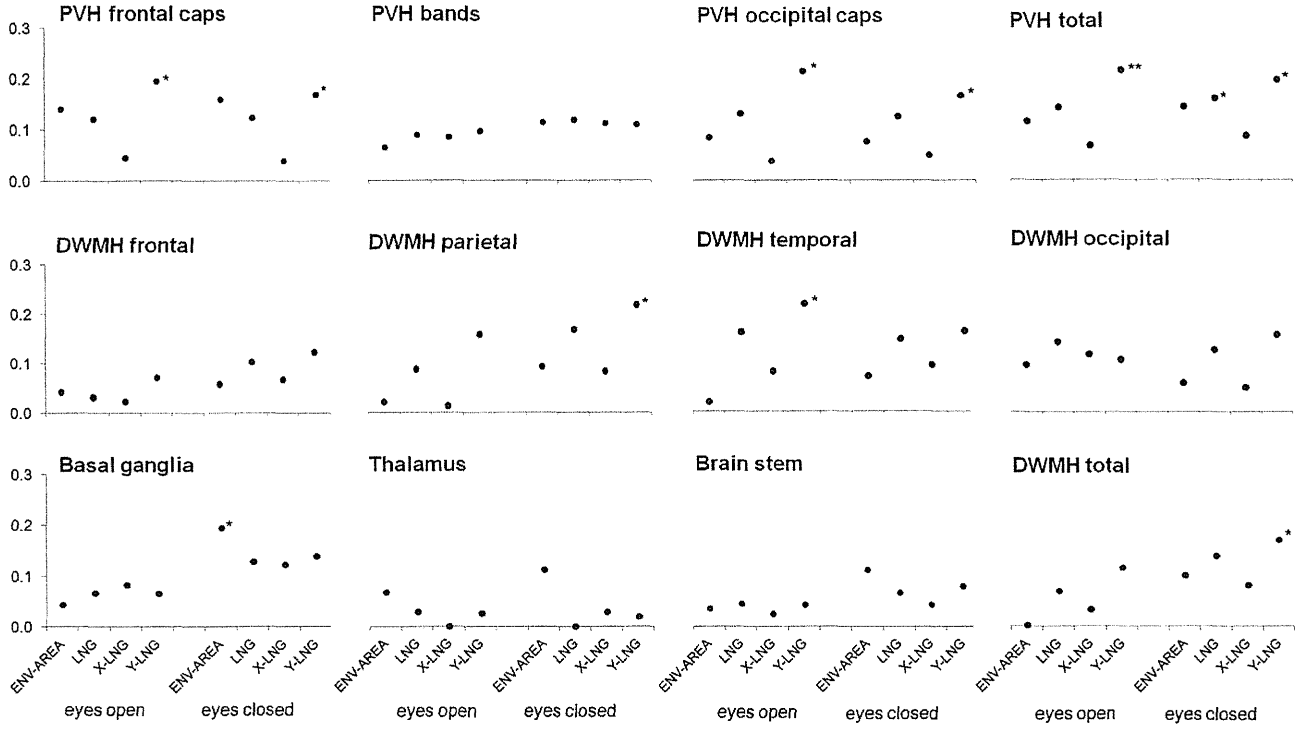

Fig. 1. Effects of regional white matter lesions (WMLs) on posture control. Effects of regional periventricular hyperintensity (PVH) and deep white matter hyperintensity (DWMH) on balance function are shown. The Y-axis denotes the absolute values of the partial Spearman rank order correlation after adjusting for age, sex, and Mini-Mental State Examination (MMSE). *$P < .05$, **$P < .01$. ENV-AREA, enveloped area of the center of gravity sway; LNG, total trajectory length of traced sway; X-LNG, trajectory length of X direction; Y-LNG, trajectory length of Y direction.

$0.0082x11 - 0.0027x12 - 0.0236x13 + 0.0525x14 + 0.239x15 + 0.0500x16 - 0.0797x17 + 0.9387x18 - 10.4655$; where $x1$ = Sex (Male:1, Female:0), $x2$ = Age (years), $x3$ = MMSE, $x4$ = Dementia Behavior Disturbance Scale, $x5$ = Geriatric Depression Scale, $x6$ = frontal DWMH (μL), $x7$ = parietal DWMH (μL), $x8$ = temporal DWMH (μL), $x9$ = occipital DWMH (μL), $x10$ = basal ganglia DWMH

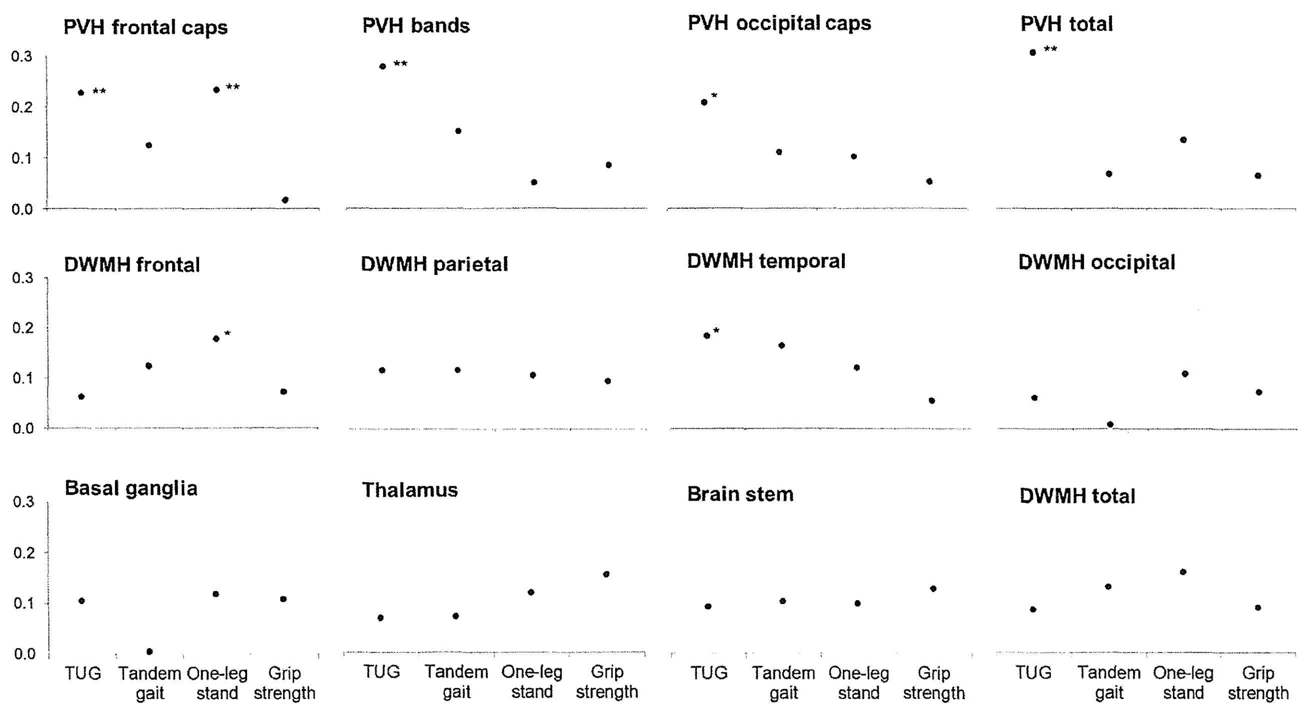

Fig. 2. Impacts of regional white matter lesions (WMLs) on gait performance. Effects of regional periventricular hyperintensity (PVH) and deep white matter hyperintensity (DWMH) on motor performance are demonstrated. The Y-axis indicates absolute values of the partial Spearman rank order correlation after adjusting for age, sex, and Mini-Mental State Examination (MMSE). *$P < .05$, **$P < .01$. TUG, Timed Up and Go.

Table 4
Association of WMLs With Previous History of Falls

	Odds Ratio	95% CI	P Value
Age	1.029	0.946–1.118	.508
Sex	0.948	0.393–2.285	.905
Mini-Mental State Examination	1.099	0.981–1.232	.103
Polypharmacy	2.557	1.078–6.062	.033
Dementia Behavior Disturbance Scale	1.014	0.977–1.053	.465
Geriatric Depression Scale	1.089	0.939–1.263	.259
PVH			
Frontal caps	1.054	1.011–1.098	.013
Bands	1.024	0.985–1.065	.234
Occipital caps	1.051	0.988–1.119	.116
Total	0.923	0.831–1.026	.138
DWMH			
Frontal	1.007	0.965–1.051	.749
Parietal	1.006	0.986–1.026	.553
Temporal	1.000	0.987–1.014	.956
Occipital	1.013	1.003–1.023	.012
Basal ganglia	1.004	0.992–1.016	.497
Thalamus	1.008	0.997–1.020	.164
Brain stem	0.997	0.986–1.008	.629
Total	0.977	0.916–1.041	.467
Brain atrophy			
Evans ratio	0.995	0.975–1.015	.608
Caudate head index	0.996	0.973–1.020	.750
Inverse cella media index	1.005	0.990–1.019	.543
Basal cistern index	0.996	0.984–1.008	.476

CI, confidence interval; DWMH, deep white matter hyperintensity; PVH, periventricular hyperintensity; SD, standard deviation; WML, white matter lesion.

