudinally in spite of the aging decline of the performances? In other words, is the BMA model able to fit the data of the baseline research and the follow-up research, and be invariant[26] longitudinally? It is uncertain whether the factors, locations, and factor-loading were equal throughout the years.

Therefore, this study examined the longitudinal factorial invariance of the BMA model on the sample investigated by the follow-up research 4 years later, by expanding from the simultaneous analysis of CFA that applied to the test of the equivalence in the multiple groups. This study shows this analytical method of giving an indication of applicability of the work of invariance of factorial structure of various measures in longitudinal studies on aging.

Methods

Subjects

The cohort investigated in this study is from Medical Sciences TMIG-LISA.[25] In the baseline research of 1992, 734 residents aged 65 and over from Nangai-Village participated in the short physical performance battery test. The response rate was approximately 86% of all the eligible residents. The samples for this study were 463 elderly (males 177, females 286) who completed all of the physical performance tests in both the baseline research (1992) and the follow-up research 4 years later (1996). This comprised 63% (463/734) and 90% (463/517) of the respondents to the physical performance tests in the baseline research and in the follow-up research 4 years later, respectively. There were six items measured; preferred walking velocity, maximum walking velocity, one leg standing with eyes opened, one leg standing with eyes closed, grip strength, and maximum finger tapping rate. Detailed descriptions of these measures were presented in our previous studies.[19,22]

Model specification

Simultaneous analysis; longitudinal factorial invariance of BMA model

When parallel data exist for more than one group, simultaneous analysis of CFA, which is structural equation modeling, is a tool that is able to test statistically whether factorial structure fits the data and is invariant across groups.[27–29] As the data used for the present study is longitudinal data repeatedly measured by the same methods (three dimensions: time point × variables × subjects), the ordinary simultaneous analysis on multigroups is not applicable for this situation. We expanded this method to use as the test of the factorial invariance between the baseline research and the follow-up research 4 years later. By using this method, we analyzed longitudinal invariance of those structures of physical performance measurements.

Individual analysis: A prerequisite for simultaneous analysis is that a model used is fitted to the data of each group. This study therefore verified the fitness level of the BMA model (Fig. 1) constituted by the previous works[22,23] as the initial model in the respective cross-sectional data, in order to examine the changes in the factorial structure of the measures in the baseline research (1992) and in the follow-up research (1996). This model was already confirmed to fit well with the data from the cross-sectional baseline research.[23] Yet, as this study population was different from that of the previous study and also the numbers of those people were different, the analysis was renewed again. On the basis of the results of the Lagrange multiplier test and the Wald test, the initial model was modified by adding or omitting a pass if necessary. Each final BMA model studied cross-sectional was presumed.

Configurable invariance: Each BMA model was simultaneously examined on the basis of its individual model taken from the 1992 and 1996 data. It was determined whether the locations of the factor-loadings of the models in both years agreed and, namely configurable invariance of both models. In the case of research on the change of longitudinal factorial structure such as this study, ordinary simultaneous analyses on the multiple groups was made to expand. The paths of covariance between the time points were added to it. This is equivalent to the model that sets the covariances in the errors of the same measuring items in the matrix of multitrait-multimethod (MTMM).[28,30] In this study, we also added all covariances of corresponding errors of the physical performance measures in the BMA model of 1992 and of 1996 to the analyzed model.

Metric invariance: After configurable invariance was confirmed, examinations were done in turn to ascertain whether the factor-loadings in the models of both year's research were equal, that is, had metric invariance.[26] The factor-loadings of the models were restricted in a similar way to the ordinary simultaneous analysis; $\eta 1$~$\eta 3$ of 1992 and $\eta 1$~$\eta 3$ of 1996 were equivalent to each other, γ, γ, λ, ζ, and ε corresponding between both years were all the same value (see Fig. 1). Based on the χ^2 values of the restrictive test, modification was done on the restrictive invariance model to release one by one the fixed variable that was significantly different. If the restrictive equation would not be rejected, as the final model of the factorial structure in the longitudinal

physical performance measurements, the model was then estimated.

