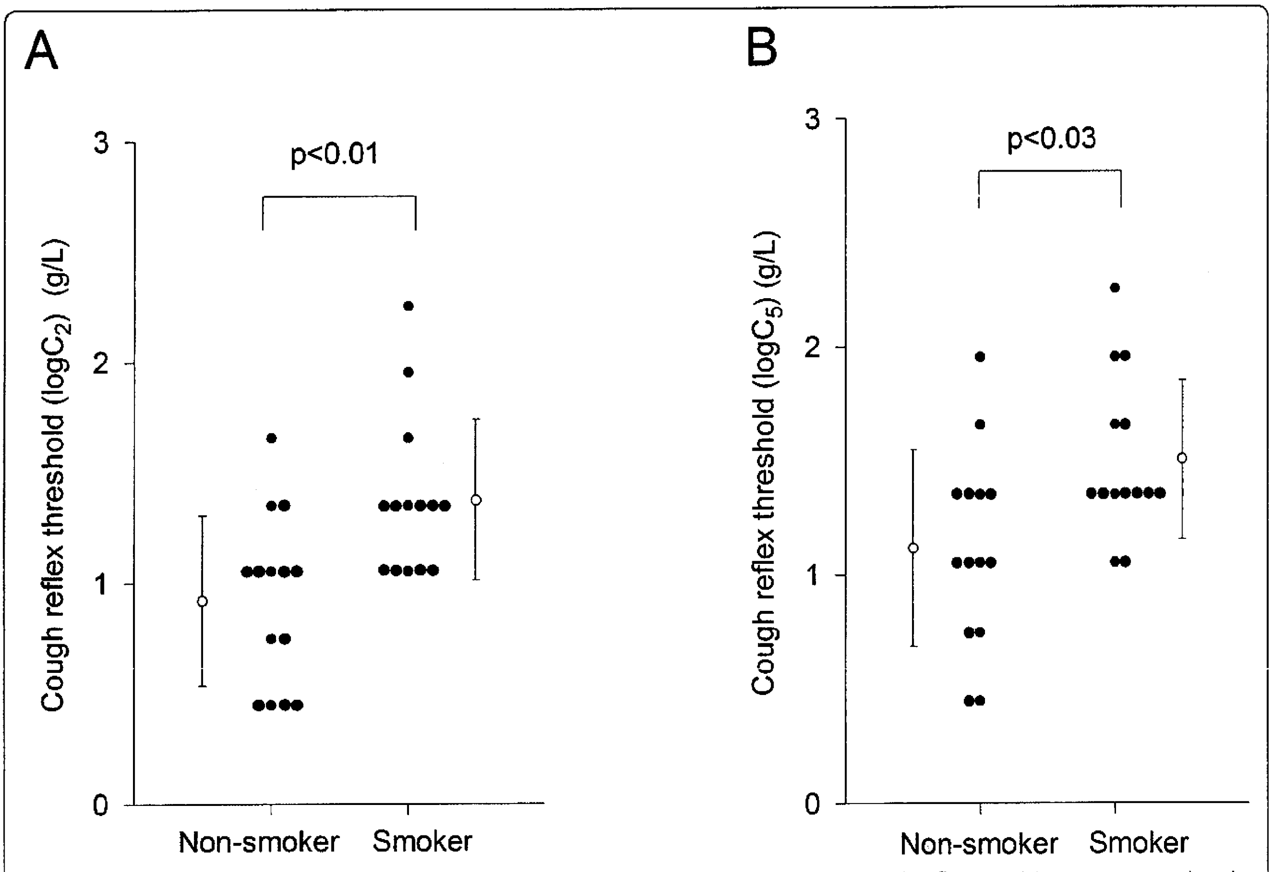

Figure 1 Comparisons of cough reflex sensitivity between non-smokers and smokers. (A) Cough reflex sensitivities are expressed as the log transformation of the lowest concentration of citric acid that elicited two or more coughs (C_2). (B) Cough reflex sensitivities are expressed as the log transformation of the lowest concentration of citric acid that elicited five or more coughs (C_5). Open circles and error bars indicate the mean value and the standard deviation in each group, respectively.

Although cough is usually referred to as a reflex controlled from the brainstem, cough can be also controlled via the higher cortical center and be related to cortical modulations [30]. Therefore, the depression of cough reflex could be due to the disruption of both the cortical facilitatory pathway for cough and the medullary reflex pathway. Since the urge-to-cough is a brain component of the cough motivation-to-action system, the depressed urge-to-cough suggests impairment of supramedullary pathways of cough reflex [6].

It is reasonable to suppose that urge-to-cough arises from sensors that mediate cough reflex. In the bronchopulmonary system, there are at least five sensors involved in this reflex [12]. The dyspnea sensation induced by external resistive loads is reported to be described as the work/effort sensation of dyspnea [31-33]. The neural pathways proposed for this sensation include corollary discharge from motor cortical centers that drive voluntary breathing, and muscle mechanoreceptors and metaboreceptors [33]. Although tobacco smoke may induce desensitization of bronchopulmonary sensors or structural changes interfering with accessibility to sensors [34,35], it is less possible to affect muscle mechanoreceptors and metaboreceptors in healthy young smokers. Therefore, the differential susceptibility to tobacco smoke in peripheral receptors/sensors may explain the dissociation of perceptions of the urge-to-cough by citric acid and dyspnea during external resistive loads. However, in the present study, although cough reflex sensitivity and the urge-to-cough log-log slope were decreased in smokers, the urge-to-cough thresholds did not change (Figure 2). This may suggest no significant changes in bronchopulmonary sensors involved in the urge-to-cough induction and the larger contribution of central gain mechanisms rather than the peripheral ones.

