We used I-PSS[22] and International Consultation on Incontinence Questionnaire Short-form (ICIQ-SF)[23] in the present study. The prevalence of LUTS was very different by the definition or the questionnaire.[9–12] We thought that using an international questionnaire would allow the comparison between the result of the present study and those of other countries. I-PSS was originally developed as a symptom index for benign prostatic hyperplasia in elderly men. Subsequently, it was widely used in epidemiological studies to quantify LUTS in both sexes. Some investigators have suggested that it might have potential for the assessment of the severity of LUTS in women.[24–26] Furthermore, Okamura estimated the psychometric properties of I-PSS for female LUTS.[27] I-PSS and ICIQ-SF were translated into Japanese, and the psychometric properties were validated.[28,29] To assess LUTS, this combination of questionnaires does not cover the whole range of urinary symptoms. However, they have frequently been used to assess LUTS in epidemiological studies. We thus used I-PSS and ICIQ-SF to estimate the prevalence of LUTS and their relationship to aging.

To date, no population-based study has evaluated the prevalence of LUTS using I-PSS and ICIQ-SF in Japan. The aim of the present study was to estimate the prevalence of LUTS in Japan and to compare it with those in other countries.

Methods

The subjects of this study were participants in the Longitudinal Study of Aging carried out at the National Institute for Longevity Sciences (NILS-LSA). NILS is the antecedent of the National Center for Geriatrics and Gerontology (NCGG).

The main purpose of the NILS-LSA is the systematic observation and description of the process of aging in humans.

In the present study, participants were stratified by both age and sex, and were random samples of community-dwelling people, aged 40 years or older in Obu-shi and Higashiura-cho, Aichi prefecture, Japan. The research area is geographically located in the center of Japan, near Nagoya, and has both urban and rural characteristics. The climate is almost average for Japan. Mail orders for participation to the first wave of the NILS-LSA were delivered to 7855 men and women aged 40 years or older. The 2510 responders attended the explanatory meeting of the present study, and 2267 subjects agreed to participate in the first wave of the NILS-LSA. The numbers of participants in 40–49, 50–59, 60–69 and 70–79 years age groups were intended to be equal. Only subjects who gave written informed consent participated in the NILS-LSA. The aging process was assessed by detailed questionnaires and examinations including clinical evaluation, body composition and anthropometry, physical functions, nutritional analysis, and psychological assessments. Every 2 years, various identical sets of medical examinations were carried out. When participants could not be followed up (e.g. they transferred to another area, dropped out for personal reasons, or died), new age- and sex-matched subjects were randomly recruited. All study waves included nearly 1200 men and 1200 women. Detailed descriptions of the sampling design and study methods were provided elsewhere.[30] The present study was based on cross-sectional analyses of the fifth wave of the NILS-LSA (2006–2008). Approximately 60% of the participants in the first wave of the NILS-LSA participated the fifth wave. The Ethics Committee of the National Center for Geriatrics and Gerontology had already approved all procedures of the NILS-LSA.

The questionnaire survey included I-PSS and ICIQ-SF, which have been validated in Japanese.[28,29] I-PSS was also validated for female LUTS.[30] Although the participants self-administered the questionnaire, a trained inspector checked the questionnaire and missing data were filled by interview.

I-PSS consists of seven symptom questions and a quality of life (QoL) index. The former include: (i) sensation of incomplete emptying; (ii) increased daytime frequency; (iii) intermittency; (iv) urinary urgency; (v) weak stream; (vi) straining; and (vii) nocturia, rated from 0 to 5 according to symptom frequency per day. The latter is rated from 0 for delighted to 6 for terrible. The severity of symptoms according to the total I-PSS was classified as none (score of 0), mild (1–7), moderate (8–19) and severe (20–35); the QoL score was categorized as mild (0–1), moderate (2–4) and severe (5–6). In the present study, we defined LUTS as I-PSS $\geq$8. The reason is that the population with I-PSS $\geq$8 shows a significant impairment of QoL.[2]

ICIQ-SF includes frequency of leakage (rating from 0 for never to 5 for all the time), amount of leakage (rating 0 for none to 6 for a large amount), interference with everyday life (rating from 0 for not at all to 10 for a great deal) and the types of urinary leakage (never, before getting to the toilet, when coughing or sneezing, during sleep, when physical active/exercising, when having finished urination and are dressed, no obvious reason, all the time). In the present study, participants were classified by the presence or absence of two or more a week urinary incontinence (more than two or three times a week: that is, rating 2 or greater in ICIQ-SF). As for the types of urinary incontinence, leakage before getting to the toilet is defined as urgency urinary incontinence (UUI), leakage when coughing or sneezing or when physically active/exercising is defined as stress urinary incontinence (SUI), leakage occurring in both instances is defined as mixed urinary incontinence (MUI), and leakage when having finished urination and having dressed is defined as postmicturitional dribble (PMD).

Participants were asked about smoking, medical history and prescribed drugs for LUTS used during the last 2 weeks, by questionnaire. The physician confirmed the responses at interview. Prescribed medications for LUTS including α-blockers, anticholinergic agents and others were checked. Medication use was recorded by asking participants to bring in all medications that they were taking.

The prevalences of the seven symptoms scoring ≥1 in I-PSS were investigated in association with age and sex.

The averages of the total I-PSS, storage score (I-PSS 2, 4, 7), voiding score (I-PSS 3, 5, 6), postmicturitional score (I-PSS 1), QoL index, and the total score of ICIQ-SF, scores of frequency and amount of urinary incontinence, and interference with everyday life were also investigated in association with age and sex.

Pearson's χ^2-test was used for comparison of proportions, and the Student's t-test was used for comparisons of averages. Trends were tested using Cochran–Mantel–Haenszel statistics. Statistical analyses were carried out using the SAS version 9.1.3 (SAS Institute, Cary, NC, USA) statistical software, and tested with a significance level set at $P < 0.05$.

Results

A total of 1200 men and 1219 women aged 40–88 years participated. After excluding three incomplete responses, the data from 1198 men and 1218 women were analyzed.

Characteristics of the participants are shown in Table 1. In both sexes, approximately one-quarter had hypertension. The second comorbidity was dyslipidemia and the third was diabetes mellitus.

The overall prevalence rates of I-PSS ≥8 and any type of two or more a week urinary incontinence were 18.5% and 5.0%, respectively (Table 2). There were significant differences between men and women in the prevalence of I-PS ≥8 (25.2% in men *vs* 11.8% in women, $P < 0.0001$), and any type of two or more a week urinary incontinence (3.3% in men *vs* 6.6% in women, $P = 0.0003$). In men and women, there were significant increases in prevalence of I-PSS ≥8 and any type of urinary incontinence with age. The prevalence rates of two or more a week SUI, UUI and MUI were greater in women; however, PMD was more frequent in men. All types of urinary leakage, except for PMD, increased in prevalence with age in men and women.

The prevalences of the seven symptoms of I-PSS are shown in Table 3. All the symptoms were significantly more frequent in men; however, in both sexes the prevalence of each symptom significantly increased with age.

As shown in Table 4, the total I-PSS score, storage score, voiding score, postmicturitional score and QoL index were significantly higher in men than in women ($P < 0.0001$). These scores increased with age in men and women ($P < 0.0001$). In every age group, the storage score was higher than the voiding score in both men and women.

As shown in Table 5, the total score of ICIQ-SF, and the scores of frequency, amount and interference with everyday life of ICIQ-SF were all significantly different between men and women ($P < 0.0001$). All scores increased with age in men ($P < 0.0001$), but were not associated with age in women.