Goodness-of-fit of models

The indices concerning goodness of fit of the models were the goodness-of-fit index (GFI), adjusted goodness-of-fit index (AGFI), χ^2, χ^2/d.f., root mean square residual (RMR), and root mean square error of approximation (RMSEA). As information criterion Akaike's information criterion (CAIC)[31] and critical N (CN)[32] were used. These statistics were used to evaluate the fitness of the models as a whole. GFI and AGFI range between 0 and 1. These are the indices that can give an indication of the proportion of variance that is explained by the model. The value that is typically interpreted to reflect an adequate fitness is more than 0.9.[33] The AGFI is the value adjusted to the influence of the number of parameters. In contrast, RMR is the index that gives an indication of the proportion that is not explained by the model. The smaller the value of RMR, χ^2, and χ^2/d.f., the better the model's fitness level in the data. However, χ^2 is substantially influenced by the sample size.[34,35] The index that divided χ^2 with the degree of freedom is the χ^2/d.f. ratio. Recommendations for an acceptable χ^2/d.f. ratio vary from as low as 2.0 to as high as 5.0.[36] The RMSEA is the index corrected caused by the influence of parameter N. It is calculated by dividing the value of the divergence between population and the model by the degrees of freedom. Less than 0.05 indicates that the model fit is good. It is judged that the model with 0.1 would not fit in the data. Information criteria are utilized in order to compare several models.[31] The low value of AIC and CAIC that are the information criteria, indicates high compatibility of the model. The larger the value of CN, the better the model's fitness level. If the group covered by the research is one, it is more than 200. The value of over 400 is required in order to be an acceptable model in case of the two groups, such as simultaneous analysis.[32]

Analysis

To detect the differences in gender, age, and longitudinal changes in the tests, a repeated-measure ANOVA with gender, age-group, and double replication of measurement serving as factors was applied to each anthropometric and physical performance measurement. The analysis was performed using a CALIS procedure in the SAS system, controlled gender and the age at the time of baseline research. In order not to take the morphological factor (subject's height and weight) into consideration, grip strength and walking speeds were corrected by dividing them by each subject's weight and square root of body height, respectively.[22]

Results

Age-related longitudinal changes and gender differences in physical performance tests

Table 1 reports the means and standard deviations of the anthropometry and physical performance measures of the baseline research and of the follow-up 4 years later for gender and age group; together with the gender and age distribution of the study population. The results were derived from the repeated-ANOVA with age and gender factors in the baseline year, for each physical performance tests. This result showed significant main effects both of gender and age group for every measurement ($P < 0.05$). It indicated that the performance was higher for males than females, and deteriorated with age. Significant longitudinal changes were founded in all measures except for one-leg standing with eyes closed ($P < 0.05$). The same result was revealed in preferred and maximum walking velocities and grip strength corrected using each subject's height or weight. It was confirmed that the main effects of gender and age group as well as the longitudinal changes for these three measures were significant ($P < 0.001$).

Individual analysis of BMA model in cross-sectional data

A BMA model needs to fit the data of each year as the prerequisite of simultaneous analysis. Therefore, the goodness-of fit of BMA model (Fig. 1) to the data of the baseline research and of the follow-up research 4 years later, was first examined.

In reference to the result of LM test, one pair of covariance among measuring error of TAPPING and M-WALK (ε2 and ε4) was added to the initial model. With this revision, the goodness-of-fit indices of the model varied. The value of χ^2 varied from 0.997 to 0.999 in the baseline research and 0.994–0.997 in the follow-up research 4 years later. In the same way, GFI varied from 0.997 to 0.999 in 1992 and 0.994–0.997 in 1996. These changes of the indices gave the information that the model was improved. All of others, AGFI, RMSEA, AIC, CAIC, and CN, did as well. The BMA model revised by adding a covariance between ε2 and ε4 was thought of as a final model of cross-sectional data separately (CROSS final model). Figure 2 shows the estimate of factor-loadings and the indices of the goodness-of-fit of the CROSS final model. Although the goodness-of-fit of the models in 1996 was lower than in 1992, the fit indicators of both years demonstrated that the models provided reasonable fit. The results did provide a demonstration of the replicability and generalizability of the factorial structure designed to explain the physical performance measures

Table 1 Age and gender distribution of the study population and mean (standard deviation) of anthropometric and physical performances measurements