Davenport et al. showed that nicotine administration inhibited urge-to-cough rating scores in smokers deprived from smoking for more than 12 hours [36]. In this study, smokers who withdrew from tobacco smoke showed a greater number of coughs, higher urge-to-cough rating and higher anxiety scores than non-

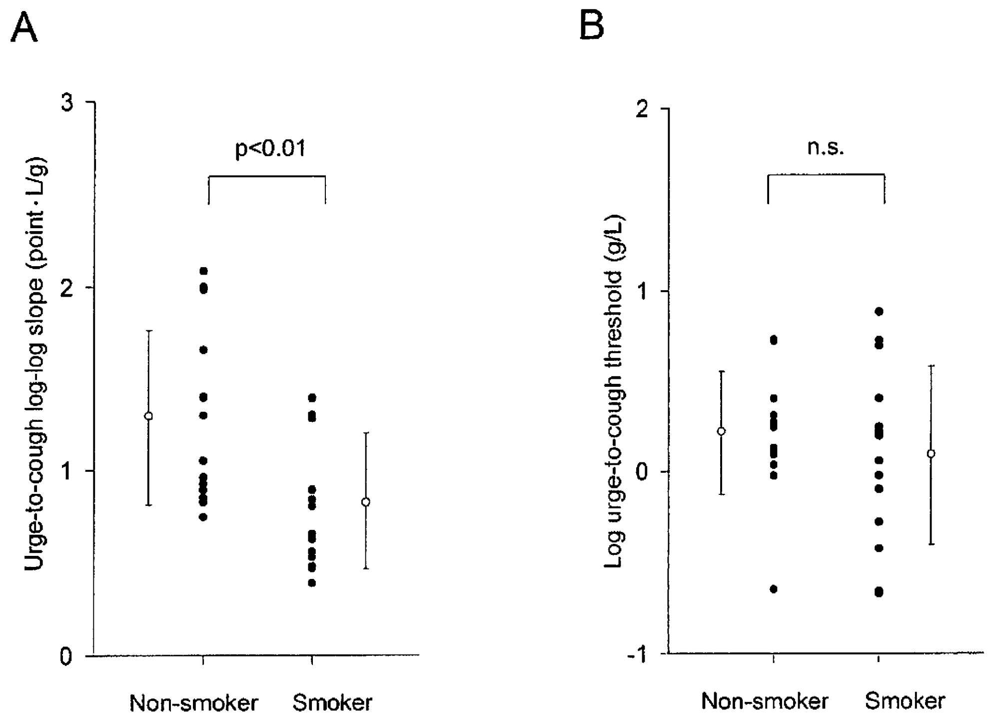

Figure 2 Comparisons of and the urge-to-cough between non-smokers and smokers. (A) The urge-to-cough log-log slope by linear regression between log citric acid concentration and the log Borg scores. (B) The urge-to-cough threshold estimated by log citric acid concentration at the log Borg Score of urge-to-cough = 0. Closed circles indicate the value of each subject. Open circles and error bars indicate the mean value and the standard deviation in each group, respectively. n.s. denotes not significant.

smokers, and the nicotine administration reduced those to match the non-smokers. The study clearly showed the role of nicotine on the central modulation of cough cognitive motivational system and motor response. However, due to a lack of the data concerning smokers without withdrawal from tobacco smoke, the state of cough cognitive motivational system in smokers with depressed cough reflex sensitivity has not been elucidated.

In the present study, we showed the cough cognitive motivational system was inhibited in smokers with

Table 2 Comparison of perceptions of dyspnea between non-smokers and smokers

	Non-smokers	Smokers	P- value
Number	14	14	
R = 10 (point)	2.3 ± 1.0	1.9 ± 1.3	n.s.
R = 20 (point)	3.1 ± 1.4	2.9 ± 1.5	n.s.
R = 30 (point)	4.4 ± 1.5	4.8 ± 1.8	n.s.
Sum (point)	9.7 ± 3.8	9.8 ± 4.8	n.s.
Slope (point · L/g)	0.14 ± 0.05	0.15 ± 0.05	n.s

Data are mean ± S.D. R = 10, R = 20 and R = 30 indicates the Borg score at R = 10, R = 20 and R = 30 $cmH_2O/L/s$, respectively. Sum indicates the summation of Borg scores at R = 10, R = 20 and R = 30 $cmH_2O/L/s$. Slope indicates the linear regression slope when estimated Borg scores were plotted against the corresponding values of resistive loads. P-values were calculated by the Mann-Whitney *U* test. n.s. denotes not significant.

depressed cough reflex sensitivity. Since it was reported that nicotine and tobacco smoking induce the endogenous opioid system [37], cognition of the urge-to-cough might be inhibited by endogenous opioids in smokers. However, this is unlikely because we failed to detect the depressed perception of dyspnea which is also inhibited by endogenous opioids [38]. To our knowledge, the depressed perception of dyspnea has not been reported in healthy smokers.