(μL), $x11$ = thalamus DWMH (μL), $x12$ = brain stem DWMH (μL), $x13$ = total DWMH (μL), $x14$ = PVH frontal caps (1 grade), $x15$ = PVH bands (1 grade), $x16$ = PVH occipital caps (1 grade), $x17$ = PVH total (1 grade), and $x18$ = Polypharmacy (yes: 1, no: 0). The receiver operating characteristic analysis revealed satisfactory discrimination for predicting falls with a sensitivity value of 76.2% and a specificity value of 75.8% when the cutoff point of this model was set at 0.403. The AUC was 0.81 (95% confidence interval, 0.74–0.88). When we added only total PVH and DWMH values in the prediction model, the AUC was decreased to 0.73 (95% confidence interval, 0.65–0.81). When results of balance/gait performance were added as variables in a similar analysis, PVH frontal caps and occipital DWMH were again extracted as predictive factors for falls (data not shown).

Discussion

Several cross-sectional and longitudinal studies have reported the correlation of global WMLs with measurements of balance, gait, and falls in the elderly;[7–14,24–29] however, the role of regional WMLs in relation to motor performance remains uncertain.[8,14,24–29] To date, only 2 studies have investigated the effects of WML burden in demented disorders.[7,8] The current study revealed the correlation of regional WMLs with posture control, gait, and falls in patients with aMCI and AD. The fallers group had a greater volume of WMLs than nonfallers, with several WMLs in particular brain regions closely associated with balance/gait function. Besides polypharmacy, PVH in frontal caps and DWMH in the occipital lobe were strong predictors for falls, independent of cognitive decline. Preventative strategies for falls in the demented elderly are a clinical challenge. Our observation indicates that careful insight into regional WMLs may greatly help to diagnose elderly patients with a higher risk of falls.

This study showed that the more severe the PVH, the more impaired balance and gait function was.[7,11,14,24–29] PVH at all sites, particularly PVH in frontal caps, was closely correlated with balance, gait, and falls, suggesting the role of frontal neural circuit in maintaining mobility function. Periventricular fibers are predominantly critical to posture control and motor function. Compared with more superficially located fibers, the deeper white matter tracts connect remote motor and sensory cortical and subcortical sites that are needed for posture control and gait. Benson et al[24] reported that frontal periventricular regions are sensitive and occipitoparietal PVH specific for lower mobility.[4] Anterior and posterior corona radiata lesions are involved in mobility decline.[28,29] Frontal and periventricular WMLs correlate with poor gait function, presumably because of disconnecting major anterior projection fibers and adjacent association fibers.[27]

Prior studies have reported that severe WMLs in the frontal lobe, basal ganglia and brain stem deteriorate walking speed and balance control.[8,14,25–29] This study revealed that DWMH in basal ganglia, parietal, and temporal lobes correlated with posture control, whereas DWMH in frontal and temporal lobes correlated with gait disturbance. DWMH in several brain regions could affect balance and mobility coordinately, contributing to a higher incidence of falls.

One of the most important findings of this study is that occipital DWMH is a strong predictor for falls. Despite this, DWMH in the occipital lobe did not show any obvious correlation with balance and gait parameters, which differed from the findings for PVH in frontal caps. We examined the possibility that occipital DWMH compromises the processing of visual information to keep body balance. This, however, seems unlikely because performance of several cognitive tests measuring visuospatial function was unchanged in the fallers. Relatedly, Van Impe et al[30] recently demonstrated that WMLs in the occipital lobe plays a significant role in balance function by using the diffusion tensor images. Static balance and movement rely on the integration of vestibular, visual, and tactile-proprioceptive information. When information from the vestibule is the only information available, WMLs in the occipital lobe account for 42% of balance disturbances.[30] The occipital subcortical region communicates not only between bilateral visual cortexes, but also between the dorsa prefrontal area, and posterior parietal and occipital areas, through the inferior front-occipital fasciculus.[30,31] This study exhibited PVH at occipital caps correlated with posture sway in the anteroposterior direction and occipital DWMH correlated with falls. It has been suggested that categorization of WMLs as periventricular or DWMH may be arbitrary and merely a reflection of total WML volume. Although these distinctions need further corroboration, occipital WMLs seem crucial for predicting falls in the demented elderly.

WMLs are composed of heterogeneous pathologic changes, including axonal and myelin loss and pallor, scattered microinfarcts, astrogliosis, dilatation of perivascular spaces, and cerebral amyloid angiopathy.[32] Although the etiology of WMLs is not fully understood, there is increasing evidence that chronic cerebral ischemia because of small-vessel disease plays a central role in the pathogenesis of WMLs.[32] Small-vessel disease is more common in subjects with AD than in nondemented elderly.[33,34] Previous studies have shown a differential distribution of WMLs between cognitively normal and AD patients.[34] In the ageing brain, WMLs are most prevalent in the frontal areas, whereas posterior regions are minimally affected. In contrast, WMLs in AD patients show more posterior involvement. Subjects with MCI had an intermediate periventricular WML burden in extent and location between cognitive normal and AD patients.[34] Although a few studies have found a role of WMLs in posterior brain for balance/gait impairment in nondemented elderly patients,[24,29,30] our study clearly demonstrated deleterious effects of posterior WMLs on gait performance in patients with aMCI and AD. Greater WMLs in posterior brain with AD pathology could account for an increased prevalence of falls.

This study has inherent limitations. First, this is a cross-sectional study and, therefore, no causality can be inferred between WMLs and falls. Prospective studies are needed to test a new hypothesis that falls among the demented elderly are not accidental events, but rather are important clinical manifestations of cerebral WMLs. Second, we used a visual rating of WMLs, but not objective evaluation using automated MR imaging analysis. However, it has been suggested that visual rating on high-resolution MR images and automated volumetric measurements are equally sensitive in detecting larger lesions.[35] More importantly, visual rating of WMLs can be more commonly available in the clinical practice. Finally, detailed data on musculoskeletal disease including arthritis were not obtained. However, we evaluated a wide range of risk factors for falls in the elderly, including age, sex, cognition, medication, BPSD, depression, muscle strength, environmental factors, and brain atrophy, and we demonstrated the specific contribution of WMLs to mobility decline in patients with AD or aMCI.

Conclusions

This study provides the first evidence of interaction between regional WMLs and balance/gait impairment in patients with aMCI and AD (mild to moderate stage). Besides polypharmacy, PVH in frontal caps and occipital WMLs are strong risk factors for falls, independent of cognitive decline. Our observations imply WML burden, but not progression of dementia, is predictive for falls in patients with AD pathology. Brain MR imaging is a routine examination for diagnosis of demented disorders. Physicians should pay greater attention to WMLs to prevent falls in the demented elderly. Intensive studies to clarify the relevant risks, natural history, and efficient treatments for WMLs are needed.

Acknowledgments

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ORIGINAL ARTICLE

Association of grip strength and related indices with independence of activities of daily living in older adults, investigated by a newly-developed grip strength measuring device

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Aim: To investigate the association of grip strength and activities of daily living independence in older adults, using a newly-developed grip strength measuring device.

Methods: Patients who visited the clinic for memory disorders at the National Center for Geriatrics and Gerontology (142 men and 205 women, mean age 74.8 ± 8.8 years) were included in the present study. Their strength during gripping performance is described in detail, and following the indices were calculated: maximum strength (MS), response time (RT), time to MS, time to reach turning point (TP), strength at TP, inclination from start to TP, time from TP to reach MS, inclination from TP to MS and ratio of strength (TP/MS). Barthel Index (BI), total scores and scores of each subclass were used for evaluating activities of daily living independence. MS was compared between the independent and dependent groups. Correlations, using partial Pearson's coefficient adjusted for age, and Mini-Mental State Examination total score were analyzed between indices and BI by sex, side, and age groups.

Results: MS was significantly higher in the independent group. MS and RT were significantly related with BI total and certain subclasses in both hands, TP/MS was significantly related in the right hand of either sex, and strength at TP was significantly related in both hands in women and in the left hand in men. Time to reach TP was particularly correlated in both hands and time from TP to reach MS in the right hand, in men. The correlation of indices varied by sex, hand side and age group, especially in men aged in their 70s, and in women aged less than 70 years and women aged in their 80s.

Conclusion: MS was shown to be useful, but some of the newly defined indices, such as RT, strength at TP, and elements regarding before and after TP until reaching MS, were also suggested to be useful. **Geriatr Gerontol Int 2014; 14 (Suppl. 2): 77–86.**

Keywords: activities of daily living independence, association, detailed evaluation, grip strength, muscle contraction.

Introduction

In geriatric medicine, evaluations of physical ability and assessment as to whether elderly patients keep their independence in activities of daily living (ADL) are essential tasks. They are included in the comprehensive geriatric assessment (CGA),[1] the importance of which has been widely recognized.[2] For the evaluation of physical ability, the grip strength test is one of the most popular and widely utilized methods,[3–5] as it is considered to be an indication of the state of muscle function.[6–9] Grip strength has been reported to be correlated with ADL or physical performance,[10–14] or to predict disability or dependence in the future.[15–18]

In order to assess the gripping ability of physically weakened older adults more precisely, we have developed a new device to analyze the detailed way in which muscles contract during gripping performance.[19] This new device can accurately measure not only very weak peak values, but also the agility or the endurance in gripping by taking the time axis into consideration. Using the data obtained from the measurement by this

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new device, we have proposed new indices and showed the difference by sex or hand side.[19]

In the present study, using the data from our newly-developed device, we investigated the association of gripping performance and independence of ADL in older adults, evaluated by total Barthel Index (BI) score and its subitems, and attempted to reveal the meaning of the newly proposed indices, as well as that of maximum grip strength.