In this survey, just 28 men (9.1%) and nine women (4.6%) who reported LUTS were medicated with α-blockers, anticholinergics and/or other drugs. The total I-PSS score in the medicated participants was significantly higher than that in the participants for whom the aforementioned drugs were not administered (9.8 ± 0.7 *vs* 4.2 ± 0.1, $P < 0.0001$).

Table 1 Characteristics of the participants in the Longitudinal Study of Aging carried out at the National Institute for Longevity Sciences

	Men	Women
n	1198	1218
Age (years)	60.7 ± 12.5	60.8 ± 12.7
40–49	279	294
50–59	289	277
60–69	274	281
70–79	283	278
80 or over	73	88
BMI (kg/m^2)	23.2 ± 2.7	22.5 ± 3.3
Comorbidity		
Hypertension	300 (25.0%)	296 (24.3%)
Dyslipidemia	106 (8.8%)	169 (13.9%)
Diabetes mellitus	78 (6.5%)	64 (5.3%)
Ischemic heart diseases	45 (4.0%)	34 (2.8%)
Cerebrovascular diseases	31 (2.6%)	24 (2.0%)
Smoking status		
Never smoker	329 (27.5%)	1099 (90.2%)
Ex-smoker	568 (47.5%)	63 (5.2%)
Current smoker	300 (25.1%)	57 (4.7%)
Sum of family annual income (yen)		
0–1 490 000	22 (1.8%)	46 (3.9%)
1 500 000–4 490 000	325 (27.3%)	378 (31.8%)
4 500 000–9 999 000	575 (48.3%)	511 (43.0%)
10 000 000 or over	268 (22.5%)	253 (21.3%)
Education level (years)	12.9 ± 2.9	12.0 ± 2.6
Medication for LUTS	38 (3.2%)	13 (1.1%)

BMI, body mass index; LUTS, lower urinary tract symptoms.

Table 2 Prevalence of lower urinary tract symptoms by age and sex

	I-PSS ≥8	Any types of urinary incontinence	I-PSS ≥8 and/or UI	SUI	UUI	MUI	PMD
Overall	446 (18.5)	120 (5.0)	504 (20.9)	76 (3.2)	62 (2.6)	28 (1.2)	19 (0.8)
Sex							
Men	302 (25.2)	40 (3.3)	309 (25.8)	10 (0.8)	22 (1.8)	2 (0.2)	16 (1.3)
Women	144 (11.8)	80 (6.6)	195 (16.0)	66 (5.4)	40 (3.3)	26 (2.1)	3 (0.3)
P-value	<0.0001	0.0003	<0.0001	<0.0001	0.0245	<0.0001	0.0024
Men							
Age (years)							
40–49	15 (5.4)	1 (0.4)	15 (5.4)	0 (0)	1 (0.4)	0 (0)	1 (0.4)
50–59	41 (14.2)	5 (1.7)	44 (15.2)	0 (0)	0 (0)	0 (0)	5 (1.7)
60–69	95 (34.7)	8 (2.9)	95 (34.7)	1 (0.4)	5 (1.8)	0 (0)	3 (1.1)
70–79	110 (38.9)	15 (5.3)	114 (40.3)	6 (2.1)	9 (3.2)	1 (0.4)	3 (1.1)
80 or over	41 (56.2)	11 (15.1)	41 (56.2)	3 (4.1)	7 (9.6)	1 (1.4)	4 (5.5)
P-trend	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	0.0345	0.0514
Women							
Age (years)							
40–49	7 (2.4)	15 (5.1)	22 (7.5)	14 (4.8)	3 (1.0)	2 (0.7)	1 (0.3)
50–59	15 (5.4)	10 (3.6)	24 (8.7)	9 (3.3)	5 (1.8)	4 (1.4)	0 (0)
60–69	33 (11.7)	18 (6.4)	42 (15.0)	15 (5.3)	12 (4.3)	9 (3.2)	1 (0.4)
70–79	64 (23.0)	24 (8.6)	75 (27.0)	20 (7.2)	10 (3.6)	6 (2.2)	0 (0)
80 or over	25 (28.4)	13 (14.8)	32 (36.4)	8 (9.1)	10 (11.4)	5 (5.7)	1 (1.1)
P-trend	<0.0001	0.0007	<0.0001	0.0332	<0.0001	0.0085	0.6434

Urinary incontinence (UI) was defined the voluntary loss of urine at least two or more a week.
I-PSS, International Prostate Symptom Score; LUTS, lower urinary tract symptoms; MUI, mixed urinary incontinence; PMD, postmicturitional dribble; SUI, stress urinary incontinence; UUI, urge urinary incontinence.

Discussion

The NILS-LSA is a population-based study using questionnaire surveys including I-PSS and ICIQ-SF to estimate the prevalence of LUTS in Japanese men and women. The overall prevalence of total I-PSS ≥8 was 18.5%, and each symptom score, storage score, voiding score and total score increased with age, similarly to those in the BACH survey and UrEpik study.[10,11] The UrEpik study estimated the same prevalence of moderate to severe LUTS among Korean men as for European men. Risk factors for LUTS were reportedly age, lifestyle, comorbidities and benign prostatic hyperplasia, especially in men.[4–8] Although the prevalences of subjects with these risk factors were probably different (data not shown), the prevalence of LUTS in Japan was similar to that in other countries.

The prevalence of I-PSS ≥8 in the present study was 25.2% in men and 11.8% in women, with a significant difference. To date, the prevalence of I-PSS ≥8 in Japanese men was reported to be 36.6% by Tsukamoto *et al.*,[13] higher than that in the present study. Because their study was carried out in a small fishing village on Hokkaido island, the background of the residents was very different from that in the present survey. The higher rate might have been caused by some factor associated with the different location.

The BACH survey showed that race/ethnicity affected the prevalence of LUTS.[11] The prevalence of I-PSS ≥8 in the present study was similar to those in other countries. The UrEpik study was carried out in four countries: the Netherlands, France, UK and Korea. It reported that the percentages of I-PSS ≥8 were 16.2–25.1% in men and 12.6–23.1% in women.[10] According to the BACH survey, the prevalence was 18.7% in the USA.[11] Interestingly, in studies using questionnaires other than I-PSS, the prevalence of LUTS was very different from the aforementioned studies. The EPIC study showed that LUTS were observed in 62.5% of men and 66.6% of women older than 40 years-of-age.[9] The Canadian Urinary Bladder Survey showed that LUTS were observed in 49.1% and 68.7% in men and women aged 41–64 years, and 51.1% and 63.8% in men and women older than 65 years.[12] A common questionnaire should be used in order to maintain comparability with studies in other countries.

Regarding the prevalence of I-PSS ≥8, we found a significant sex difference in the present study (25.2% in men *vs* 11.8% in women, $P < 0.0001$). Homma *et al.* reported that the incidences of voiding and postvoid