Respiratory sensation such as various types of dyspnea and the urge-to-cough are the result of sensory activation of subcortical and cortical neural pathways. Some of these pathways are shared across respiratory modalities while activation of some neural areas are modality specific [15]. There are many brain imaging studies concerning dyspnea using different techniques to induce dyspnea. Despite the use of different intervention techniques, the common predominant neural activity has been found in the insula, operculum, and frontal cortex areas, the anterior cingulated cortex, the posterior cingulated cortex, the cerebellum, the thalamus, and the amygdala [13,39]. In contrast, there is only one brain imaging study concerning the urge-to-cough by Mazonne et al. [14]. Their functional magnetic resonance imaging study showed activation in insula, anterior cingulated, primary sensory cortex, orbitofrontal cortex, supplementary motor area and cerebellum during the induction of the urge-to-cough by capsaicin [14]. Although it is still unclear how these brain regions relate to the respiratory sensations, our study may suggest that shared brain regions, such as insula, anterior cingulated, and cerebellum, which are activated by both dyspnea and urge-to-cough are not suppressed by tobacco smoke. Since it has been proposed that initiation of a reflex cough response requires the urge-to-cough to facilitate it [6], the depressed cough reflex sensitivity in healthy smokers might be explained solely by the supramedually mechanism.

Cigarette smoking appears to be a major risk factor for respiratory tract infections [4]. As cough is a normal reflex and respiratory defense mechanism, blunted cough reflex sensitivity may contribute to the risk of respiratory tract infection in cigarette smokers. Moreover, since dyspnea is usually a symptom at a relatively advanced stage of respiratory tract infection whereas cough represents at earlier stages, the blunted urge-to-cough may contribute to the development of respiratory tract infections in smokers due to failure to seek proper medical service.

Conclusions

Our study showed that decreased cough reflex sensitivity in healthy smokers was accompanied by a decreased cognition of the urge-to-cough whereas it was not accompanied by the alternation of perception of dyspnea. Physicians should pay attention to the perceptual alterations of cough in smokers.

Abbreviations

C_2: the lowest concentration of citric acid that elicited two or more coughs; C_5: the lowest concentration of citric acid that elicited five or more coughs.

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Authors' contributions

MK and SE participated in the design of the study, collected and analyzed data, and drafted the manuscript. EN, PG, CS and MY participated in the design of the study and collected the data. TE and MK participated in design of the study and helped to draft the manuscript. All the authors read and approved the final manuscript.

Competing interests

The authors declare that they have no competing interests.

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ORIGINAL ARTICLE: SOCIAL RESEARCH, PLANNING AND PRACTICE

Understanding the oldest old in northern Japan: An overview of the functional ability and characteristics of centenarians

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Aim: To increase knowledge of the functional ability of centenarians by examining the situation of Japanese centenarians residing in an urban region in northern Japan.

Methods: Questionnaires focused on functional ability, demographics, housing and care needs were received from 56 centenarians and 104 control subjects: 56 aged 80–89 and 48 aged 90–99.

Results: Centenarian physical capabilities, care needs and health history were diversified. Centenarians most commonly resided with family in the community and were likely to utilize informal and insurance care services. Gender differences in functional ability by age groups known as gender cross-over were observed in control subjects but reduced in centenarians. A few who reported physical limitations were not entitled to receive nationally subsidized care services suggesting inaccuracies may have occurred during certification determination.

Conclusion: Centenarians in northern Japan represent a heterogeneous cohort suggesting multiple paths to the attainment of advanced old age. This is the first study designed to provide a solid knowledge base of actual circumstances experienced by centenarians specifically in northern Japan. **Geriatr Gerontol Int 2010; 10: 78–84.**

Keywords: aged, aging, health services for the aged, health status, gender characteristics.

Introduction

Japan, a nation famous for longevity, is one of the fastest graying nations in the world. The Japanese population aged over 65 will rise from 20.1% in 2006 to 26% by 2015 and 30.9% by 2030.[1] The number of centenarians in Japan in 2005 was 25 554, 85.2% being female, and is projected to increase to over 166 000 by 2025.[1] With continuous developments in medical care, people are expected to live longer while the prevalence of individuals living with disabilities and or diseases requiring care is also anticipated to increase.

Due to the historical stigma towards institutionalized care combined with the lack of adequate long-term care facilities, many elderly people were hospitalized for long periods of time in regular hospitals.[2] Long-Term Care Insurance (LTCI) introduced in Japan in April 2000 aimed to increase home care services, reduce the number of hospitalizations and unnecessary medical expenses, and increase support to the elderly and their burdened caregivers.

Centenarians represent a heterogeneous cohort and require a diverse range of care from informal and formal care services. By understanding the strengths and weaknesses of LTCI and its utilization by centenarians in

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Japan, other nations may be able to more effectively customize health-care systems to meet the needs of the oldest old.

This paper aims to provide an analysis of centenarians focusing upon functional ability, social situation, and care status. The authors wished to elucidate the effectiveness of the current LTCI system in allocating care and services to the oldest old.

Methods

This is the first study to investigate centenarians in Sendai City, northern Japan. Sendai City reported 1.4 centenarians per 10 000 people,[3] double the general rate in the USA of 0.7 per 10 000.[4] At the time of this study, the sex ratio of centenarians in Sendai City was 6.75 females to one male.