Methods

Study population

The participants of the present analyses were recruited at the outpatient clinic for memory disorders at the National Center for Geriatrics and Gerontology, Japan at Obu City, Aichi Prefecture in Japan. The period of recruitment was from 18 October 2010 to 10 June 2011. Inclusion criteria were principally the patients who visited our memory disorder clinic for the first time and could understand the instructions on how to measure grip strength with the new device. Before the examination, their blood pressure was measured, and those with higher than 160 mmHg systolic pressure were excluded. The participants of the present study were 347 patients (142 men and 205 women, average age 75.0 ± 9.1 years).

Average Mini-Mental State Examination (MMSE) score was 21.1 ± 6.1 in men and 20. 2 ± 5.7 in women.

Evaluations of ADL independence by BI and participant grouping

Independence of the ADL was evaluated by BI[20] questionnaire. The index is composed of 10 items regarding bathing, grooming, feeding, dressing, toilet use, ascend/descend stairs, bowel management, bladder management, bed/wheelchair transfer and mobility (level surface), totaling 100 points as a full score. Participants were classified into two groups based on the total BI score. Those with a total score of 100 points were classified as independent, and those with less than 100 points as dependent. They were also classified by the scores on each of the 10 component subitems of BI (full score, less than full score).

Newly-developed device for measuring grip strength

Using the force-gauge (manufactured by IMADA, Toyohashi, Japan; product no. ZP-500N) for measuring industrial products, the signal output from the device is sent to a computer (Fig. 1). At the moment an LED lamp on the device lights up, the examinee is encouraged to grip the handle, and the grip strength is constantly recorded by the computer. How the gripping strength is produced can be automatically described on the computer monitor. Not only can it measure the maximum (peak) grip strength accurately, even very low levels of strength, but it can also measure the response time, agility (catching ability) or endurance (holding ability).

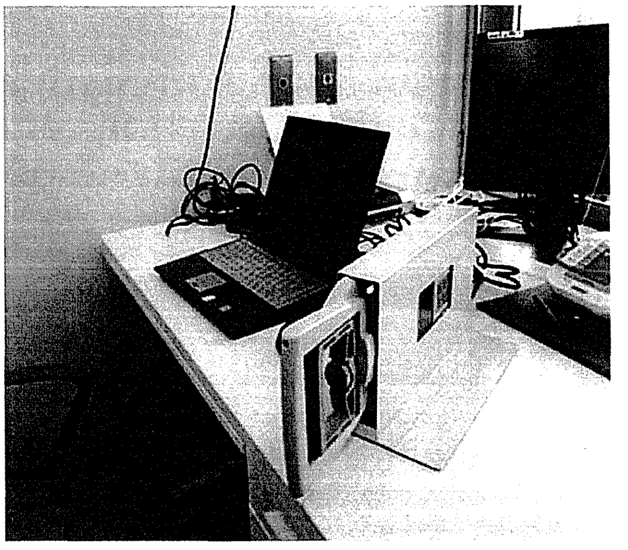

Figure 1 Newly-developed device for measuring grip strength. Force-gauge (made by IMADA, Toyohashi, Japan) can be used for measuring industrial products, such as the operation switch on a deluxe automobile. The gauge is equipped with an easy-grip handle. The signal output from the device is sent to the computer. The moment the LED lamp on the device lights up, the examinee grips the handle. Grip strength is constantly recorded by the computer. How the gripping strength is produced is automatically described on the computer monitor.

Method for measuring grip strength and items calculated

The participants were mostly elderly patients, whose grip strength was measured in the sitting position, with their elbows flexed approximately 90°. In the agility examination, the examinees were asked to grip the handle as soon as the lamp illuminated. The time and the pattern to reach the peak value were then evaluated.

For the analyses to assess agility in detail, from the graph showing the data output and recorded on the computer monitor, we selected four points: (i) lamp lights up; (ii) time to start gripping; (iii) turning point when curve inclination changes; and (iv) peak. We then defined nine indices, calculated with these four points as follows: (1) maximum strength; (2) response time; (3) time to reach maximum strength; (4) time to reach turning point; (5) strength at turning point; (6) inclination from start to turning point; (7) time from turning point to reach maximum strength; (8) inclination from turning point to maximum strength; and (9) ratio of strength (turning point/maximum); (Fig. 2).

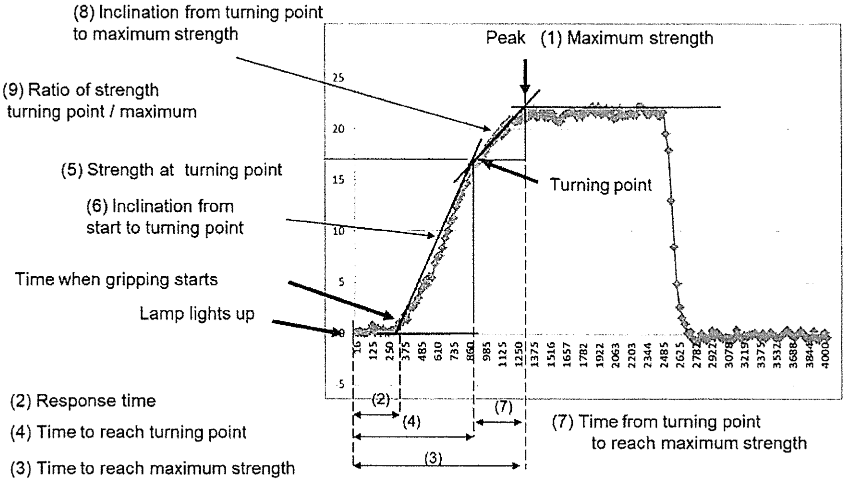

Figure 2 A graph showing nine detailed indices in the agility examination.

Statistical analyses

The average maximum grip strength was compared between the independent group and dependent group (both BI total score and each subclass item). Also, the average absolute values of each of the aforementioned nine items were calculated, and then the relationships were investigated between those items and BI scores of the total, and that of each subclass: bathing, grooming, feeding, dressing, toilet use, ascend/descend stairs, bowel management, bladder management, bed/wheelchair transfer and mobility were investigated with Pearson's coefficient, utilizing SPSS version 19 for Windows (SPSS, Chicago, IL, USA) was used. Partial correlations adjusted for age and total score of MMSE were also examined. Furthermore, the relationships between the nine grip strength measuring items and total BI scores of the three different age groups, below 70 years, 70s and 80s, were also investigated with partial Pearson's coefficient, adjusted for MMSE. *P*-values less than 0.05 were considered statistically significant. The study protocol was approved by the Committee on Ethics of Human Research of the National Institute for Longevity Sciences. Written informed consent was obtained from each participant.

Results

Participant characteristics

The demographic data of participants are listed in Table 1. There were significant differences between the independent group and dependent group in age, height, weight, and BI score (both total and each subclass item) in both sexes. Significant differences were seen in five of the nine newly advocated indices with the right hand in men, and in seven of the nine items in women. Significant differences were seen only in women regarding two indices: time to reach maximum strength and ratio of strength (turning point/maximum).

Comparisons of maximum grip strength

The partial correlation coefficients between the maximum grip strength and BI total score, after adjusting age and sex, were 0.296 for the right hand ($P < 0.001$) and 0.295 for the left hand ($P < 0.001$), showing significant relationships. Even after adjusting for MMSE total score, they were 0.228 for the right hand ($P < 0.001$) and 0.238 for the left hand ($P < 0.001$), and the relationships remained significant.

Comparisons among groups divided in terms of scores for total BI and each of the 10 subclass items in men showed significant differences between the full score (independent) group and those losing points (dependent) in total BI and all subitems. Similarly in women, except in one item of feeding, significant differences were shown between the independent and dependent group for almost all subitems, as well as for total BI (Table 2).