Baseline	Male				Female				Repeated measures ANOVA		
age group	65–69	70–74	75–79	80+	65–69	70–74	75–79	80+	Age group	Gender	Repeated survey year
N	80	65	26	6	112	100	44	30			
Height (cm)											
1992	158.1 (5.0)	157.6 (5.8)	156.3 (6.5)	154.2 (3.9)	146.3 (5.1)	144.6 (5.4)	143.2 (5.9)	142.3 (5.3)	***	***	***
1996	157.4 (5.1)	156.7 (5.9)	155.3 (6.2)	153.6 (4.0)	145.3 (5.6)	143.4 (5.6)	142.1 (6.5)	141.1 (5.6)			
Weight (kg)											
1992	54.9 (6.5)	54.5 (7.7)	53.4 (8.1)	52.9 (6.8)	50.7 (8.3)	48.8 (8.0)	46.3 (7.9)	44.6 (6.4)	**	***	***
1996	54.6 (6.9)	53.7 (7.7)	52.2 (8.2)	49.8 (5.1)	49.7 (8.3)	47.5 (8.1)	44.8 (7.6)	43.5 (6.3)			
Grip strength (kg)											
1992	33.4 (5.5)	33.1 (5.8)	27.7 (5.8)	26.0 (4.2)	20.8 (4.3)	19.0 (4.0)	18.5 (4.4)	16.5 (3.6)	***	***	*
1996	34.9 (5.5)	32.6 (6.4)	29.1 (5.6)	23.8 (9.0)	22.5 (4.4)	20.0 (4.8)	18.8 (4.5)	17.9 (4.4)			
Maximum finger tapping rate (Hz)											
1992	5.8 (0.8)	5.7 (0.8)	5.4 (0.6)	4.7 (0.6)	5.4 (0.6)	5.0 (0.6)	5.0 (0.6)	5.0 (0.8)	***	**	**
1996	5.5 (0.8)	5.6 (0.6)	5.3 (0.6)	4.7 (0.6)	5.2 (0.7)	5.0 (0.6)	5.0 (0.7)	4.9 (0.6)			
Preferred walking velocity (m/sec)											
1992	1.3 (0.2)	1.2 (0.2)	1.2 (0.2)	1.1 (0.2)	1.2 (0.2)	1.1 (0.2)	1.0 (0.2)	0.9 (0.2)	***	***	**
1996	1.2 (0.2)	1.1 (0.2)	1.1 (0.2)	1.0 (0.2)	1.1 (0.2)	1.0 (0.2)	0.9 (0.3)	0.8 (0.2)			
Maximum walking velocity (m/sec)											
1992	2.1 (0.4)	2.1 (0.3)	1.8 (0.4)	1.7 (0.1)	1.8 (0.3)	1.6 (0.3)	1.6 (0.4)	1.4 (0.3)	***	***	**
1996	2.0 (0.4)	1.8 (0.4)	1.7 (0.4)	1.5 (0.3)	1.7 (0.3)	1.4 (0.3)	1.4 (0.4)	1.2 (0.3)			
One leg standing with eyes opened (sec)											
1992	49.4 (18.8)	42.7 (20.8)	31.2 (23.2)	20.3 (22.0)	41.3 (21.9)	31.2 (21.9)	18.2 (16.7)	16.4 (16.7)	***	***	**
1996	44.6 (21.9)	34.8 (23.5)	24.1 (19.9)	21.5 (17.8)	31.4 (22.0)	20.3 (20.1)	13.1 (17.9)	8.0 (11.0)			
One leg standing with eyes closed (sec)											
1992	6.1 (5.2)	5.6 (5.6)	4.2 (5.7)	3.5 (2.1)	5.6 (6.1)	3.7 (2.7)	2.9 (1.8)	2.5 (2.0)	***	*	
1996	5.7 (5.1)	4.0 (3.9)	3.5 (5.7)	6.0 (8.4)	5.5 (5.8)	3.7 (3.9)	2.2 (2.0)	2.1 (1.7)			

*$p < 0.05$; **$p < 0.01$; ***$p < 0.001$.