Resident registrars in Sendai City, the second largest city in northern Japan with a population of approximately 1 million people, were manually searched by the principal investigator (S. F.) and all names, addresses, gender and birthdates of the 135 registered centenarians (individuals aged 100 years or older as of 1 January 2007) were selected for the present study. Simultaneously, 135 people aged 90–99 years and 135 people aged 80–89 years were recorded as controls subjects. Immediately following each centenarian located in the registrar book, the next 80–89-year-old and 90–99-year-old individuals listed in the subsequent pages were selected as control subjects. Of the 405 questionnaires, 160 (39.5%) were completed by 56, 48 and 56 respondents aged 80–89, 90–99 and 100–107 years, respectively, and included for analysis in this study.

Questionnaires mailed on the same date included questions relating to the respondents demographics, activities of daily living (ADL) and instrumental activities of daily living (IADL) levels, and care situation.

Questionnaire respondents were assessed for problems in carrying out ADL using the Barthel Index (BI), a widely used 10-item ADL scale.[5] Individuals were divided into six groups according to BI score based upon research by Gondo:[6] Independent A (score 100); Independent B (score 80–99); Minimal Help (score 60–79); Partially Dependent (score 40–59); Very Dependent (20–39); and Totally Dependent (score <20). Independent (combination of Independent A and B scores) and Dependent (combination of Very Dependent and Totally Dependent scores) were used for analysis.

More complex IADL were evaluated using the IADL scale created by Lawton and Brody.[7] This scale ranges 0–8 points for women and 0–5 points for men where a score of 8 for women or 5 for men means that no help is needed.

To analyze the levels of care required, the LTCI care needs level designations given to recipients by the Japanese Ministry of Health, Labor and Welfare were used. Applicants are categorized into one of three categories: self-supporting, support needs levels 1 through 2 (called "yoshien" in Japanese), or care needs levels 1 through 5 (called "yokaigo" in Japanese). Self-supporting individuals are ineligible to receive LTCI assistance. Support needs levels and care needs levels receive eligibility ranging from the fewest amount of community-based services: Support 1, to the maximum allotted amount of care including community as well as institutional services (Care 5). Individuals with LTCI certification choose which services they receive and the company to provide the care.

Care services used by respondents were divided into informal services provided by unpaid family members and formal services comprised of LTCI services and privately paid services.

Informed consent was obtained from all participants. This study was conducted in accordance with the ethical guidelines of Tohoku University School of Medicine.

Statistical analysis was conducted using Microsoft Office Excel 2003 and SPSS ver. 15.0. Analysis was performed using independent samples tests, two-tailed Student's t-test for equality of means, Kruskal–Wallis one-way ANOVA, and test of means using ANOVA. $P < 0.05$ was considered significant.

Results

The status of centenarian and control subjects is shown in Table 1. Fifty-six centenarians ranging in age from 100–107 years (mean 102.0 ± 1.3 years; males : females, 10:46) and 104 control subjects including 56 respondents aged 80–89 (mean 83.7 ± 2.2 years) and 48 respondents aged 90–99 (mean 92.4 ± 2.2 years) were included in this study. No significant differences in response rate were observed between gender or age groups (Fig. 1).

Centenarian physical functioning was lower than 80–99-year-old control subjects ($P < 0.001$). Mean BI scores for 90–99-year-old males were higher than 90–99-year-old females ($P < 0.0001$). There were more Independent centenarian males than females (45.5% vs 18.2%). The percentages of 90–99-year-old and centenarian Independent males were both three times larger than females. The prevalence of Dependent centenarians was 20% more than controls. The proportion of Dependent males was higher than females for both 80–89-year-old (14.82% vs 8%) and centenarian (54.6% vs 47.7%) respondents.

IADL scores showed a general decline as respondent age increased ($P < 0.001$). Differing patterns of IADL status by age were shown between males and females. Males aged 90–99 years showed higher IADL levels than both 80–89-year-old and centenarian respondents.

Respondents reported experiencing various comorbidities including hypertension, dementia, swallowing