Table 3 Prevalence of the seven symptoms in International Prostate Symptom Score

	Score ≥1 Sensation of incomplete emptying	Increased daytime frequency	Intermittency	Urinary urgency	Weak stream	Straining	Nocturia
Overall	591 (24.5)	1372 (56.8)	537 (22.2)	731 (30.3)	946 (39.2)	355 (14.7)	1487 (61.6)
Sex							
Men	387 (32.3)	724 (60.4)	365 (30.5)	410 (34.2)	580 (48.4)	252 (21.0)	790 (65.9)
Women	204 (16.8)	648 (53.2)	172 (14.1)	321 (26.4)	366 (30.1)	103 (8.46)	697 (57.2)
P-value	<0.0001	0.0003	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
Men							
Age (years)							
40–49	63 (22.6)	137 (49.1)	33 (11.8)	29 (10.4)	69 (24.7)	26 (9.3)	88 (31.5)
50–59	88 (30.5)	169 (58.5)	83 (28.7)	69 (23.9)	120 (41.5)	49 (17.0)	147 (50.9)
60–69	100 (36.5)	181 (66.1)	105 (38.3)	128 (46.7)	162 (59.1)	66 (24.1)	225 (82.1)
70–79	106 (37.5)	187 (66.1)	112 (39.6)	140 (49.5)	180 (63.6)	83 (29.3)	257 (90.8)
80 or over	30 (41.1)	50 (68.5)	32 (43.8)	44 (60.3)	49 (67.1)	28 (38.4)	73 (100)
P-trend	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
Women							
Age (years)							
40–49	28 (9.5)	136 (46.3)	12 (4.1)	52 (17.7)	43 (14.6)	7 (2.4)	72 (24.5)
50–59	40 (14.4)	155 (56.0)	30 (10.8)	57 (20.6)	72 (26.0)	16 (5.8)	125 (45.1)
60–69	57 (20.3)	153 (54.5)	45 (16.0)	78 (27.8)	88 (31.3)	23 (8.2)	199 (70.8)
70–79	59 (21.2)	151 (54.3)	62 (22.3)	102 (36.7)	121 (43.5)	42 (15.1)	225 (80.9)
80 or over	20 (22.7)	53 (60.2)	23 (26.1)	32 (36.4)	42 (47.7)	15 (17.1)	76 (86.4)
P-trend	<0.0001	0.0271	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001

Table 4 Total, storage, voiding and postmicturitional score of International Prostate Symptom Score by age and sex

	Total I-PSS	Storage score	Voiding score	Postmicturional score	QoL index
Overall	4.33 ± 5.18	2.35 ± 2.51	1.56 ± 2.79	0.41 ± 0.96	3.10 ± 1.35
Sex					
Men	5.33 ± 5.75	2.56 ± 2.69	2.11 ± 3.14	0.57 ± 1.11	3.27 ± 1.36
Women	3.34 ± 4.33	2.06 ± 2.27	1.02 ± 2.29	0.26 ± 0.75	2.94 ± 1.32
P-value	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
Men					
Age (years)					
40–49	2.15 ± 2.73	1.15 ± 1.45	0.65 ± 1.46	0.35 ± 0.84	2.76 ± 1.30
50–59	3.76 ± 4.09	1.73 ± 1.72	1.55 ± 2.56	0.48 ± 0.96	3.07 ± 1.25
60–69	6.63 ± 5.87	3.37 ± 2.99	2.64 ± 3.27	0.62 ± 1.13	3.38 ± 1.37
70–79	7.72 ± 6.69	3.81 ± 2.89	3.19 ± 3.78	0.72 ± 1.25	3.67 ± 1.33
80 or over	9.59 ± 7.18	4.85 ± 3.12	3.74 ± 3.84	1.00 ± 1.58	3.97 ± 1.32
P-trend	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001
Women					
Age (years)					
40–49	1.47 ± 2.16	1.10 ± 1.46	0.27 ± 1.02	0.11 ± 0.34	2.50 ± 1.24
50–59	2.36 ± 2.99	1.57 ± 1.69	0.61 ± 1.42	0.18 ± 0.57	2.87 ± 1.23
60–69	3.63 ± 4.35	2.30 ± 2.40	1.03 ± 2.32	0.30 ± 0.75	3.05 ± 1.36
70–79	5.10 ± 5.22	2.92 ± 2.59	1.79 ± 2.98	0.38 ± 1.02	3.25 ± 1.35
80 or over	6.14 ± 6.10	3.35 ± 2.75	2.34 ± 3.40	0.44 ± 1.07	3.32 ± 1.17
P-trend	<0.0001	<0.0001	<0.0001	<0.0001	<0.0001

I-PSS, International Prostate Symptom Score; QoL, quality of life.

Table 5 International Consultation on Incontinence Questionnaire Short-form by age and sex

	Total score	Score of frequency	Score of amount	Interference with everyday life
Overall	1.80 ± 3.05	0.49 ± 0.85	0.84 ± 1.37	0.46 ± 1.08
Sex				
Men	0.86 ± 2.48	0.24 ± 0.71	0.37 ± 1.03	0.25 ± 0.93
Women	2.71 ± 3.27	0.74 ± 0.90	1.30 ± 1.50	0.67 ± 1.18
P-value	<0.0001	<0.0001	<0.0001	0.0001
Men				
Age (years)				
40–49	0.24 ± 1.41	0.06 ± 0.37	0.11 ± 0.59	0.07 ± 0.55
50–59	0.35 ± 1.39	0.12 ± 0.51	0.18 ± 0.68	0.05 ± 0.30
60–69	0.88 ± 2.33	0.24 ± 0.66	0.42 ± 1.10	0.22 ± 0.73
70–79	1.52 ± 3.32	0.40 ± 0.89	0.64 ± 1.35	0.47 ± 1.29
80 or over	2.66 ± 3.96	0.77 ± 1.21	0.90 ± 1.34	0.99 ± 1.81
P-trend	<0.0001	<0.0001	<0.0001	<0.0001
Women				
Age (years)				
40–49	2.81 ± 3.22	0.77 ± 0.89	1.61 ± 1.62	0.64 ± 1.04
50–59	3.25 ± 3.45	0.86 ± 0.91	1.14 ± 1.44	0.77 ± 1.22
60–69	2.41 ± 3.14	0.67 ± 0.91	1.12 ± 1.36	0.60 ± 1.14
70–79	2.43 ± 3.14	0.67 ± 0.88	1.12 ± 1.36	0.64 ± 1.19
80 or over	2.59 ± 3.53	0.70 ± 0.95	1.11 ± 1.38	0.77 ± 1.55
P-trend	0.1334	0.1564	0.0056	0.668

ICIQ-SF, International Conference on Incontinence Questionnaire Short-Form.

symptoms were higher in men, whereas those of storage symptoms were similar in men and women. In the present study, the incidence of storage symptoms was also higher in men. The BACH and EPIC studies showed no significant sex difference (18.7% in men *vs* 18.6% in women, $P = 0.96$ and 62.5% *vs* 66.6%, *P*-value not shown, respectively).[9,11] The data of the Seoul center in the UrEpik study showed 19.9% in women and 16.2% in men (*P*-value not reported).[10] The prevalence of overactive bladder was higher in women in European countries, but interestingly was higher in men in Japan.[9,12,21] Although the reasons remain unclear, race or ethnicity might affect the prevalence of storage symptoms.

We showed that the prevalence of I-PSS ≥8 increased with age. Similar relationships were shown in the UrEpik, EPIC, Canadian and BACH studies. The storage score, voiding score and postvoid score also significantly increased with age, as shows by the afore-mentioned studies.[9–12]

In Japan, the prevalence of urinary incontinence was reported to be 7.2–22% in men and 27.5–34.5% in women.[15–19] In the present study, the prevalence of urinary incontinence was 3.3% in men and 6.6% in women. The prevalence in the present study was less than those of previous studies. The reasons were thought to be related to the sampling and examination procedures, and the definition of urinary incontinence. Actually, 2.8–5.7% of men and 6.4–12.8% of women leaked urine at least twice or more per week. Those prevalences were similar to findings in the present study.[15,17,18] According to the BACH and EPIC studies, they were 5.3 and 5.4% in men and 10.4 and 13.1% in women, respectively, showing higher prevalence in the USA and European countries.[9,31] The present study also showed a twofold prevalence of urinary incontinence in women. Homma *et al.* revealed that the prevalence of pad use was 2% in Japanese men and 7% in women.[23] Regarding the types of urinary incontinence, the most frequent were UUI in men (1.8%) and SUI in women (5.4%) in this survey. Other studies also showed a higher prevalence of UUI in men; however, the rates of either SUI or MUI were higher in women.[9,12,31] Furthermore, the relationships between the prevalence of urinary incontinence and aging appeared to be equivalent among the other studies.[9,12,31] Postmicturition dribble was not associated with age in either sex; however, all types of urinary leakage, except PMD, increased with age.