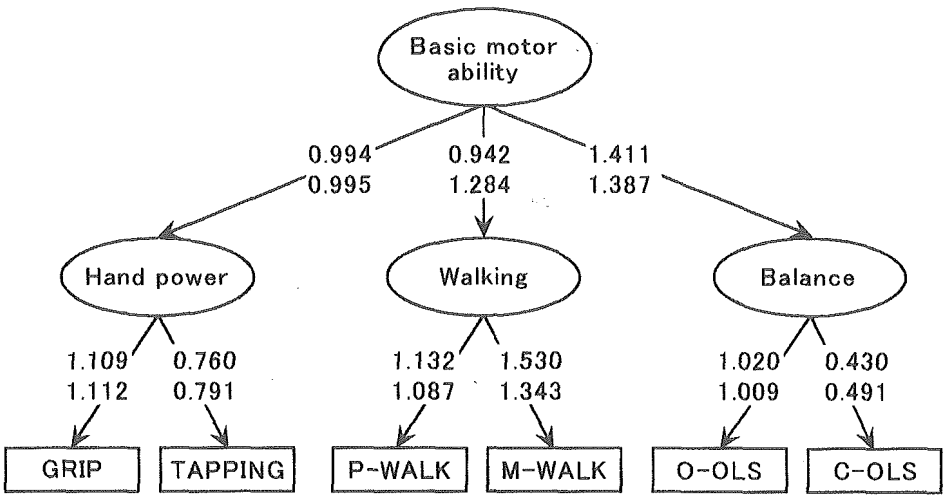

Figure 2 Estimates of factor loading of the cross-sectional final *basic motor ability* model (CROSS final model). GRIP, grip strength with handedness; TAPPING, maximum finger tapping rate; PV-WALK, preferred walking velocity; MV-WALK, maximum walking velocity; O-OLS, one-leg standing with eyes opened; C-OLS, one-leg standing with eyes closed. Leaving out six measuring errors. Observation N = 463, controlled gender and age at the time of baseline research. Upper; baseline (1992) χ^2 = 1.994 (d.f. = 1), GFI = 0.999, AGFI = 0.970, RMSEA (90%L, 90%U) = 0.004 (., 0.143), AIC = –0.006, CAIC = –5.140, CN = 888. Lower; follow-up 4-years later (1996) χ^2 = 4.292 (d.f. = 1), GFI = 0.997, AGFI = 0.936, RMSEA (90%L, 90%U) = 0.085(0.016, 0.173), AIC = 2.292, CAIC = –2.842, CN = 413.

investigated the cross-sectional research of the baseline and 4 years later.

Simultaneous analysis of BMA model in longitudinal data

As it was confirmed that the same model (CROSS final model) fit both data in 1992 and 1996, in individual analysis, the models of both years were analyzed simultaneously (i.e. simultaneous analysis).

First, an examination was conducted without any restrictions of the equal values of the factor-loadings and variables. The result showed that the model well fitted the longitudinal data; GFI = 0.998, AGFI = 0.943, RMR = 0.014, χ^2 = 6.113, χ^2d.f. = 3, RMSEA (90%L, 90%U) = 0.045 (., 0.102), AIC = –0.113, CAIC = –15.287, and CN = 590. From these results it can be interpreted that the factors and those locations of the factorial structure of the measures are invariant from 1992 to 1996, namely, configurable invariance. These results did provide a strong demonstration of the replica ability of the factorial structure designed to explain the physical performance measures for the older adults.

Next, the longitudinal BMA model fixed each of paralleling variables of 1992 and 1996 to the equal values was tested (Table 2, LONG model 1). The results of the tests for releasing equality constraints of this model are given in Table 2. The error (ε4) of GRIP of restrictive invariance model was not statistically equivalent. Therefore, a model releasing the restriction that the values of ε4 in both researches were equal was examined (Table 2, LONG model 2). As shown in the LONG model 2, this result demonstrated that all of the variables, the factor-loadings, and the errors (except ε4) were statistically identifiable values between the models in 1992 and 1996. By this releasing of a restriction, all goodness-of-fit indicators showed that the model was improving; as an example, GFI varied from 0.989 to 0.995. As these evaluations, the LONG model 2 was regarded as the longitudinal final model. The estimates in the LONG model 2 are shown in Table 3. The results of the covariances between both years' measuring items were left out. It was presented that each factorial structure of 1992 and of 1996 was identical and that all factor-loadings were equal to each other statistically. In brief, both models were metric invariant[26] over a period of 4 years, longitudinally.