Table 1 Background characteristics of participants by age

	80–89 years old			90–99 years old			≥100 years old		
	Total	Male	Female	Total	Male	Female	Total	Male	Female
Characteristics									
No. of participants (%)	56[††]	28 (50.0)	28 (50.0)	48[††]	12 (25.0)	36 (75.0)	56[††]	10 (19.6)	46 (80.4)
Age, mean ± SD	83.7 ± 2.2	83.3 ± 2.0	84.1 ± 2.4	92.4 ± 2.2	92.6 ± 2.4	92.3 ± 2.2	102.0 ± 1.3	101.7 ± 1.3	102.0 ± 1.4
Age, range	80–89	80–89	80–89	90–99	90–98	90–99	100–107	100–103	100–107
Living arrangements, *n* (missing)	56	28	28	46 (2)	12	34 (2)	56	10	46
Alone (%)	7 (12.5)	2 (7.1)	5 (17.9)	3 (6.25)	1 (8.3)	2 (5.6)	1 (1.8)	0 (0.0)	1 (2.1)
With family (%)	46 (82.1)	25 (89.3)	21 (75.0)	32 (66.7)	9 (75.0)	23 (63.9)	41 (73.2)	8 (80.0)	33 (71.7)
With spouse	16	13	3	7	6	1	0	0	0
With biological child	15	9	6	14	2	12	26	6	20
Multigenerational housing 1	14	3	11	9	1	8	9	1	8
Multigenerational housing 2	1	0	1	2	0	2	6	1	5
Institution (%)	3 (5.3)	1 (3.6)	2 (7.1)	13 (27.1)	2 (16.7)	9 (25.0)	14 (25.0)	2 (20.0)	12 (26.1)
Functional ability, *n* (missing)	52 (6)	27 (1)	25 (3)	47 (1)	11 (1)	36	55 (1)	10	45 (1)
Barthel Index, mean ± SD	86.7 ± 27.0[†]	77.1 ± 30.9	88.7 ± 21.2	63.5 ± 31.2[†]	91.8 ± 15.2[‡]	54.9 ± 29.7[‡]	44.2 ± 33.9[†]	48.5 ± 39.4	43.3 ± 33.0
Independent A % (100)	53.8	44.4	64.0	23.4	72.7	8.2	7.3	18.2	4.6
Independent B % (80–99)	15.4	18.5	12.0	12.8	9.1	13.9	16.4	27.3	13.6
Minimal help % (60–79)	15.4	14.8	16.0	27.7	18.2	30.6	18.2	0.0	22.7
Partially dependent % (40–59)	3.9	7.4	0.0	10.6	0.0	13.9	9.1	0.0	11.4
Very dependent % (20–39)	7.7	7.4	8.0	19.1	0.0	25.0	18.2	27.3	15.9
Totally dependent % (<20)	3.9	7.4	0.0	6.4	0.0	8.3	30.9	27.3	31.8
Lawton and Brody IADL, mean ± SD[§]		3.5 ± 1.7	5.8 ± 3.0		4.0 ± 1.2	1.6 ± 1.7		1.3 ± 1.6	1.3 ± 1.9
Smoking status, *n* (missing)[¶**]	52 (4)	28	24 (4)	46 (2)	12	34 (2)	55 (1)	10	45 (1)
Current smoker	7	6	1	1	1	0	0	0	0
Ex-smoker	16	14	2	7	6	1	7	5	2
Never smoker	29	8	21	38	5	33	48	5	43

[†]For total Barthel Index (BI) scores, $P < 0.001$. [‡]For male vs female mean BI scores, $P < 0.0001$. [§]Male and female total instrumental activities of daily living (IADL) scores by age groups, $P < 0.001$. [¶]Gender differences in smoking status by age, $P < 0.001$. **For smoking status by age, $P < 0.0001$. [††]Proportion of females increases by age, $P < 0.0001$. SD, standard deviation.

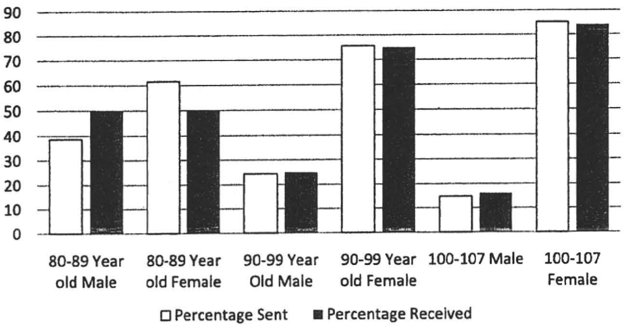

Figure 1 Response rates by age and sex. Open bars denote percentage of questionnaires sent by age and sex groups. A total of 405 questionnaires were sent, 135 to each age group of 80–89, 90–99, and 100–107 year olds. Closed bars denote the percentage of questionnaires received by age and sex groups. A total of 160 questionnaires including 56, 48 and 56 questionnaires by 80–89, 90–99 and 100–107 year olds, respectively, were received.

disorders, osteoporosis, breast cancer and depression at the time of the questionnaire. Other respondents reported past histories of stroke, lung disease, breast cancer and heart attacks. In contrast, a small number of respondents reported continued independence, wellness, and freedom from major illnesses and dementia. Some centenarians reported continuing driving, shopping, sightseeing and attending university classes.

Less than 25% of centenarians in this study reported care beginning before the age of 92 years while 12.1% began receiving care after their 100th birthday (mean age when care began 95.0 ± 5.5 years). Over 75% of centenarians reported receiving care for less than 10 years, the shortest being 11 months and the longest being over 23 years.

Most centenarians (75%) lived in their own private home. Among community-dwelling elderly, 97.6% (41/42) of centenarians lived in family and multigenerational households. The prevalence of third generational families, which include children, grandchildren and great grandchildren, increased with the age of the care respondent. Second generational families, which included children and grandchildren, were more prevalent than third generational families in homes containing a centenarian. One centenarian lived independently and no centenarians had a living spouse. The rates of institutionalization increased with respondent age ($P < 0.001$) though the ratio of institutionalized to community-dwelling centenarians is slightly less than 90–99 year olds.

An application for LTCI had been made by 75% of centenarians (42/56) compared to less than 57% of controls (Fig. 2a). Two of the 42 centenarians who applied for LTCI did not qualify to receive assistance. A total of 16 centenarians (28.6%), 10 whom lived with their biological children, did not have a LTCI support or care needs level.