Correlations between nine grip strength items measured and BI

Partial correlations between the nine grip strength items measured and BI score (total score and each of 10 subitems), adjusted for age and MMSE, were examined for both hands in men (Table 3) and in women (Table 4). In men, maximum grip strength was significantly correlated with eight items in the left hand and five in the right, as well as with the total score in both hands. Response time was significantly correlated with five items in the left hand, four in the right hand and total score in both hands. Time to voach turning point was significantly correlared with five items and with total score in the left hand. Strength at turning point was significantly correlated with four items in the left hand

Table 1 General characteristics of participants

Men		Independent (n = 87)	Dependent (n = 55)	P-value
	Age (years)	72.6 ± 8.7	75.5 ± 10.5	0.073
	Height (cm)	163.9 ± 5.7	160.2 ± 7.2	0.001
	Weight (kg)	61.2 ± 8.8	57.1 ± 11.2	0.017
	BMI (kg/m^2)	22.8 ± 2.9	22.1 ± 3.2	0.209
	MMSE score	23.0 ± 5.2	18.1 ± 6.3	<0.001
Barthel Index	Total score	100.0 ± 0.0	78.9 ± 21.6	<0.001
	Feeding	10.0 ± 0.0	9.4 ± 2.0	0.002
	Bed/wheel-chair transfer	15.0 ± 0.0	13.9 ± 2.9	<0.001
	Grooming	5.0 ± 0.0	3.8 ± 2.2	<0.001
	Toilet use	10.0 ± 0.0	8.3 ± 2.4	<0.001
	Bathing	5.0 ± 0.0	3.5 ± 2.3	<0.001
	Mobility	15.0 ± 0.0	13.6 ± 3.7	0.001
	Ascend/descend stairs	10.0 ± 0.0	8.5 ± 2.7	<0.001
	Dressing	10.0 ± 0.0	8.0 ± 2.8	<0.001
	Bowel management	10.0 ± 0.0	6.6 ± 3.0	<0.001
	Bladder management	10.0 ± 0.0	6.2 ± 2.9	<0.001
Nine new indices	Response time (ms)	360.2 ± 153.6	425.6 ± 188.2	0.026
	Time to reach turning point (ms)	692.6 ± 252.2	807.8 ± 304.9	0.016
	Strength at turning point (kg)	24.5 ± 8.3	18.3 ± 7.7	<0.001
	Inclination from start to turning point (kg/ms)	0.082 ± 0.045	0.054 ± 0.037	<0.001
	Time to reach maximum strength (ms)	1276.4 ± 464.6	1302.3 ± 422.1	0.740
	Maximum strength (kg)	28.3 ± 8.2	21.6 ± 8.8	<0.001
	Time from turning point to reach maximum strength (ms)	583.8 ± 403.2	494.5 ± 362.5	0.186
	Ratio of strength (turning point/maximum) (%)	85.7 ± 11.5	84.9 ± 11.3	0.663
	Inclination from turning point to maximum strength (kg/ms)	0.010 ± 0.010	0.009 ± 0.008	0.451

Women		Independent (n = 144)	Dependent (n = 61)	P-value
	Age (years)	74.2 ± 8.8	80.1 ± 6.6	<0.001
	Height (cm)	149.8 ± 6.4	144.6 ± 7.1	<0.001
	Weight (kg)	47.9 ± 8.2	46.1 ± 9.1	0.154
	BMI (kg/m^2)	21.3 ± 3.1	22.0 ± 3.8	0.171
	MMSE score	21.4 ± 5.4	17.3 ± 5.5	<0.001
Barthel Index	Total score	100.0 ± 0.0	80.7 ± 17.6	<0.001
	Feeding	10.0 ± 0.0	9.4 ± 1.6	<0.001
	Bed/wheel-chair transfer	15.0 ± 0.0	13.9 ± 2.3	<0.001
	Grooming	5.0 ± 0.0	3.4 ± 2.4	<0.001
	Toilet use	10.0 ± 0.0	9.1 ± 2.0	<0.001
	Bathing	5.0 ± 0.0	2.8 ± 2.5	<0.001
	Mobility	15.0 ± 0.0	13.8 ± 2.8	<0.001
	Ascend/descend stairs	10.0 ± 0.0	8.3 ± 2.9	<0.001
	Dressing	10.0 ± 0.0	8.4 ± 2.5	<0.001
	Bowel management	10.0 ± 0.0	6.5 ± 3.0	<0.001
	Bladder management	10.0 ± 0.0	6.2 ± 2.5	<0.001
Nine new indices	Response time (ms)	388.6 ± 138.0	492.3 ± 186.7	<0.001
	Time to reach turning point (ms)	761.8 ± 279.4	838.3 ± 273.4	0.077
	Strength at turning point (kg)	16.7 ± 5.8	11.3 ± 4.7	<0.001
	Inclination from start to turning point (kg/ms)	0.048 ± 0.027	0.031 ± 0.017	<0.001
	Time to reach maximum strength (ms)	1261.2 ± 385.8	1397.4 ± 394.3	0.025
	Maximum strength (kg)	19.3 ± 6.0	14.0 ± 5.6	<0.001
	Time from turning point to reach maximum strength (ms)	499.4 ± 331.5	559.2 ± 335.6	0.248
	Ratio of strength (turning point/maximum) (%)	86.1 ± 10.2	80.9 ± 12.9	0.003
	Inclination from turning point to maximum strength (kg/ms)	0.007 ± 0.005	0.005 ± 0.004	0.119

BMI, body mass index; MMSE, Mini-Mental State Examination.

Table 2 Comparisons of maximum grip strength between independent and dependent groups of total Barthel Index score and each Barthel Index subitem

		Men			Women		
		Independent (*n*)	Dependent (*n*)	*P*-value	Independent (*n*)	Dependent (*n*)	*P*-value
Total score	Right	28.3 ± 8.2 (87)	21.6 ± 8.8 (54)	<0.001	19.3 ± 6.0 (142)	14.0 ± 5.6 (59)	<0.001
	Left	27.3 ± 8.0 (87)	21.1 ± 8.6 (55)	<0.001	17.9 ± 5.7 (143)	12.9 ± 5.4 (60)	<0.001
Feeding	Right	26.3 ± 8.8 (134)	15.4 ± 5.4 (6)	0.003	17.9 ± 6.3 (194)	14.0 ± 4.7 (7)	0.11
	Left	25.4 ± 8.7 (135)	15.9 ± 4.9 (6)	0.009	16.5 ± 6.0 (196)	13.2 ± 6.9 (7)	0.15
Bed/wheelchair transfer	Right	26.3 ± 8.8 (130)	17.5 ± 7.7 (9)	0.004	18.1 ± 6.2 (189)	11.4 ± 5.0 (11)	<0.001
	Left	25.4 ± 8.6 (131)	17.3 ± 8.1 (9)	0.006	16.9 ± 5.9 (190)	10.3 ± 3.9 (12)	<0.001
Grooming	Right	26.8 ± 8.7 (126)	16.1 ± 5.9 (13)	<0.001	18.4 ± 6.2 (181)	12.2 ± 4.3 (20)	<0.001
	Left	25.8 ± 8.3 (127)	15.5 ± 7.0 (13)	<0.001	17.0 ± 6.0 (183)	10.9 ± 3.6 (20)	<0.001
Toilet use	Right	26.9 ± 8.8 (121)	18.4 ± 6.5 (18)	<0.001	18.1 ± 6.3 (190)	12.5 ± 4.5 (10)	0.007
	Left	26.0 ± 8.5 (122)	17.4 ± 6.5 (18)	<0.001	16.8 ± 6.0 (191)	11.4 ± 4.3 (11)	0.004
Bathing	Right	27.0 ± 8.6 (122)	15.7 ± 6.1 (15)	<0.001	18.5 ± 6.1 (175)	12.6 ± 5.1 (25)	<0.001
	Left	26.1 ± 8.3 (123)	14.7 ± 5.6 (15)	<0.001	17.1 ± 5.9 (176)	12.2 ± 5.3 (26)	<0.001
Mobility	Right	26.4 ± 8.8 (131)	16.0 ± 5.6 (8)	0.001	18.0 ± 6.2 (190)	12.8 ± 6.7 (10)	0.01
	Left	25.4 ± 8.6 (132)	16.1 ± 6.3 (8)	0.003	16.7 ± 5.9 (191)	11.7 ± 6.0 (11)	0.006
Ascend/descend stairs	Right	26.8 ± 8.7 (125)	16.9 ± 6.8 (14)	<0.001	18.3 ± 6.2 (183)	12.4 ± 5.0 (17)	<0.001
	Left	25.8 ± 8.4 (126)	16.3 ± 7.1 (14)	<0.001	17.0 ± 5.9 (184)	11.2 ± 4.5 (18)	<0.001
Dressing	Right	26.9 ± 8.6 (121)	17.8 ± 7.7 (18)	<0.001	18.3 ± 6.2 (183)	12.4 ± 4.7 (17)	<0.001
	Left	25.8 ± 8.5 (121)	18.9 ± 8.1 (19)	0.0001	17.0 ± 5.9 (184)	11.0 ± 4.0 (18)	<0.001
Bowel management	Right	27.4 ± 8.3 (108)	20.0 ± 9.1 (32)	<0.001	18.8 ± 6.1 (163)	13.1 ± 5.3 (37)	<0.001
	Left	26.3 ± 8.1 (108)	19.8 ± 9.2 (33)	<0.001	17.5 ± 5.8 (164)	11.8 ± 4.6 (38)	<0.001
Bladder management	Right	27.3 ± 8.7 (104)	20.8 ± 8.3 (35)	<0.001	18.9 ± 6.2 (158)	13.6 ± 5.1 (42)	<0.001
	Left	26.6 ± 8.5 (104)	19.8 ± 7.7 (36)	<0.001	17.6 ± 6.0 (159)	12.4 ± 4.4 (43)	<0.001

Table 3 Partial correlations between nine grip strength items measured and Barthel Index (total score and each sub items) adjusted for age and Mini-Mental State Examination total score in men