In the present study, just 51 participants (2.1%) were medicated. Their total scores of I-PSS were significantly higher than those of the participants who were not medicated. The BACH survey also showed a similarity: just 3.5% of men and 2.0% of women were medicated.[11] Only a small proportion of LUTS patients receive treatment.

There were some limitations to the present study. It was a community-based study, with random sampling of men and women, but was limited geographically to the NILS-LSA area. There was no apparent evidence of representative results of Japanese people. Another limitation was that we used a self-reporting system to measure LUTS without urological examination. It was possible that participants were bashful about reporting urination conditions, and underreported. However, this limitation is common to large epidemiological studies.

A third limitation was that many individuals who were invited declined to participate in the NILS-LSA. This might affect the results, if the prevalence of LUTS was different in non-respondents relative to those who did respond.

To our knowledge, this is the first population-based study published that evaluates LUTS in Japanese men and women, using I-PSS and ICIQ-SF, drawing on a broad representative age range in both sexes. In the future, we will carry out a longitudinal study regarding LUTS, and study the association between LUTS and medical problems.

Disclosure statement

No potential conflicts of interest were disclosed.

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Does high educational level protect against intellectual decline in older adults?: A 10-year longitudinal study[1]

YUKIKO NISHITA*, CHIKAKO TANGE, and MAKIKO TOMIDA *National Center for Geriatrics and Gerontology*

FUJIKO ANDO *Aichi Shukutoku University*

HIROSHI SHIMOKATA *Nagoya University of Arts and Sciences*

Abstract: This study examined the relation between educational level and intellectual change in Japanese older adults. Participants (age = 65–79 years, n = 593) comprised the first-wave participants of the National Institute for Longevity Sciences-Longitudinal Study of Aging (NILS-LSA). They were followed for 10 years and were tested six times. Educational levels were divided into two groups (low-educated or high-educated), and intellectual changes for the 10 years were assessed using the Japanese Wechsler Adult Intelligence Scale-Revised Short Forms (JWAIS-R-SF); subtests included Information, Similarities, Picture Completion, and Digit Symbol. General linear mixed-model analyses revealed that education had not affected 10-year changes of the Information, Similarities, and Picture Completion subtest scores. In contrast, education was significantly associated with a change in the Digit Symbol subtest score; individuals with higher levels of education showed greater decline than those with less education, although they had higher ability at every time point. These findings suggest that higher education does not protect against intellectual decline in late life, although it is associated with long-term individual differences in intelligence.

Key words: intelligence, education, older adults, longitudinal study.

Many studies have suggested that early-life educational level is associated with better intellectual abilities in late life (e.g., Kaufman & Lichtenberger, 2006; Schaie, 2005; Wechsler, 1981). However, recent articles based on longitudinal data have shown conflicting results with respect to the relation between educational level and intellectual changes in old age. Some longitudinal studies have reported that educational attainment moderates intellectual decline in samples of older adults (e.g., Alvarado, Zunzunequi, Del Ser, & Beland, 2002; Arbuckle, Maag, Pushkar, & Chaikelson, 1998; Evans, Beckett, Albert, Hebert, Scherr, Funkenstein, & Taylor, 1993; Farmer, Kittner, Rae, Bartko, & Regier, 1995; Koster, Penninx, Bosma, Kempen, Newman, Rubin, Satterfield, Atkinson, Ayonayon, Rosano, Yaffe, Harris, Rooks, Van Eijk, & Kritchevsky, 2005; Lee, Kawachi, Berkman, & Grodstein, 2003; Lyketsos, Chen, & Anthony, 1999). However, others disagree with these findings, suggesting

*Correspondence concerning this article should be sent to: Yukiko Nishita, Section of NILS-LSA, Center for Gerontology and Social Science, National Center for Geriatrics and Gerontology, Gengo, Morioka-cho, Obu 477-8511, Japan. (E-mail: nishita@ncgg.go.jp)

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that higher education does not protect against intellectual decline (e.g., Seeman, Huang, Bretsky, Crimmins, Launer, & Guralnik, 2005; Tucker-Drob, Johnson, & Jones, 2009; Van Dijk, Van Gerven, Van Boxtel, Van der Elst, & Jolles, 2008; Wilson, Hebert, Scherr, Barnes, Mendes de Leon, & Evans, 2009; Zahodne, Glymour, Sparks, Bontempo, Dixon, Macdonald, & Manly, 2011), or that relations between education and intellectual change appear to differ by intellectual domain (e.g., Alley, Suthers, & Crimmins, 2007; Anstey & Christensen, 2000; Anstey, Hofer, & Luszcz, 2003).

From the perspective of the *cognitive reserve* hypothesis, it is noteworthy that previous longitudinal studies have reported the mixed results described above. The hypothesis of cognitive reserve asserts that older individuals with greater experiential resources exhibit better cognitive functioning and are able to tolerate brain pathology before displaying clinical symptoms (Scarmeas & Stern, 2004; Stern, 2002). Stern (2002) postulated that high cognitive reserve may allow individuals to cope more successfully with age-related brain changes, and that one of the most well-established proxy measures of cognitive reserve capacity in the elderly was educational attainment, which is thought to reflect more effective use of brain networks or cognitive paradigms.

Two competing cognitive reserve models could offer insight into the effect of education on the rate of cognitive change (Stern, 2002; Van Dijk et al., 2008). First, if high education was found to slow the rate of cognitive decline, this finding would support an *active* cognitive reserve hypothesis. In this case, individuals with higher education would be hypothesized to process tasks more efficiently. Further, because they make more efficient use of brain networks, the same amount of organic cognitive damage would result in a smaller decline in cognitive function relative to those with less education. Second and alternately, if educational level does not relate to the rate of cognitive change, this would support a *passive* cognitive reserve hypothesis. If aging individuals begin to lose cognitive function from a common cause, such as normal aging brains, people with higher education would change at a rate similar to the total population, but would continue to perform at a higher level at any age because of greater baseline brain reserve. These theories of *active* and *passive* cognitive reserve processes are often evaluated with respect to the implications for *moderation* versus *stability* (Salthouse, 2003; Tucker-Drob et al., 2009) or *differential-preservation* versus *preserved-differentiation* (Bielak, Anstey, Christensen, & Windsor, 2012; Salthouse, 2006).

Inconsistencies in previous longitudinal studies may be due to some methodological differences among the studies. For example, studies differed in the number of consecutive assessments, or the measures of intellectual abilities used.

In terms of the number of assessments, some studies (e.g., Alvarado et al., 2002; Arbuckle et al., 1998; Evans et al., 1993; Farmer et al., 1995; Koster et al., 2005; Lee et al., 2003; Lyketsos et al., 1999) examined intellectual change by calculating a difference between only two test occasions and then used traditional regression analysis or repeated measures analysis of variance techniques. However, ideally, to estimate a true change, intellectual ability should be assessed at multiple time points rather than using a simple difference in two test administrations (Alley et al., 2007; Wilson et al., 2009). The use of three or more assessments of longitudinal intellectual aging can reduce measurement error (Winkens, Schouten, Van Breukelen, & Berger, 2006) as well as avoid the regression toward the mean phenomenon (Dufouil, Fuhrer, Dartigues, & Alpérovitch, 1996; Zahodne et al., 2011). Moreover, the use of three or more assessments makes possible the use of more sophisticated analytic techniques, such as multilevel modeling or general linear mixed modeling (Laird & Ware, 1982; Morrell, Brant, & Ferrucci, 2009; Verbeke & Molenberghs, 1997).