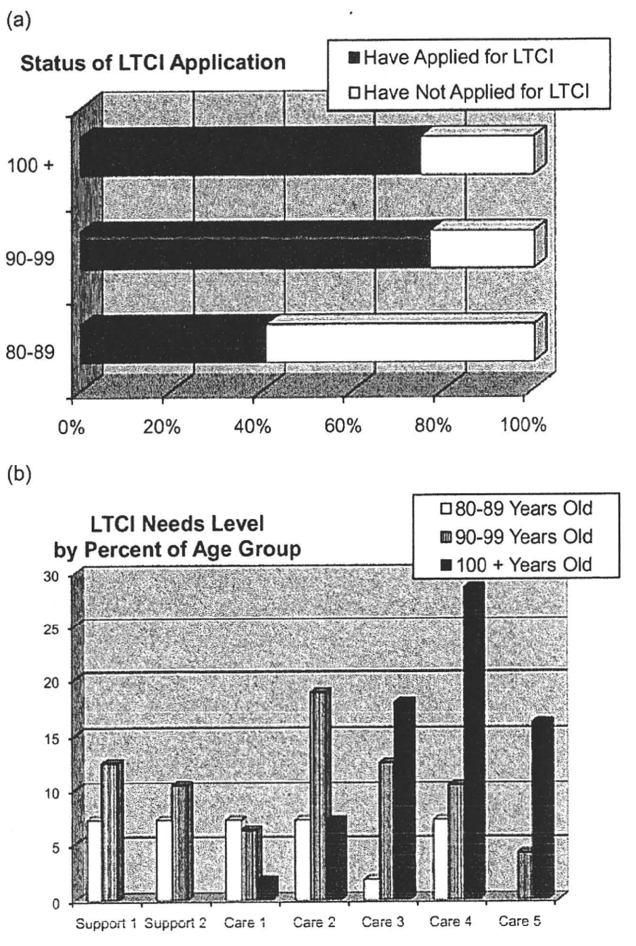

Figure 2 Status of Long-Term Care Insurance (LTCI) by age. (a) Status of applications for LTCI. Open bars show individuals who had not applied for LTCI while closed bars show individuals who had applied for LTCI. Respondents were 80–89 ($n = 54$), 90–99 ($n = 48$) and 100–107 years old ($n = 56$). (b) Percentage of respondents by age group who were eligible for LTCI according to their LTCI care needs level. Open bars represent 80–89-year-old respondents ($n = 13$), closed bars represent 90–99-year-old respondents ($n = 25$), and striped bars represent 100–107-year-old respondents ($n = 40$). Care needs levels range from Support 1, those who are eligible to receive the least amount of services, to Care 5, those who are eligible to receive the maximum amount of services.

The number of respondents who qualified to receive a LTCI support or care needs level increased with age among control recipients ($P < 0.005$) (Fig. 2b). More than 71% of centenarians qualified for LTCI compared to less than 38% of 80–89 year olds who received a support or care needs level and were eligible to utilize LTCI assistance ($P < 0.001$). Centenarians were five times more likely to receive higher care level numbers than 80–89-year-old recipients and three times more likely than 90–99-year-old recipients.

Centenarians were more likely to receive care regularly and to receive LTCI services ($P < 0.001$). Over 73% of centenarians received care regularly. Of the 70% of centenarians (39/56) who reported receiving insurance services, 20.5% (8/39) also received private services. Forty percent more centenarians used LTCI services than 80–89 year olds.

Care needs level beneficiaries receiving care regularly significantly correlated with an increase in recipient age from 52% of 80–89 year olds to over 90% of centenarians ($P < 0.001$). More than 87% of centenarians with LTCI care needs levels receive LTCI services compared to 71.4% of 80–89 and 66.6% of 90–99-year-old controls ($P < 0.004$).

Over 58% of centenarians reported receiving informal care compared to 35.6% of controls ($P < 0.001$). Those receiving informal care were more likely to also receive LTCI services ($P < 0.001$), private services ($P < 0.01$) and care regularly ($P < 0.001$) than those who did not receive informal care. Fewer Independent centenarians (30.7%) reported receiving informal care compared to over 74% of Dependent centenarians ($P < 0.001$).

Centenarians reported receiving 15 different formal services (Fig. 3a) and 17 informal services (Fig. 3b). LTCI services were primarily focused on ADL (41%) followed by medical (37%) and IADL (22%). Informal services focused mainly on IADL (57%) followed by ADL (39%) and medical (4%).