			Total score	Feeding	Bed/wheel-chair transfer	Grooming	Toilet use	Bathing	Mobility	Ascend/ descend stairs	Dressing	Bowel management	Bladder management
Response time	Right	*r*	–0.22*	–0.22*	–0.12	–0.10	–0.16	–0.25**	–0.22*	–0.15	–0.19*	–0.14	–0.04
	Left	*r*	–0.24**	–0.29**	–0.16	–0.12	–0.13	–0.27**	–0.23**	–0.18*	–0.25**	–0.06	–0.07
Time to reach turning point	Right	*r*	–0.22*	–0.30**	–0.13	–0.12	–0.13	–0.15	–0.28**	–0.12	–0.12	–0.09	–0.14
	Left	*r*	–0.25**	–0.29**	–0.14	–0.06	–0.15	–0.10	–0.25**	–0.12	–0.20*	–0.19*	–0.18*
Strength at turning point	Right	*r*	0.17	0.12	0.07	0.13	0.10	0.23*	0.10	0.10	0.14	0.16	0.09
	Left	*r*	0.26**	0.15	0.13	0.22*	0.16	0.32**	0.17	0.21*	0.16	0.14	0.18*
Inclination from start to turning point	Right	*r*	0.18*	0.16	0.09	0.12	0.10	0.13	0.15	0.08	0.07	0.11	0.22*
	Left	*r*	0.20*	0.15	0.08	0.16	0.09	0.11	0.16	0.07	0.07	0.20*	0.26**
Time to reach maximum strength	Right	*r*	0.13	–0.10	0.06	0.06	0.14	0.09	0.04	0.12	0.21*	0.14	0.07
	Left	*r*	–0.01	–0.08	0.00	–0.06	0.08	0.11	–0.05	0.02	–0.06	–0.05	0.00
Maximum strength	Right	*r*	0.26**	0.15	0.12	0.18*	0.18*	0.31**	0.16	0.17	0.22*	0.20*	0.16
	Left	*r*	0.30**	0.17	0.15	0.25**	0.23*	0.36**	0.20*	0.23**	0.17*	0.18*	0.23**
Time from turning point to reach maximum strength	Right	*r*	0.30**	0.10	0.17	0.15	0.25**	0.21*	0.24**	0.23*	0.33**	0.22*	0.18*
	Left	*r*	0.15	0.11	0.10	–0.03	0.19*	0.20*	0.10	0.11	0.07	0.07	0.13
Ratio of strength (turning point/maximum)	Right	*r*	–0.22*	–0.07	–0.17	–0.14	–0.20*	–0.19*	–0.20*	–0.17	–0.18*	–0.06	–0.18*
	Left	*r*	–0.09	–0.06	–0.07	–0.02	–0.17*	–0.07	–0.06	0.04	–0.01	–0.12	–0.09
Inclination from turning point to maximum strength	Right	*r*	0.06	0.11	0.09	0.03	0.02	0.12	0.09	0.06	–0.07	–0.04	0.06
	Left	*r*	0.07	0.08	0.08	0.12	–0.06	–0.05	0.09	–0.03	–0.01	0.12	0.10

**$P < 0.01$, *$P < 0.05$.

Table 4 Partial correlations between nine grip strength items measured and Barthel Index (total score and each sub items) adjusted for age and Mini-Mental State Examination total score in women

			Total score	Feeding	Bed/wheel-chair transfer	Grooming	Toilet use	Bathing	Mobility	Ascend/ descend stairs	Dressing	Bowel management	Bladder management
Response time	Right	*r*	–0.14	0.26	–0.05	–0.12	–0.02	–0.16*	0.04	–0.17*	0.07	–0.19*	–0.14
	Left	*r*	–0.16*	–0.10	–0.07	–0.22**	–0.06	–0.16*	0.02	–0.11	0.07	–0.15*	–0.18*
Time to reach turning point	Right	*r*	0.01	0.10	0.10	0.04	0.04	0.03	0.07	–0.03	0.04	–0.12	–0.05
	Left	*r*	0.02	0.03	0.05	–0.07	0.02	0.02	0.09	–0.04	0.08	–0.02	–0.03
Strength at turning point	Right	*r*	0.26**	0.09	0.20**	0.16*	0.11	0.22**	0.12	0.21**	0.15*	0.22**	0.23**
	Left	*r*	0.23**	0.04	0.17*	0.17*	0.09	0.13	0.14	0.15*	0.16*	0.24**	0.25**
Inclination from start to turning point	Right	*r*	0.14	–0.10	0.07	0.02	0.07	0.04	0.10	0.12	0.06	0.20**	0.17*
	Left	*r*	0.11	–0.04	0.09	0.03	0.06	0.02	0.05	0.12	0.03	0.15*	0.16*
Time to reach maximum strength	Right	*r*	–0.11	–0.02	0.04	–0.02	–0.07	–0.01	–0.05	–0.10	–0.08	–0.20**	–0.15*
	Left	*r*	–0.04	0.00	0.01	0.02	–0.05	0.07	–0.02	–0.02	0.01	–0.13	–0.09
Maximum strength	Right	*r*	0.22**	0.06	0.20**	0.15*	0.06	0.19**	0.12	0.17*	0.13	0.18*	0.20**
	Left	*r*	0.23**	0.03	0.19**	0.18*	0.08	0.15*	0.13	0.16*	0.16*	0.19**	0.22**
Time from turning point to reach maximum strength	Right	*r*	–0.14	–0.10	–0.04	–0.06	–0.11	–0.04	–0.11	–0.09	–0.13	–0.12	–0.14
	Left	*r*	–0.06	–0.02	–0.02	0.03	–0.07	0.08	–0.08	–0.01	–0.04	–0.15*	–0.09
Ratio of strength (turning point/maximum)	Right	*r*	0.24**	0.13	0.18*	0.18*	0.25**	0.19**	0.15*	0.18*	0.19*	0.13	0.14
	Left	*r*	0.11	0.08	0.02	–0.01	0.06	–0.04	0.10	0.00	0.09	0.22**	0.17*
Inclination from turning point to maximum strength	Right	*r*	0.04	0.01	–0.01	–0.03	–0.04	–0.02	0.05	0.02	0.01	0.10	0.12
	Left	*r*	0.12	0.02	0.09	0.08	0.07	0.07	0.05	0.08	0.09	0.11	0.12

**$P < 0.01$, *$P < 0.05$.

and with total score. Different from the results before adjustment, in the right hand only one index gained significance. Time from turning point to reach maximum strength and ratio of strength (turning point/maximum strength) were significantly related to seven and five items, respectively, as well as to the total score in the right hand. Inclination from start to turning point was significant only in total score and some subclass items in both hands (Table 3). In women, maximum grip strength was significantly related to seven items in the left hand and six in the right, as well as with the total score in both hands. Response time was significantly related to four items in the left hand and three in the right, whereas the total score was significant only in the left hand. Strength at turning point, differing slightly from men, was significant in seven items in the right hand and six in the left, as well as in the total score in both hands. The ratio of strength (turning point/maximum strength) was significant in seven items and the total score in the right hand (Table 4).

Correlations between nine grip strength items measured and total BI scores in three different age groups

In men aged in their 70s, six out of nine items, namely, response time, time to reach turning point, strength at turning point, maximum grip strength, time from turning point to reach maximum strength and ratio of strength (turning point/maximum), were correlated with total BI score in the right hand, whereas five items, response time, time to reach turning point, strength at turning point, inclination from start to turning point and maximum grip strength, were related with total BI score in the left hand (Table 5). In the age group below 70 years, just two items, strength at turning point and ratio of strength (turning point/maximum), were related in both hands (Table 5). In the 80s age group, no item was correlated in the right hand, and response time and inclination from start to turning point were correlated in the left hand (Table 5).

Much different from men, in women aged in their 70s only one item, strength at turning point, was correlated in the right hand, and also only one item, response time, was correlated in the left (Table 5). In the age group below 70 years, no item was correlated in the right hand, whereas four items, response time, time to reach turning point, time to reach maximum strength and time from turning point to reach maximum strength (all of these were time-related items), showed significant correlations in the left hand. In women aged in their 80s, strength at turning point and maximum strength were correlated in both hands, and time from turning point to reach maximum strength was correlated in the right hand (Table 5).

Discussion

The grip strength test is one of the most popular and widely utilized methods for evaluating muscle strength.[3–5] It is doubtful, however, whether a grip strength device, originally made for young people, is suitable for measuring very weak strength, because average grip strength of female residents (mean age 83.2 years) in a nursing home was reported to be as low as 8.7 kg.[21] We have developed a new grip-strength measuring device that not only measures small values accurately, but also evaluates muscle contraction in detail, by taking a time axis into consideration, and defined various indices, which were shown to be different by sex or side in a previous study.[19]

In the present study, we have investigated the association of grip strength and independence of ADL in older adults, comparing the data from our newly-developed device and the internationally utilized BI to determine whether the newly advocated indices are associated with limitations in ADL. Maximum grip strength was proved to be a very good index, which could be shown with precise values; however, response time, values at the turning point and ratio of strength (turning point/maximum strength), although correlated with the indices, varied by sex or hand side (Tables 3 and 4). When we first introduced this device, we thought that not only measuring the maximum strength, but also the time to reach maximum strength, would be important. The time to reach maximum strength, however, was not found to be significant in either sex or in total BI score, or in most of the subclass indices. As a matter of fact, although no association was seen in time to reach maximum strength, some relationships were seen in time to reach turning point and time from turning point to reach maximum, especially in men (Tables 3 and 4). Therefore, the meaning of time might not be the same before and after the turning point. Also, strength at turning point was found to be correlated with total BI score and several subclass items, especially in women.