A second methodological difference concerns which domain of intellectual ability was being measured; it remains possible that education may have different effects on the changes in different intellectual domains. For example, in their review of the literature, Anstey and Christensen (2000) found that education appears to be more predictive for crystallized ability, but less predictive for fluid ability or processing speed. Similarly, Wilson et al. (2009) pointed out that their results were based on overall global cognition, so they could not establish whether education was related to decline in some intellectual domains but not others. Additionally, some studies (e.g., Evans et al., 1993; Farmer et al., 1995; Lee et al., 2003) have used mental status measures that assess the most basic level of cognitive abilities (e.g., the Mini Mental State Examination; Folstein, Folstein, McHugh, Practical, & Patients, 1975). Such basic level measures may be insensitive to change among well-educated older adults due to ceiling effects that prevent detection of changes within the upper levels of functioning, resulting in spurious relations between initial performance and change (Tucker-Drob et al., 2009). Thus, multiple and more sensitive assessments that reflect greater variability in intellectual functions might better address educational differences in future research.

The present study

The purpose of the present study was to determine whether educational level is associated with the rate of intellectual change in community-dwelling older Japanese. The important characteristics of this study included the following: (a) the participants were followed for 10 years, tested six times, and general linear mixed models were used to analyze the data; and (b) to measure intelligence in late life, we used neuropsychological tests to cover the multiple intellectual abilities of the adults: the Japanese Wechsler Adult Intelligence Scales-Revised Short Forms (JWAIS-R-SF; Kobayashi, Fujita, Maekawa, & Dairoku, 1993). The JWAIS-R-SF includes four standardized subtests (Information, Similarities, Picture Completion, and Digit Symbol). To our knowledge, this may be the first study that approaches the effect of educational levels on intellectual changes for Japanese older adults.

Methods

Participants

The data for the present study were collected as a part of the National Institute for Longevity Sciences-Longitudinal Study of Aging (NILS-LSA; Shimokata, Ando, & Niino, 2000). The NILS-LSA is a population-based prospective cohort study of aging and age-related diseases. The participants were sex- and age-stratified random samples of Japanese community-dwelling adults aged from 40 to 79 years at baseline (Wave1: 1997–2000). This baseline sample consisted of 2267 participants who were followed up every 2 years (Wave2: 2000–2002, Wave3: 2002–2004, Wave4: 2004–2006, Wave5: 2006–2008, Wave6: 2008–2010). Informed consent was obtained from each participant at the beginning of the study.

We selected an initial sample of individuals who were aged 65 years or older at baseline ($n = 816$). We excluded individuals who: (a) provided data only at baseline ($n = 210$) because longitudinal analyses required a minimum of two valid scores per individual, (b) had a history of dementia at baseline ($n = 1$), or (c) had missing data on all dependent variables at baseline or on the independent variables ($n = 12$). Based on these criteria, the data from 593 individuals were included at baseline. Mean age at baseline was 70.96 years ($SD = 3.90$ years, age range = 65–79 years), with 46.54% of the sample being women.

Measures

Intelligence. The Wechsler Adult Intelligence Scale (WAIS) is one of the most popular tools for assessing intelligence (Wechsler, 1944). In this study, intelligence was assessed using the JWAIS-R-SF (Kobayashi et al., 1993). The trained testers (clinical psychologists or psychology graduate students) administered the test to each participant one on one. The JWAIS-R-SF consists of the following four subtests: Information, Similarities, Picture Completion, and Digit Symbol.

1 Information: Participants were asked general knowledge questions covering people, places, and events (29 items, possible range 0–29). This subtest measured the fund of factual knowledge.
2 Similarities: Participants were asked to tell what way two things are alike (14 items, possible range 0–28). This subtest measured logical abstract reasoning.
3 Picture Completion: Participants were asked to spot the missing element in a series of drawings (21 items, possible range 0–21). This subtest measured the long-term visual memory and the ability to differentiate essential from inessential details.
4 Digit Symbol: Participants were asked to write down the symbol that corresponded to a given number (as many as they could in 90 s, possible range 0–93). This subtest measured processing speed and visual-motor coordination.

Educational levels. Participants self-reported their level of education on a scale with four options (1 = *elementary school or junior high school*, 2 = *high school or junior high school under the former Japanese educational system*, 3 = *higher vocational school or junior college*, and 4 = *college or graduate college*). The baseline sample reported 47.39% ($n = 281$) elementary school or junior high school, 35.92% ($n = 213$) high school or junior high school under the former Japanese educational system, 10.96% ($n = 65$) higher vocational school or junior college graduates, and 5.73% ($n = 34$) college or graduate college graduates. Given this distribution, we divided educational levels into two groups: the low-educated group (level = 1) and the high-educated group (levels = 2–4).

Covariates. At baseline assessment, marital status (0 = unmarried, 1 = married), occupation (0 = inoccupation, 1 = having occupation), smoking (0 = nonsmoker, 1 = smoker) and past and present illness (stroke, hypertension, heart disease, and diabetes: 0 = none, 1 = having past or present illness) were examined using questionnaires.

Results

Statistical analyses were performed using the SAS System version 9.1.3. A p-value of <0.05 was considered statistically significant.

Sample characteristics

Table 1 presents the baseline sample characteristics by level of education. There were no significant differences in age, sex, and other covariates by educational levels. All baseline intelligence scores in the high-educated group were significantly greater than in the low-educated group (all $ps < .001$).

In addition, compared with the excluded group ($n = 210$), which provided data only at baseline, this study sample showed higher scores on all intelligence measures (Information, 10.30 vs. 13.13, $t(793) = 6.47, p < .001$; Similarities, 8.73 vs. 11.17, $t(792) = 5.41$, $p < .001$; Picture Completion, 7.40 vs. 9.74, $t(794) = 7.87$, $p < .001$; Digit Symbol, 34.17 vs. 39.62, $t(792) = 6.49, p < .001$). However, there were no significant differences between the level of education, $\chi^2(3) = 4.24$, *ns*.

Participation in follow up

There was an average of 4.18 repeated measurements per participant (range 2–6). The mean duration of follow up from baseline to final assessment for each participant was 6.80 years (range 1.92–11.21 years). Information about follow-up participation is summarized in Table 2. The participation rates in Wave5 and Wave6 in the high-educated group were significantly higher than in the low-educated group (Wave5, $\chi^2(1) = 4.53$, $p = .033$; Wave6, $\chi^2(1) = 5.39, p = .020$). However, there were no significant differences between the level of education and the participation rate in other follow-up measures (Wave2, $\chi^2(1) = .50$, *ns*; Wave3, $\chi^2(1) = .04$, *ns*; Wave4, $\chi^2(1) = .46$, *ns*).