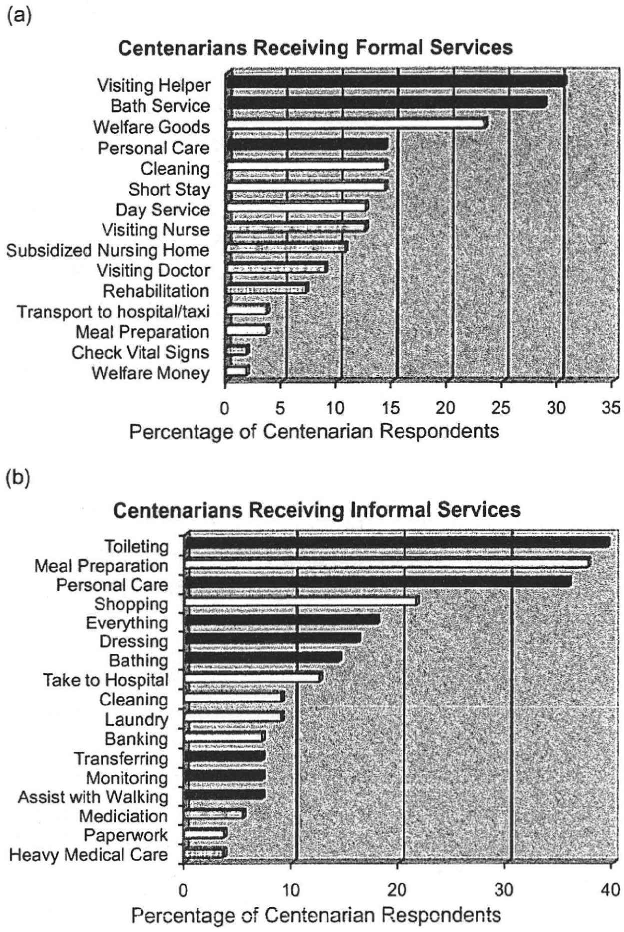

Figure 3 Percentage of centenarians who utilize various formal and informal services. (a) Percentage of indicated formal services including services subsidized by LTCI and privately paid services. (b) Percentage of centenarians receiving the indicated informal services. For both (a) and (b), categories of activities of daily living (ADL) services are denoted by closed bars, categories of instrumental activities of daily living (IADL) services denoted by open bars include day service (senior day care centers which provide various activities ranging from recreation and social activities for individuals with high ADL functioning to rehabilitation and bathing for individuals with lower ADL functioning), receive welfare goods (which include provision of subsidized care equipment such as automatic beds, raised toilet seats, wheelchairs, walkers and hand rails), short stay (which are limited duration programs which include overnight accommodation at a facility, primarily designed for caregiver relief, where the individual returns to their private home after a short period) and paperwork (paperwork related to coordination and payment of care services), and medically oriented services shown in vertically striped bars include subsidized nursing home (LTCI provides some money for institutional fees) and heavy medical care (tube drainage and tube feeding). Percentages of centenarian users are shown.

Discussion

Centenarians in the current study represent a diverse group of individuals ranging from functionally independent to completely dependent and comatose supporting previous research by Evert *et al.*[8] who categorized centenarians into three groups: delayers, escapers and survivors. Some centenarians in this study reported continuing to function autonomously suggesting possible escape from age-associated illnesses which would have limited their ability to continue IADL and supporting previous findings that dementia in centenarians is not inevitable.[9] Individuals who began receiving care after 92 years may have delayed the onset of age-associated illnesses supporting the compression of morbidity hypothesis[10] while others who live with various diseases or disorders may be survivors. Three centenarians reported receiving care for over 20 years, further suggesting the existence of centenarians who survive to advanced age while suffering from disease.

Male 90–99 year olds exhibited higher functional abilities than 80–89 year old and centenarian respondents suggesting that males who live longer are physically healthier than their female counterparts. This supports the gender cross-over phenomenon described by Ohrui *et al.*[11] suggesting that physically weaker males died at younger ages and only the physically strongest males are able to survive to advanced old age while females continue to survive with more physical impairments. The gender cross-over effect in this study peaks in 90–99 year olds and is greatly reduced among centenarians. Although centenarian males comprise the minority of centenarians, they continue to have higher BI and IADL scores than females. Interpretations of gender cross-over are limited, however, due to the small sample size of males aged 90–99 years old.

This study suggests, but due to the limited size of 90–99 year old males is unable to confirm, previous findings by Perls[12] that male centenarians tend to be better off than female centenarians in terms of physical functioning and that females seem to be physiologically stronger in old age and more likely than males to be able to live with chronic illnesses and disabilities.

While other studies have focused upon centenarians gathered on a certain date,[13] this was impossible in the present study due to the subject demographic collection methods in Japan. The principal investigator S. F. obtained centenarian and control subject data by manually searching over 1 million names printed in city registrar books stored at seven local city offices. This process took 3 months during which the registrar books were not updated.

In this study, two centenarians failed to qualify for LTCI services. By denying LTCI certification it is implied that the individual has high physical and mental abilities. However, the BI level of one of the centenarians denied certification is partially dependent and may suggest misevaluation. It is vital that measurement tools for LTCI eligibility be adjusted to effectively evaluate the centenarian population.

Multigenerational households are more prominent in Japan than other industrialized countries. In Japan, 8.5% of households are multigenerational[14] in contrast to 3% in Great Britain.[15] Multigenerational households may affect the lower levels of institutionalization found in this study as nearly 10% of centenarians in this study live in multigenerational housing. The New England Study found 27% of centenarians lived with family[16] compared to over 71% in this study. Sendai City reports a high proportion of family and multigenerational housing suggesting continuation of traditional cultural practices of aging parents living with their children. Although the rate of institutionalized Japanese centenarians in this study is much less than the 61% found in the New England study, only one centenarian reported living alone compared to 12% in the USA.[16] Low levels of institutionalization reported in this survey may also be affected by the inability of institutionalized care recipients to provide informed consent or refusal by families to report the institutionalization of a family member. In Japan, when a family member enters an institution it is common to keep the registered address as a private residential address and not to change it to an institutional address to avoid social stigmas and therefore it is possible that some of the questionnaires did not reach the elderly person due to incorrect addresses.