From the aforementioned, turning point was suggested to be worth measuring, although its meaning warrants further investigation; it could have something to do with the proportional change of the fast and slow twitch fiber contraction, or something else, such as the relative involvement of flexors and extensors in gripping performance. In order to determine this with greater certainty, further studies should be carried out, such as simultaneous electromyography measurement. In the analyses of the separate age groups, particularly in the group of men aged below 70 years, the strength at turning point was associated with total BI scores, although maximum grip strength was not. In the group of women aged below 70 years, in the left hand, neither maximum grip strength nor strength at turning point was related with total BI scores, and some other indices,

Table 5 Partial correlations between nine grip strength items measured and total Barthel Index scores in three different age groups, adjusted by Mini-Mental State Examination score

Age		Men			Women		
		Below 70 years (n = 38)	70s (n = 67)	80s (n = 36)	Below 70 (n = 45)	70s (n = 71)	80s (n = 85)
Response time	Right hand	−0.12	−0.34**	−0.14	0.20	−0.08	−0.07
	Left hand	−0.12	−0.33**	−0.40*	−0.33*	−0.27*	−0.09
Time to reach turning point	Right hand	0.16	−0.42**	−0.11	0.01	−0.01	0.08
	Left hand	0.15	−0.27*	−03.2	−0.34*	−0.01	0.06
Strength at turning point	Right hand	0.41*	0.25*	0.26	0.07	0.26*	0.30**
	Left hand	0.35*	0.36**	0.31	0.11	0.22	0.35**
Inclination from start to turning point	Right hand	0.16	0.21	0.31	0.18	0.15	0.14
	Left hand	−0.16	0.28*	0.37*	0.22	0.07	0.18
Time to reach maximum strength	Right hand	0.08	0.06	0.07	−0.10	−0.15	−0.16
	Left hand	−0.23	0.04	−0.1	−0.48**	0.11	−0.02
Maximum strength	Right hand	0.24	0.35**	0.28	0.08	0.16	0.29**
	Left hand	0.09	0.43**	0.30	0.12	0.20	0.35**
Time from turning point to reach maximum strength	Right hand	0.03	0.36**	0.19	−0.11	−0.16	−0.25*
	Left hand	−0.32	0.22	0.16	−0.38*	0.13	−0.07
Ratio of strength (turning point / maximum)	Right hand	0.39*	−0.29*	0.17	0.02	0.23	0.21
	Left hand	0.52**	−0.20	0.22	−0.02	−0.02	0.18
Inclination from turning point to maximum strength	Right hand	−0.07	0.12	0.06	0.15	0.02	0.12
	Left hand	0.07	0.07	−0.03	0.25	0.02	0.17

**$P < 0.01$, *$P < 0.05$.

involving time elements rather than strength were significant. These time-related items were influenced by sex or by side (right or left). This could be as a result of the changes of the quality of the muscle,[22] such as the rates of fast and slow twitch fiber, respectively, or the proportion of the fat infiltration.

As the participants of the present study were assumed to have cognitive problems, we adjusted for MMSE score in the analyses (Tables 3–5). Even after that, however, the results were almost the same in men, with a difference becoming apparent in only one item – inclination from start to turning point. In women, differences became apparent in five items (data not shown), suggesting that cognitive function might be influenced more in women. Further detailed analyses will have to be carried out to elucidate the associations between cognitive function, grip strength and the related new indices. With regard to the association between dementia and gripping performance in particular, further careful studies are required with separation of dementia into vascular, Alzheimer type, Lewy body disease or other types.

So far there have been several studies expressing the association between grip strength and ADL.[11–18] All but one related to ADL performance as a whole.[13] Although most of the studies compared the sex difference, none of them focused on the side difference nor differentiated the subjects by age groups. Thus, to our knowledge, the present study carried out the most detailed analyses to date, such as the subclass items of ADL or the influences of sex, side, or age. Furthermore, we investigated the detailed items during muscle contraction, which were shown for the first time while taking the time axis into consideration. Thus, it has become possible to analyze such detailed items by utilizing our elaborate new device equipped with a machine for quality control in the industrial product field. The detailed indices showed the difference, not only when comparing the difference between an independent group and those with clearly lower levels of ADL, but also with those who require only light assistance (group with total BI score of 95 or 90). This was suggested by the finding that right hand inclination from start to turning point was significantly lower in the 95 and 90 point group than in the 100 point group, although a significant difference was not seen in maximum strength (data not shown), which an ordinary device can measure as a solitary index.

Notwithstanding, the number of participants in the present study might not be large enough to confirm the significance of these indices, as the results on the significance of some of the indices changed when the participants were divided into three different age groups, particularly in women. This was seen in the ratio of strength (turning point/maximum).

There were some limitations to the present study. First, the analyses were carried out only in a Japanese population, and in participants with some cognition problems. Also, although we found some relationships between grip strength and BI scores, they remained rather weak. This might derive from the fact that the distribution of the BI was not even, shifting towards the full or nearly full score group. To more properly assess the influence of gripping performance and ADL, therefore, it might be necessary to use other indices, such as instrumental ADL, or gain a greater number of patients. These are issues to be investigated in future.

For hand side we used right versus left, but it would be more appropriate to consider this based on the hand dominance. However, it was not easy (or simple) to separate the participants by hand dominance, because when asked about their dominancy, 134 male patients replied right, three replied left, three replied both, two replied right but switched from left and eight did not answer. In women, 195 replied right, four replied left, six replied both, one replied right but switched from left and 20 did not answer. We therefore carried out the investigation with the classification of right and left. Nevertheless, for ratio of strength (turning point/maximum), significant correlations were seen with many subitems only in the right hand in both sexes, as was the case for time from turning point to reach maximum strength in men (Tables 3 and 4).

The device itself is still also limited to research purposes, and further improvements must be made to adapt it for more practical use, both in software so that the detailed indices are read automatically, and in hardware, including the handle section, for more comfortable gripping by older adults.

Despite those limitations, however, we will carry out further analyses on the various functions of older adults, by increasing the number of study population, and show the effectiveness of these indices, as the measuring method has advantages: it can be carried out safely and in a very short time with subjects in a sitting position, and can measure isometric contractions that are considered to be proper in measuring strength in elderly people. The device is accurate, of which measuring values (maximum strength) accorded quite well with those of Jamar Hydraulic Hand Dynamometer (data not shown).

In summary, we investigated the association of grip strength and the independence of ADL in older adults, using the data from a newly-developed grip strength measuring device. The maximum grip strength was shown to be associated with ADL in many items of the BI, but some of the newly defined indices, such as response time, strength at turning point, elements regarding before and after turning point until the strength reaches maximum, were shown to be associated with some ADL-related items. Some of the associations were different from those with the maximum grip strength, and they varied by sex, hand side or age groups. This new device, considering the time axis and novel items for measuring, could possibly be used effectively for applications in evaluating the functions of older adults, although further investigations will be required in order to determine the meaning or usefulness of the newly advocated indices.

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Disclosure statement

The authors declare no conflict of interest.

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ORIGINAL ARTICLE

Effect of cerumen impaction on hearing and cognitive functions in Japanese older adults with cognitive impairment

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Aim: To assess the effect of cerumen impaction and its removal on hearing ability and cognitive function in elderly patients with memory disorders in Japan.

Methods: Pure tone audiometry (PTA) and the Mini-Mental State Examination (MMSE) were administered to participants before and after cerumen removal. Participants who had cerumen impaction in the better-hearing ear comprised the case group; the control group consisted of participants who either did not have cerumen impaction or had it in the worse hearing ear. Hearing and cognition changes were compared between the groups after cerumen removal.

Results: A total of 55 patients who completed all examinations were assigned to the case group (29 patients) or the control group (26 patients). The average hearing change was 4.6 ± 7.4 in the case group and 0.9 ± 0.9 in the control group ($P = 0.029$). The average change in MMSE score was 0.7 ± 2.5 in the case group and −1.0 ± 4.1 in the control group ($P = 0.068$). The case group showed a significant improvement in MMSE scores after age adjustment compared with the control group ($P = 0.049$).

Conclusion: Hearing improved significantly in the case group relative to controls after cerumen removal. A significant cognitive improvement in the case group relative to controls was additionally observed after cerumen removal with age adjustment. Thus, the present results suggest routine ear canal examinations might benefit elderly individuals with memory disorders. **Geriatr Gerontol Int 2014; 14 (Suppl. 2): 56–61.**

Keywords: cognitive impairment, dementia, hearing impairment, Mini-Mental State Examination, pure tone audiometry.

Introduction

Cerumen is a complex of ceruminous and sebaceous gland secretions, and various other substances in the ear canal. Dry and wet variations of cerumen are found in humans, and the presence of either is different among the ethnic groups.[1] The wet variation is present in over 90% of white and black people. A combination of wet and dry variations is seen in populations of certain parts of the Middle East and Southeast Asia. The dry variation is major in North China, Korea and Japan, and is present in approximately 70–80% of Japanese people.