Educational levels and intellectual change

General linear mixed models were used to evaluate the effects of the level of education on the rate of intellectual change over time. We obtained fixed effects (i.e., average effects for the group of educational levels) and random

Table 1 Descriptive statistics of baseline sample by level of education

Variable	High-educated (n = 312)	Low-educated (n = 281)	t/χ^2 test	
Age at baseline, mean (*SD*)	70.70 (3.96)	71.26 (3.82)	$t(591) = 1.75$	*ns*
Sex, women, *n* (%)	138 (44.23)	138 (49.11)	$\chi^2(1) = 1.41$	*ns*
Marital status, married, *n* (%)	253 (81.09)	216 (76.87)	$\chi^2(1) = 1.59$	*ns*
Occupation, having occupation, *n* (%)	86 (27.56)	79 (28.11)	$\chi^2(1) = 0.02$	*ns*
Smoking, smoker, *n* (%)	57 (18.27)	49 (17.44)	$\chi^2(1) = 0.07$	*ns*
Past and present illness, *n* (%)				
Stroke	17 (5.45)	15 (5.34)	$\chi^2(1) = 0.00$	*ns*
Hypertension	130 (41.67)	101 (35.94)	$\chi^2(1) = 2.04$	*ns*
Heart disease	66 (21.15)	47 (16.73)	$\chi^2(1) = 1.88$	*ns*
Diabetes	36 (11.54)	34 (12.10)	$\chi^2(1) = 0.04$	*ns*
Intelligence at baseline, mean (*SD*)				
Information	15.32 (5.66)	10.70 (4.21)	$t(591) = 11.17$	***
Similarities	13.36 (5.27)	8.73 (4.70)	$t(590) = 11.23$	***
Picture Completion	10.51 (3.41)	8.88 (3.73)	$t(591) = 5.57$	***
Digit Symbol	44.09 (10.16)	34.61 (8.32)	$t(589) = 12.32$	***

Note. The final sample consisted of 593 participants who had at least two visits. Data were missing as follows: Similarities, $n = 1$; Digit Symbol, $n = 2$.
***$p < .001$. *ns* = not significant.

Table 2 Follow-up participation information

	Participants, *n* (high-educated/low-educated)	Follow-up years from baseline, mean (*SD*)
Baseline	593 (312/281)	0.00
Wave2	566 (296/270)	2.05 (0.11)
Wave3	443 (232/211)	4.08 (0.18)
Wave4	363 (195/168)	6.20 (0.25)
Wave5	289 (165/124)	8.28 (0.28)
Wave6	223 (131/92)	10.27 (0.28)

Note. The final sample consisted of 593 participants who had at least two visits.

effects (i.e., individual deviation from the fixed effects) to model individual intellectual change. That is, intellectual change was assumed to follow the mean path of the group, except for person-specific random effects that cause the initial individual level of functioning to be higher or lower and the rate of change to be faster or slower. In addition, general linear mixed models can handle missing data more appropriately than traditional models (e.g., general linear models), so they can use all available data during follow up. Moreover, the correlation between the repeated measures is properly accounted for through the variance-covariance structure of the random effects. A general linear mixed model was chosen for the analysis of intellectual change in some recent studies (e.g., Alfaro-Acha, Snih, Raji, Kuo, Markides, & Ottenbacher, 2006; Crane, Gruhl, Erosheva, Gibbons, McCurry, Rhoads, Nguyen, Arani, Masaki, & White, 2010; Ganguli, Du, Dodge, Ratcliff, & Chang, 2006; Nishita, Tange, Tomida, Ando, & Shimokata, 2012a; Van Dijk et al., 2008; Wilson, Beckett, Barnes, Schneider, Bach, Evans, & Bennett, 2002). Further information on the application of general linear mixed models to repeated measures data is published elsewhere (e.g., Laird & Ware, 1982; Morrell et al., 2009; Verbeke & Molenberghs, 1997).

Table 3 Educational levels and 10-year change in intelligence as estimated from linear mixed effects models

Intelligence scale	Model terms	Parameter estimate	*SE*	*p*-value
Information	Education	4.44	0.39	***
	Time	−0.09	0.03	**
	Education × time	−0.02	0.04	*ns*
Similarities	Education	4.36	0.38	***
	Time	−0.09	0.04	*
	Education × time	0.00	0.04	*ns*
Picture completion	Education	1.37	0.26	***
	Time	0.10	0.03	***
	Education × time	−0.04	0.03	*ns*
Digit symbol	Education	8.66	0.71	***
	Time	−0.27	0.06	***
	Education × time	−0.22	0.07	**

Note. Higher scores indicate better performance. Possible score for the Information is 0–29; Similarities 0–28; Picture Completion 0–21; Digit Symbol 0–93. Time = years since baseline; Education = 0 (low level education: reference) or 1 (high level education). In addition to the terms shown in the table, each model included terms to control for the fixed effects of age at baseline, sex, marital status, occupation, smoking, each past and present illness and practice effect were included as covariates, and the random effects of the intercept (baseline performance) and slope (change over time).
***$p < .001$.
**$p < .01$.
*$p < .05$. *ns* = not significant.

The model used in the current study included fixed terms for the Intercept (baseline performance for an individual with value zero on all predictors), Education (0 = low-educated group, 1 = high-educated group), Time (time in years since baseline), and an Education × Time interaction term. Age (at baseline), sex (0 = men, 1 = women), marital status (0 = unmarried, 1 = married), occupation (0 = inoccupation, 1 = having occupation), smoking (0 = nonsmoker, 1 = smoker) and each past and present illness (0 = none, 1 = having past or present illness) were included as covariates. In addition to controlling for practice effects, we added indicators of prior exposure to the tests. To do this, we followed the procedure described by Alley et al. (2007) to account for the effects of repeated test exposures, by assigning the respondents a 0 for baseline participation and then 1 at each subsequent administration of tests for intellectual assessment. Moreover, random effects of intercept (baseline performance) and slope (change over time) were calculated using an unstructured covariance matrix. The term of primary interest for this study was the Education × Time interaction, which reflects whether the high- or low-educational groups differ in the rate of change in intellectual performance over time. Table 3 shows the general linear mixed models estimates for each intelligence score as a function of educational levels over a 10-year period. Figure 1 gives visual representations of intellectual changes as a function of educational levels.

The term for Education was significant for all subtests (Information, $\beta = 4.44$, $p < .001$; Similarities, $\beta = 4.36$, $p < .001$; Picture Completion, $\beta = 1.37$, $p < .001$; Digit Symbol, $\beta = 8.66$, $p < .001$). As can be seen in Figure 1, participants in the high-educated group scored better compared with those in the low-educated group on all intellectual abilities. The term for Time was also significant for all subtests (Information, $\beta = -0.09$, $p = .003$; Similarities, $\beta = -0.09$, $p = .015$; Picture Completion, $\beta = 0.10$, $p < .001$; Digit Symbols, $\beta = -0.27$, $p < .001$). As can be seen in Figure 1, scores of Information, Similarities, and Digit Symbol subtests showed a trend for a decline over time as the study progressed. In contrast, there was a significant improvement in performance over time on the Picture Completion subtest.

Of particular importance to the current study was the test of the Education × Time interaction, which would show whether intellectual change over time varied with educational levels. The interaction was not statistically significant for the subtests of Information, Similarities, and Picture Completion. However, on the Digit Symbol subtest score, there was significant interaction ($\beta = -0.22$, $p = .002$), indicating that the rate of change of the Digit Symbol scores was significantly related to educational level. The direction of this association indicated that there was greater decline for individuals in the high-educated group (*slope* = −0.49, $p < .001$) than in the low-educated group (*slope* = −0.28, $p < .001$).