In the present study, the longitudinal factorial invariance of the BMA model was analyzed by using the approach expanded from the ordinal simultaneous analysis. The results indicated statistically that the factorial structures of the physical performance measures in 1992 and 1996 were equal, in spite of longitudinal aging declines in each measure. Thus, they showed that the factors and their configuration in the structure of the physical performance tests were identical and that the values of all factor-loadings of the structure were equal, even 4 years after the baseline research. These examinations indicated that the simultaneous analysis of CFA of structural equation modeling was applicable as an approach of statistically examining the invariance of the factorial structure measuring an identical group longitudinally.

Table 2 Univariate lagrange multiplier test for releasing equality constraints of *basic motor ability* model

	LONG model 1		LONG model 2	
	χ^2	$Pr > \chi^2$	χ^2	$Pr > \chi^2$
λ1: [GRIP 1992: *Hand power* 1992] = [GRIP 1996: *Hand power* 1996]	0.004	0.951	0.365	0.546
λ2: [TAPPING 1992: *Hand power* 1992] = [TAPPING 1996: *Hand power* 1996]	0.169	0.681	0.000	0.989
λ3: [P-WALK 1992: *Walking* 1992] = [P-WALK: *Walking* 1996]	2.941	0.086	0.073	0.787
λ4: [M-WALK 1992: *Walking* 1992] = [M-WALK: *Walking* 1996]	4.592	0.032	1.633	0.201
λ5: [O-OLS 1992: *Balance* 1992] = [O-OLS 1996: *Balance* 1996]	0.925	0.336	1.562	0.211
λ6: [C-OLS 1992: *Balance* 1992] = [C-OLS 1996: *Balance* 1996]	0.664	0.415	0.560	0.454
γ1: [*Hand power* 1992: *Basic motor ability* 1992] = [*Hand power* 1996: *Basic motor ability* 1996]	0.125	0.724	0.252	0.616
γ2: [*Walking* 1992: *Basic motor ability* 1992] = [*Walking* 1996: *Basic motor ability* 1996]	0.012	0.915	1.767	0.184
γ3: [*Balance* 1992: *Basic motor ability* 1992] = [*Balance* 1996: *Basic motor ability* 1996]	0.086	0.969	1.129	0.288
ε1: [ε1: ε1 1992] = [ε1: ε1 1996]	0.522	0.470	0.447	0.504
ε2: [ε2: ε2 1992] = [ε2: ε2 1996]	0.279	0.598	0.187	0.665
ε3: [ε3: ε3 1992] = [ε3: ε3 1996]	9.698	0.002	3.612	0.057
ε4: [ε4: ε4 1992] = [ε4: ε4 1996]	15.572	< 0.0001	–	–
ε5: [ε5: ε5 1992] = [ε5: ε5 1996]	1.782	0.182	1.538	0.215
ε6: [ε6: ε6 1992] = [ε6: ε6 1996]	0.390	0.532	0.399	0.528
covariance ε2–ε4: [ε4: ε2 1992] = [ε4: ε2 1996]	1.982	0.159	0.210	0.647
ζ1: [ζ1: ζ1 1992] = [ζ1: ζ1 1996]	0.271	0.603	0.151	0.698
ζ2: [ζ2: ζ2 1992] = [ζ2: ζ2 1996]	3.134	0.077	0.129	0.720
ζ3: [ζ3: ζ3 1992] = [ζ3: ζ3 1996]	0.570	0.447	0.478	0.489

N = 463, controlled the gender and age at the time of 1992.
LONG model 1, all equality constraint of the factor-loadings and residuals of both years; $\chi^2 = 31.078$ (d.f. = 21); p = 0.072; GFI = 0.989; AGFI = 0.959; RMSEA = 0.032 (., –0.055); AIC = –10.923; CAIC = 118.724; CN = 485.
LONG model 2, releasing equality contraint of only the measuring errors of GRIP (ε4) of both years.
$\chi^2 = 15.066$ (d.f. = 20); p = 0.773; GFI = 0.995; AGFI = 0.979; RMSEA = 0.000 (., –0.028); AIC = 24.934; CAIC = –127.602; CN = 961.