Cerumen impaction is more common in children, the elderly and individuals with an intellectual disability.[1] Indeed, the prevalence of cerumen impaction appears to increase with age in adults; in the geriatric population (those aged 65 years and older), the incidence of cerumen impaction is reportedly 19–34%.[2–4] Furthermore, studies have shown that people with an intellectual disability have a higher prevalence (24–25%) of cerumen impaction, regardless of age.[5,6] Cerumen impaction is also more likely to occur in people with wet type cerumen.[1] Cerumen impaction leads to itching, pain, hearing loss, tinnitus, vertigo and choronic otitis externa. Hearing loss caused by cerumen impaction is up to 40 dB.[7] The prevention of hearing loss is advantageous, because hearing loss has been implicated as an independent risk factor for cognitive impairment and

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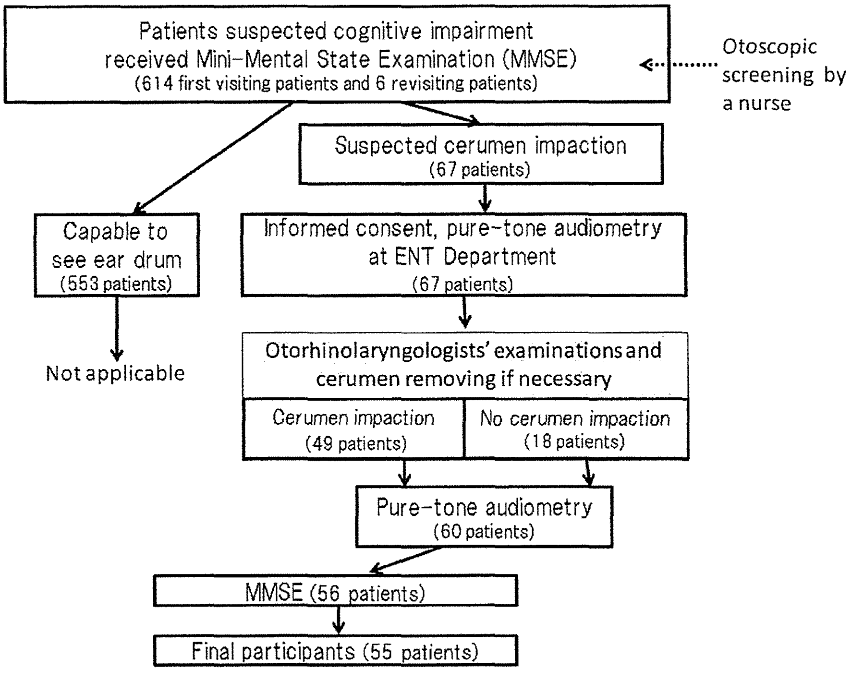

Figure 1 Study protocol.

dementia.[8,9] Moore *et al.* studied the influence of cerumen impaction clearance on Mini-Mental State Examination (MMSE) performance.[10] In their study, 65.5% of the participants had cerumen in at least one ear, and hearing and the MMSE score improved significantly in participants with impacted cerumen after cerumen removal. In an earlier study, we reported that cerumen impaction of the better-hearing ear (BHE) was observed in 10.7% of community-dwelling Japanese older adults aged older than 60 years.[11] Cerumen was significantly associated with poorer hearing and a lower MMSE score.

The aim of the present study was to investigate the potential contribution of cerumen impaction and cerumen removal on hearing and cognitive function in Japanese patients with memory disorder.

Methods

Participants

The participants were 67 patients (28 males, 39 females; mean age 81.7 ± 5.6 years) who visited the Center for Comprehensive Care and Research on Memory Disorders (CCCRMD), National Institute for Longevity Science, National Center for Geriatrics and Gerontology between 9 July to 30 November in 2012. The study protocol was approved in advance by the Committee of the Ethics of Human Research of the National Center for Geriatrics and Gerontology (NCGG). The study protocol is shown in Figure 1. The patients who visited the center because of a memory disorder were first asked to complete the MMSE and were then given an otoscopic screening by a nurse. If cerumen impaction was suspected, it was recommended to the patients that they visit the Ear, Nose and Throat (ENT) Department, and detailed information regarding the present study was provided to them at the ENT department. Written informed consent was obtained from each patient who agreed to participate in the study. The initial audiometric test was carried out before evaluation of the ear by otorhinolaryngologists. After the pure tone audiometry (PTA) assessment, the participants were given ear canal examinations by an otorhinolaryngologist and cerumen removal was carried out, if necessary. Regardless of whether significant cerumen impaction was observed, the PTA assessment was administered to participants. The second MMSE was administered weeks to months later at the center. Participants who could not complete the PTA or MMSE were excluded from the present study. Seven participants could not complete the PTA because of poor reproducibility. Four participants refused to complete the second MMSE. One participant was excluded from the study because she began memantine hydrochloride regimen between the first and the second MMSE. Thus, the total number of participants was 55 (25 male, 30 female; mean age 81.3 ± 5.8 years, range 68–93 years). A total of 33 of the participants were not taking medications to treat dementia at any time during the study. The remaining 12 patients were taking medication for memory disorders during the study period (memantine hydrochloride: 2 patients, donepezil hydrochloride: 8 patients, memantine and donepezil: 2 patients); however, these patients did not begin, end or change medications during the course of the study.

Functional assessment

The MMSE[12] was administered to participants by clinical psychologists both before and after the otological examination. Functional assessment was also administered using the Barthel Index[13] before the otological examination.

The PTA measurement was carried out by a clinical laboratory technician using a diagnostic audiometer (AA-75; RION, Tokyo, Japan) that was calibrated according to Japanese Industrial Standards T 1201. The air-conduction pure tone average of hearing thresholds (AHT) of the right and left ears were calculated as the average of 0.5, 1, 2 and 4 kHz for each ear before and after the otological examination. The BHE was decided by the AHT after cerumen removal.

Ceruman removal was carried out under a microscope using irrigation and suction procedures. Cerumen impaction was diagnosed if the volume of cerumen exceeded one-third of the ear canal.

The MMSE-administering psychologist and the audiometric examiner were uninformed about the presence or absence of cerumen impaction.

A questionnaire assessing participants' frequency of ear cleaning, cerumen type, and incidence of itching within the ear canal was also administered to the participants and their family. Ear cleaning less than once a month was defined as no ear cleaning.

Statistical analysis

The participants who completed the entire process were divided into two groups. The case group consisted of participants who had cerumen impaction in the BHE, whereas the control group included participants who either did not have cerumen impaction both or had it only in the worse hearing ear.

Statistical analyses were carried out using the statistical analysis system (SAS) version 9.3 (SAS Institute, Cary, NC, USA). Unless otherwise stated, all values are presented as the mean ± SD. The χ^2-test for categorical variables and the Student's *t*-test for continuous variables were used to assess differences in characteristics between the two groups. A general linear model for assessment of correlation between changes in MMSE score and changes in the AHT of the BHE was carried out in the case group. Then, a general linear model adjusted by age, sex, baseline MMSE score and changes in the AHT of the BHE was used to assess differences in the changes in MMSE score between the case and control groups. A value of $P < 0.05$ was considered statistically significant.

Results

Table 1 shows the characteristics of participants with and without cerumen impaction. There were no significant differences in age, sex, Barthel Index score, AHT of the BHE, baseline MMSE score or duration of the first and the second MMSE between the two groups. There

Table 1 Participant characteristics and changes in pure tone audiometry and MMSE scores after cerumen removal

	All participants	Cerumen impaction of BHE	No cerumen impaction of BHE	*P*-value†
n	55	29	26	
Age	81.3 ± 5.8	79.9 ± 5.4	82.8 ± 5.8	0.055
Male, *n* (%)	25 (45.5%)	15 (51.7%)	10 (38.5%)	0.324
No ear cleaning, *n* (%)	23 (41.8%)	15 (51.7%)	8 (30.8%)	0.222
Wet type earwax, *n* (%)	14 (25.5%)	7 (24.1%)	7 (26.9%)	0.735
Ear canal itching, *n* (%)	16 (29.1%)	6 (20.7%)	10 (38.5%)	0.274
Baseline AHT of BHE (dB)	42.6 ± 15.5	43.2 ± 15.4	41.9 ± 15.8	0.748
Barthel Index‡	90.4 ± 13.8	89.0 ± 14.4	91.8 ± 13.3	0.483
AHT of BHE after cerumen removal (dB)	39.8 ± 14.1	38.6 ± 12.5	41.0 ± 15.9	0.535
Change in AHT (dB)	2.8 ± 6.4	4.6 ± 7.4	0.9 ± 0.9	0.029
Baseline MMSE score	18.0 ± 6.3	17.6 ± 6.6	18.5 ± 6.0	0.61
MMSE score after cerumen removal	17.9 ± 6.7	18.3 ± 6.8	17.5 ± 6.7	0.657
Change in MMSE score	−0.1 ± 3.4	0.7 ± 2.5	−1.0 ± 4.1	0.068
Time between MMSE (days)	41.0 ± 28.4	43.2 ± 34.2	38.4 ± 19.6	0.549

Data presented as mean ± standard deviation. †The *t*-test for continuous data, χ^2-test for categorical data. ‡One participant in the no cerumen impaction of best hearing ear (BHE) group and two participants in cerumen impaction of BHE group did not have the Barthel Index estimated. AHT, air-conduction pure-tone average of hearing thresholds; MMSE, Mini-Mental State Examination; PTA, pure tone audiometry.