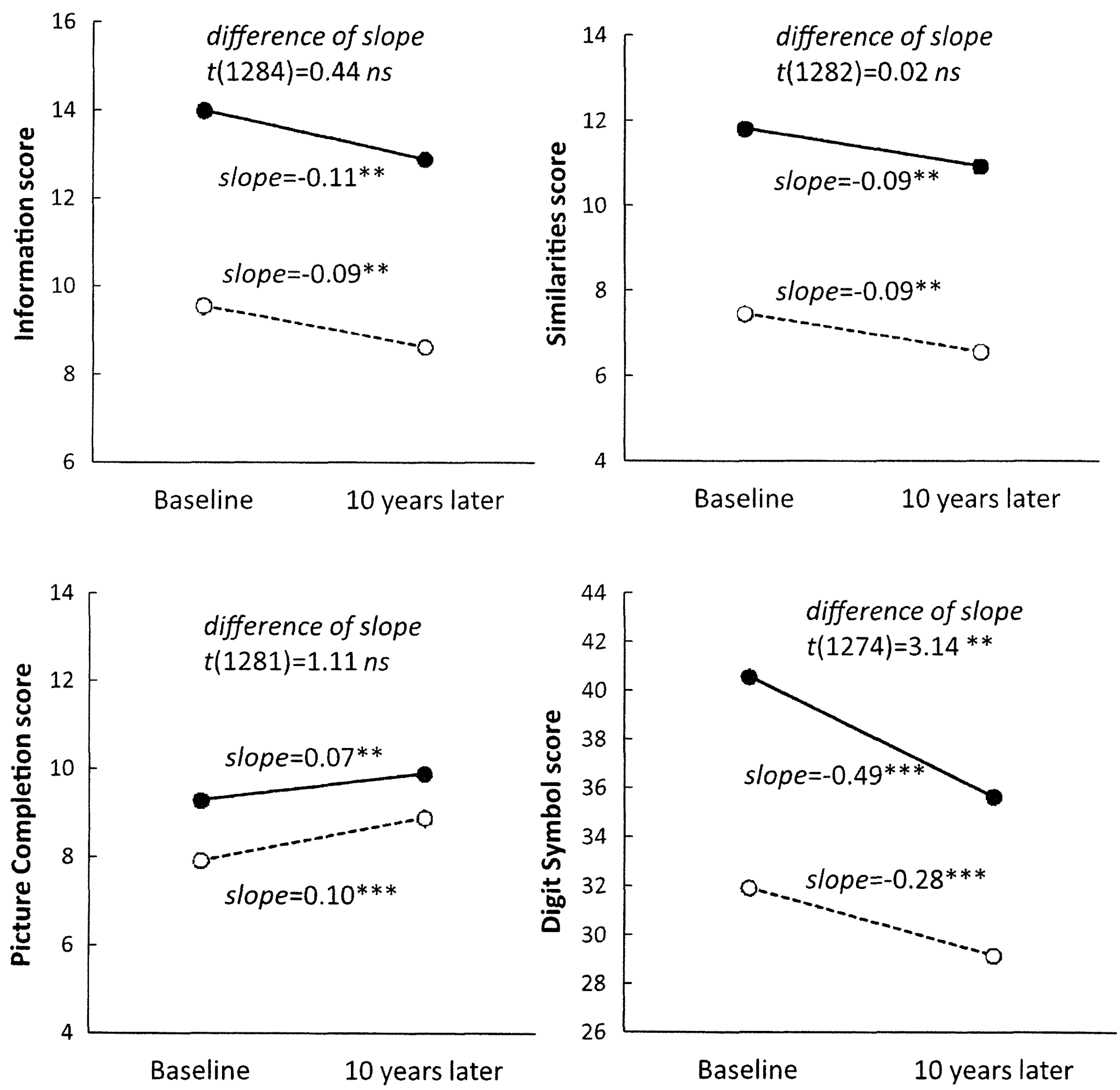

Figure 1 Model-predicted 10-year change in intelligence by education levels. (a) The solid lines are estimated for individuals with a high education level; the dashed lines are estimates for individuals with a low education level. (b) Higher scores indicate better performance. Possible score for the Information is 0–29; Similarities 0–28; Picture Completion 0–21; Digit Symbol 0–93. (c) All models controlled for age at baseline, sex, marital status, occupation, smoking, each past and present illness and practice effect. (d) ***$p < .001$, **$p < .01$, *$p < .05$, *ns* = not significant.

Discussion

Summary and discussion of findings

The purpose of this study was to determine whether educational attainment was associated with the rate of intellectual change among a community sample of Japanese 65 years of age and over. The participants were followed for approximately 10 years and tested a maximum six times (at baseline and 2, 4, 6, 8, and 10 years after baseline).

As expected, level of education had a large cross-sectional effect on all intellectual performances. Some insist that education may improve brain function. That is, because enriched environments result in a greater number of synapses, individuals with higher education may enter old age with a greater synaptic density (Jacobs, Schall, & Scheibel, 1993). Additionally, education early in life is related to adult occupation or lifestyle, so higher education may result in greater intellectual activities in occupations or leisure pursuits throughout life (Kramer, Bherer, Colcombe, Dong, & Greenough, 2004). Thus, educational attainment early in life might have direct or indirect association with intellectual functions later in life.

In contrast, the relation between education and intellectual change differed by intellectual domain. However, on the whole, there was no statistically significant protective effect of higher education on changes in intellectual abilities over time, although education was associated with long-term individual differences in intelligence. Therefore, the *active* cognitive reserve hypothesis was *not* supported by the results of this study.

Information, similarities, and picture completion subtests. The Education × Time interaction was not statistically significant for the Information, Similarities, and Picture Completion subtests, suggesting that there were no effects of educational attainment on intellectual change over time. These findings are consistent with some recent studies that have observed no effects of education on intellectual change with aging (e.g., Seeman et al., 2005; Tucker-Drob et al., 2009; Van Dijk et al., 2008; Wilson et al., 2009; Zahodne et al., 2011). Thus, these results support a *passive* cognitive reserve hypothesis, in which individuals with higher educational attainment continue to perform at a high level compared with similarly aged individuals with less education, but change at a similar rate (Stern, 2002; Van Dijk et al., 2008).

Regardless of the educational level, the Information and Similarities subtest scores displayed a slightly declining trend with the progress of the study. These subtest scores consist of the verbal scales of the WAIS-R-SF, assessing the fund of factual knowledge and logical abstract reasoning that are reflective of crystallized intelligence (Cattell & Horn, 1978; Kaufman & Lichtenberger, 2006). Crystallized intelligence is strongly influenced by culture and experience, and is considered to remain relatively intact through adulthood. Longitudinal data from a previous study suggest that there is an increase in crystallized intelligence (measured using the "verbal meaning" test) until the age of 60 years, with little decline thereafter (Schaie & Willis, 2002). Our study sample with a baseline age of greater than 65 years was likely to show a similar intellectual decline over a 10-year period. However, the influence of education on this aging-associated change was not observed.

In contrast, the Picture Completion subtest is a performance scale in the WAIS-R-SF that measures fluid intelligence, which is more reflective of aging (Cattell & Horn, 1978). However, contrary to our expectations, trajectories of individual change showed improvements that were reflected in the Picture Completion test score, after adjusting for practice effects. The Picture Completion subtest consists of a basically simple task of finding missing parts of familiar pictures with a simple motor, or vocal output (pointing, or one-word responses). Therefore, it has been suggested that the Picture Completion subtest might be resilient to the impact of brain damage (Kaufman & Lichtenberger, 2006), and to hold up with age better than most other performance tests (Wechsler, 1944). In addition, habituation to the test situation or attrition might be important factors in the increased Picture Completion test score. It is suggested that the design of future studies should take these factors that may confound the results of longitudinal studies into consideration.

Digit symbol subtest. The digit symbol subtest measures processing speed, which is considered to be highly reflective of aging (Kaufman & Lichtenberger, 2006; Wechsler, 1944). Therefore, it is noteworthy that education in early life, which is a marker of cognitive reserve, contributed to the 10-year persistence of earlier differences in the Digit Symbol score, even after 65 years of age. Moreover, the Education × Time interaction was statistically significant for the Digit Symbol subtest. Surprisingly, individuals with higher levels of education actually experienced a greater decline in the Digit Symbol subset scores than those with less education, although they had a higher ability at every point in time.