Table 2 Results of the general linear model

Adjustment	Change in MMSE score in case group	Change in MMSE score in control group	*P*-value
	0.7 ± 0.6	−1.0 ± 0.7	0.068
Age	0.8 ± 0.7	−1.1 ± 0.7	0.049
Sex	0.7 ± 0.6	−1.2 ± 0.7	0.05
Baseline MMSE	0.6 ± 0.6	−1.0 ± 0.7	0.079
Changes in AHT of BHE	0.7 ± 0.6	−1.1 ± 0.7	0.065
All of above	0.8 ± 0.7	−1.3 ± 0.7	0.043

Data presented as least mean square ± standard error. AHT, air-conduction pure-tone average of hearing thresholds; BHE, best hearing ear; MMSE, Mini-Mental State Examination.

was a non-significant trend in the case group towards a lower incidence of ear cleaning and ear canal itching. There were no significant differences in the prevalence of wet type cerumen between the case group (24.1%) and the control group (26.9%). Changes in AHT were significantly larger in the case group than in the control group. Differences in MMSE score before and after otorhinolaryngological intervention differed with marginal significance between the case group and control group ($P = 0.068$).

Two participants classified as having severe hearing loss before cerumen removal (an AHT of 70 dB or greater) were reclassified as having moderate hearing loss (an AHT of 40–69d B) after cerumen removal. Two participants classified as having moderate hearing loss before cerumen removal were reclassified as having mild hearing loss (an AHT of less than 40 dB) after cerumen removal. There was a marginal significant correlation between hearing improvement and differences in the MMSE scores ($R^2 = 0.166$, $P = 0.079$).

Table 2 shows the results of the general linear analysis. There was a significant improvement in MMSE score in the case group after cerumen removal compared with the control group, after adjusting for age; however, adjusting for sex, baseline MMSE score or AHT change rendered this improvement non-significant. Nevertheless, a significant effect of BHE cerumen impaction on the change in MMSE score was observable even after the addition of all adjustments. Furthermore, the only measured variables that significantly affected the changes in MMSE scores after cerumen removal was BHE cerumen impaction ($P = 0.043$; age: $P = 0.297$, sex: $P = 0.300$, baseline MMSE score: $P = 0.323$, change of AHT: $P = 0.894$).

Discussion

In the present study, hearing improved significantly in participants who had BTE cerumen impaction after cerumen removal, and a significant cognitive improvement in the case group relative to controls was observed after cerumen removal with age adjustment.

The cognitively impaired older adults are suggested to have high rates of cerumen impaction, because older adults and people with an intellectual disability have been found to show high prevalence rates of this condition.[2–6] Moore *et al.* reported that 65.6% of residents in a skilled nursing facility had cerumen impaction in at least one ear.[10] The reason for a higher prevalence of cerumen impaction in people with an intellectual disability is still unknown. Several possibilities include poor hygiene and anatomical abnormalities of the ear canal, such as stenosis with Down syndrome, were suggested as possible causes. The reason for a higher prevalence of cerumen impaction in older adults is more clearly accounted. As the skin in the ear canal ages, the surface epithelium thins, the subcutaneous tissue atrophies, the ceruminous glands and the sebaceous glands produce less oil, and the hair in the ear canal lengthens.[1] All of these changes inhibit the excretion of cerumen. Furthermore, the tendency of aging ear canal skin to bleed easily renders cerumen removal aversive and consequently less frequent. Previous reports about the prevalence of cerumen impaction have been from countries where the wet variation of cerumen is present in 90% of the population. In Japan, an estimated 70–80% of the population has the dry variation of cerumen. In a previous study, we reported that cerumen impaction of the BHE was suspected in 10.7% of community-dwelling Japanese older adults above the age of 60 years.[11] However, we only examined the ear canal by otoscopy in that previous study, and thus could not confirm the degree of impaction. In the present study, in which we were limited to first-visit patients at the CCCRMD, 7.0% (43 of 614) of participants had cerumen impaction that exceeded one-third of the ear canal. This frequency was quite low compared with Western countries.[2–4,10] The prevalence of wet type cerumen in the present study was 25.5%, and the incidence of wet cerumen with impaction and wet cerumen without impaction was not significantly different. The cause of a non-significant incidence of wet cerumen impaction in the present study might be due to the low participants. Furthermore, that genetic diagnosis of wet cerumen was not carried out was a limitation of the present study.

Hearing loss has been reported as an independent risk factor for cognitive impairment and dementia.[8,9] Moore *et al.* reported significant improvement of hearing and MMSE score after cerumen removal.[10] Similarly, Oron *et al.* reported a significant difference in participants' Raven's Standard Progressive Matrices Test scores before and after cerumen removal.[14] In the present study, the change in MMSE score during 40 days in the case group was 0.7, whereas the change in MMSE score in the control group was −1.0. Uhlmann *et al.* reported that a decline in MMSE score in hearing impaired senile dementia of the Alzheimer's type was nearly double that of normal hearing patients.[15] The means of AHT of BTE in the participants of the present study were over 40 dB, thus moderate hearing loss might accelerate the decline of MMSE score, whereas the improvement of hearing partially improved the MMSE score during 40 days. It is possible that hearing improvement is directly or indirectly associated with cognitive function. In the present study, the change in AHT showed a marginal association with the change in MMSE score. Thus, the improvement in MMSE score might result from the direct and the indirect effect of hearing, such as stimulation from environmental sounds and improved speech recognition. The medical sequelae of cerumen impaction include tinnitus, a feeling of fullness in the ear, pain, hearing loss, vertigo, cough and external otitis.[1] Elimination of these peripheral symptoms of cerumen impaction might also contribute to cognitive improvement. Further investigations that clarify the effect of ear canal hygiene on hearing and cognitive function for longer period are necessary.

Although the prevalence of cerumen impaction is low in Japan compared with Western countries, cerumen removal can have similar effects on hearing and cognition. Thus, routine ear canal examinations and cleaning could benefit older adults in Japan. Although methods for wet type cerumen removal have been investigated,[16] there is minimal information regarding the removal of dry type cerumen. The use of ear picks sometimes causes severe injury of the ear.[17] It has also been warned that the use of a cotton tip increases the risk of cerumen impaction and otitis externa.[18] Therefore, the development and assessment of effective methods for removal are imperative.

The present study found that 7.0% of new patients with memory disorders had cerumen impaction. Evaluation of hearing after cerumen removal resulted in a statistically significant improvement. Improvement in cognition relative to controls was also significant after adjustment for age. Thus, routine ear canal examinations can benefit older adults with memory disorders.

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Disclosure statement

The authors declare no conflict of interest.

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ORIGINAL ARTICLE

Developing an interdisciplinary program of educational support for early-stage dementia patients and their family members: An investigation based on learning needs and attitude changes

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Aim: The National Center for Geriatrics and Gerontology has begun to provide educational support for family caregivers through interdisciplinary programs focusing on patients in the early stage of dementia. These interdisciplinary programs have established two domains for the purpose of "educational support": cure domains (medical care, medication) and care domains (nursing care, welfare). In the present study, we examined the learning needs and post-learning attitude changes of patients and their families who participated in these programs in order to assess the effectiveness of an interdisciplinary program of educational support in each of these domains.

Methods: A total of 170 participants (51 dementia patients, 119 family members) were included in the study. Data were obtained from electronic health records, and through a written survey administered before and immediately after each program.

Results: A high percentage of patients and family members desired knowledge about the progression and symptoms of dementia, as well as measures to prevent progression, both of which fall under the medical care content. For patients, education in the medical care content increased their motivation to live. For families, education in the medical and nursing care contents promoted their understanding of dementia, while education in medication and welfare contents improved their skills for handling dementia patients and their symptoms.

Conclusion: Both patients and family members expressed a need to learn medical care content, including the progression and disease symptoms of dementia, and methods to prevent the progression of dementia symptoms. Their responses showed that learning medical care was effective for understanding dementia. We suggested that medical care content was the core of interdisciplinary educational support for early-stage dementia patients and their family members. **Geriatr Gerontol Int 2014; 14 (Suppl. 2): 28–34.**

Keywords: attitude changes, early-stage-dementia, educational support, interdisciplinary, learning needs, medical care content.

Introduction

The number of dementia patients in Japan is steadily increasing. In response to this situation, the "Future Direction of Dementia Policy -June 2012–" highlighted "early diagnosis and early care" as the foundation of care.[1] The Japanese Ministry of Health, Labor and Welfare advocates the strengthening of day-to-day family support in the community, irrespective of the stage of dementia.[2] Previous studies have shown that providing family caregivers of dementia patients with a psycho-educational program for a fixed period improves the trust between caregivers and patients, and provides caregivers with an understanding of the disease and coping ability for caregiving.[3,4] Chien *et al.* stated that when care managers provided sessions on self-care and restoring or building family relationships, the patients' symptoms stabilized, caregivers felt their care to be less burdensome, and the admission rates and periods of admission to medical institutions decreased.[5] In

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