There are two possible explanations for this finding. First, it is possible that highly educated adults might make the most of their high quality crystallized ability to supplement the declining fluid ability, or processing speed (Alley et al., 2007). As a result, when highly educated adults get to be aged 65 years or older, they eventually begin to lose their crystallized abilities (for example, measured by the Information and Similarities subtest) to draw on educational attainment, and as a result experience a faster rate of decline in processing speed than those with lower education. This phenomenon could be explained in terms of the *compensation* hypothesis, in which intact domains compensate for declines in other cognitive abilities until they, too, begin to deteriorate, leading the way for more rapid decline (Alley et al., 2007; Reuter-Lorenz & Mikels, 2006; Zahodne et al., 2011).

Second, it may be possible that the low-educated group showed a greater rate of decline in intellectual performance before age 65 years, prior to baseline. That is, for low-educated older adults, the rate of decline in processing speed could have been greater earlier in life, but slower after age 65 years. In contrast, it is possible that the high-educated group had very small or little decline in processing speed earlier in life (before age 65 years), but that their greatest rate of decline was observable after baseline. Thus, our findings may reflect a difference in the "onset of degeneration" (Alley et al., 2007) in processing speed between higher- and lower-educated older adults.

Some studies have reported that education was not related to the rate of change in processing speed (Christensen, Hofer, Mackinnon, Korten, Jorm, & Henderson, 2001; Tucker-Drob et al., 2009; Van Dijk et al., 2008). However, these previous studies had shorter durations (5–7-year periods) than our investigation (10-year period), or were restricted to the range of educational level in the samples (not enough low-education or high-education participants were included). Considering the better methods used in the present study, our results may reflect a true null finding of education on the change in processing speed; however, further studies on the matter are still needed. In order to confirm the abovementioned explanations, longer study observation periods (including age groups younger than 65 years) and the analyses of inflection points or nonlinear trajectories in processing speed will be required in future research.

Limitations and future directions

Our study has some important limitations. First, it should be noted that this study included participants who were, on the whole, at higher baseline levels of intellectual functioning. Therefore, our findings may only be relevant to healthier aging patterns among community-residing older adults. Second, the statistical models used in this study did not include several factors that may influence intelligence, such as the visual and auditory senses, or motor functions. Third, it remains possible that cognitive reserve mechanisms may act differently in intellectual domains outside of this study (e.g., episodic memory and working memory). Therefore, we must limit our conclusion to the levels and rates of change in intelligence, as measured using the JWAIS-R-SF (Information, Similarities, Picture Completion, and Digit Symbol). Fourth, the measure of educational attainment in this study assumes an equivalence of educational quality across persons and time. However, this is unlikely to be true. Other measures, such as literacy or acquired knowledge, may better address the quality of education as the marker of cognitive reserve. In addition, we assessed the level of educational attainment by using a categorical scale with only four options. However, it is likely that individuals with very low education (fewer than 6 years) may experience the greatest intellectual declines in late life (Lyketsos et al., 1999). Further studies are required to measure educational experience, defined as the number of years of schooling, in order to examine the possibility of steeper decline among older adults with very low educational attainment.

Additionally, differences in adult lifestyle may increase cognitive reserve by making the individual more resilient (Scarmeas, Zarahn, Anderson, Habeck, Hilton, Flynn, Marder, Bell, Sackeim, Van Heertum, Moeller, & Stern, 2003). So the relation between education in early life and intellectual change in late life may be mediated by participation in leisure activities or an occupation throughout adulthood. Moreover, there are several psychological factors that may modulate or mediate the relation between education and intelligence. For example, Nishita, Tange, Tomida, Ando, and Shimokata (2012b) suggest that the personality trait of openness to experience, highly correlated with education, influences intellectual change in later adulthood. Van Dijk et al. (2008) asserts that physical or mental health factors have important effects on intellectual change in late life, and that even higher educated individuals, who may initially have a benefit of greater cognitive reserve, are not protected against the effects of intellectual aging once they acquire certain physical or mental disease. An understanding of the precise nature and mechanisms of the relation between education in early life and intellectual change in late life invite further studies, including lifestyle and personal traits.

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ORIGINAL ARTICLE

Age-related changes in skeletal muscle mass among community-dwelling Japanese: A 12-year longitudinal study

Hiroshi Shimokata,[1] Fujiko Ando,[2] Atsumu Yuki[3] and Rei Otsuka[4]

[1]*Graduate School of Nutritional Sciences, Nagoya University of Arts and Sciences,* [2]*Faculty of Health and Medical Sciences, Aichi Shukutoku University, Nisshin,* [3]*Faculty of Education, Kochi University, Kochi, and* [4]*Section of the NILS-LSA, National Center for Geriatrics and Gerontology, Obu, Japan*

Aim: The present study aimed to evaluate age-related changes in skeletal muscle mass among community-dwelling middle-aged and elderly Japanese.

Methods: This 12-year longitudinal study of a community-dwelling population in Japan included 15 948 examinations of 1962 men and 1990 women. We assessed appendicular muscle mass (AMM) using dual X-ray absorptiometry and calculated the skeletal muscle index (SMI) using the AMM divided by height squared (kg/m^2). Low muscle mass was defined as muscle mass minus two standard deviations below the mean for young healthy adults. Leg extension power (watts) was measured as an index of muscle function. Longitudinal data of skeletal muscle mass were analyzed using a general linear mixed-effect model.

Results: The prevalence of low muscle mass at the first wave of examinations was 27.1% in men and 16.4% in women. Longitudinal analysis showed that skeletal muscle mass decreased with aging during the 12-year study period except in middle-aged men, and to a greater extent in elderly men (*P* for trend, <0.001). Skeletal muscle mass decreased slightly, but significantly, in women. Although a cross-sectional analysis showed that SMI did not differ with age in women, leg extension power per leg muscle mass and grip strength per arm muscle mass as indices of muscle quality were significantly lower in older women (*P* for trend, <0.001 for both).

Conclusion: Age-related decreases in muscle mass were trivial, especially in women, but the quality of muscle decreased with aging in both sexes. **Geriatr Gerontol Int 2014; 14 (Suppl. 1): 85–92.**

Keywords: aging, epidemiology, longitudinal study, sarcopenia, skeletal muscle.

Introduction

Aging is associated with a progressive loss of neuromuscular function that often leads to progressive disability and loss of independence along with a reduced quality of life among the elderly.[1–6] The loss of skeletal muscle mass and strength with biological and pathological aging is now commonly described as sarcopenia.[1] This decline of skeletal muscle is thought to be inevitable even among healthy older adults. The European Working Group on Sarcopenia in Older People (EWGSOP) assumed that muscle loss is a required component for a diagnosis of sarcopenia, as well as low muscle strength and/or low physical performance.[6]

However, the rate at which community-dwelling populations lose skeletal muscle mass with aging is unclear, because accurate assessments of muscle mass can be challenging. Skeletal muscle mass can be determined by anthropometric measurements, bioelectrical impedance analysis and dual X-ray absorptiometry (DXA),[7,8] and DXA is the most effective method recommended for clinical practice.[7] However, DXA is usually impractical for epidemiological surveys, because it is costly and it involves exposure to radiation, although minimal.

The definition of low muscle mass (sarcopenia by muscle mass) proposed by Baumgartner in the Population of New Mexico Elder Health Survey has been widely applied.[9] This definition uses the ratio between appendicular skeletal muscle mass (ASM) of the upper and lower limbs (kg) and height squared (m^2; ASM/

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Correspondence: Professor Hiroshi Shimokata MD PhD, Graduate School of Nutritional Sciences, Nagoya University of Arts and Sciences, 57 Takenoyama, Iwasaki-cho, Nisshin City, Aichi 470-0196, Japan. Email: simokata@nuas.ac.jp