The recruitment of centenarians can be extremely difficult. In a study by Hirose *et al.*, of the approximately 1800 centenarians available for study, only 273 agreed to participate, representing a sample size of 15.2%.[17] Moreover, in a study by Shimizu *et al.*, only 22% of the total centenarians in Tokyo were included for study.[18] In contrast, this study reports a centenarian participation rate in Sendai City of 41.5%, double that of Shimizu *et al.*, and more than three times that of Hirose *et al.*[17,18]

The overall participation rate was expected due to multiple unavoidable factors including; high centenarian mortality rate, cognitively impaired individuals inability to provide informed consent, questionnaire length and the slow updating of city registrars.

Although every effort was made to minimize selection bias, it may be unavoidable due to methodological limitations of the questionnaire study protocol. Permission for this study from the Japanese Ministry of Justice and from Sendai City Office permitted only a one-time questionnaire and introduction letter to be sent to selected participants. The researchers were prohibited from contacting respondents by phone, in person visit or follow-up correspondence due to restrictions under Japanese law.

Data gathered may be limited in size and by response rate, however, these are an invaluable resource as this is the first study to provide insight into the situation of centenarians in northern Japan and is an excellent opportunity to increase understanding of how the oldest old utilize the new LTCI program.

In conclusion, centenarians represent a diverse group of individuals with distinctive needs. Centenarians can be classified into various groups suggesting numerous paths to attaining longevity. Gender cross-over, most prevalent among 90–99 year olds, decreased among centenarians. It is possible individuals have been misevaluated under the LTCI program and investigation is needed to determine if the LTCI system effectively assesses centenarians. This is the first in-depth look into the actual situation of community-dwelling oldest old in northern Japan examining functional ability and care service utilization.

By increasing understanding of the health needs of centenarians, government officials can target future health-care services to prepare for the increasing demands from this growing population. Future investigation of centenarians should focus upon the reasons for applying or not applying to LTCI, medical history, family and genetic profiles, and satisfaction with the health-care system.

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鈴木裕介

Geriatr Gerontol Int 2011

ORIGINAL ARTICLE

Physical and functional factors in activities of daily living that predict falls in community-dwelling older women

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Aim: In order to propose rehabilitation strategies for the reduction of falls risk, thereby preventing falls in older women, the present study was designed to explore the physical and functional factors related to actual incidence of falls.

Methods: Fifty-eight female patients aged 65 years and older (mean age ± standard deviation, 80.5 ± 5.7), who were attending a geriatric outpatient clinic participated. All the participants were assessed with their activities of daily living, gait and balance using various scales. Their handgrip strength and muscle strength of lower extremities were also measured using dynamometers. Falls of the participants during the 6 months follow-up period were recorded.

Results: Correlation analysis investigating associations between the scores of assessment scales and actual measurement of muscle strength and balance showed that there were significant correlations between handgrip strength and Falls Efficacy Scale, Functional Reach test, Timed Up and Go test, Berg Balance Scale, Motor Fitness Scale, motor Functional Independence Measure in fallers and non-fallers. A binary logistic stepwise regression analysis incorporating all the possible variables into the model revealed that only inability to "being able to go up and down the staircase" in the Motor Fitness Scale remained a significant variable to predict falls during the period of observation.

Conclusion: The results confirmed that the sub-item in the Motor Fitness Scale has a possibility of being a significant predictor of falls in older women, and therefore might prove useful in considering specific rehabilitation program on falls prevention as well as screening this population at risk of falls. **Geriatr Gerontol Int 2011; 11: ••–••.**

Keywords: activities of daily living, incidence of falls, physical performances, preventing falls, risk assessment of falls.

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Introduction

According to an estimate by the Ministry of Health, Welfare and Labor, there are approximately 1.7 million-bedridden older adults in Japan in 2010 and it will increase to 2.3 million in 2025.[1] Also, the survey showed that 12% of older adults in a bedridden state occurred as a consequence of falls and related injuries, which are the second greatest cause after stroke. While the incidence of stroke almost remained unchanged for the last 10 years, fractures are reported to have increased by 1.5 times during this decade.[2] In Japan, bedridden older persons remain a major medical and social problem. Greater attention should be directed to falling, because it is one of the direct causes of older persons becoming bedridden.

Falls are frequent and recurrent problems among older people and one of the major incidences that affect the activities of daily living (ADL) and quality of life (QOL). One in three persons over 65 years of age and almost half of those who were over 80 years of age reportedly fell at least once a year.[3] The chance of recurrent falls increases with advancing age and it was reported that 8–17% of those who were 75 years or older[3] sustained multiple falls.[3–6] The consequences of falls include hip fractures, soft tissue injuries,[7–10] fear of falling,[10] hospitalization, increased immobility and greater disability.[9] Furthermore, falls can lead to loss of self-confidence in one's ability to perform routine daily tasks, eventually relating to the occurrence of social withdrawal (sometimes termed "post-fall syndrome").[11]

Various risk factors of falls have been raised based on the results of both retrospective and prospective studies. These factors include age, number of chronic diseases, body composition, muscle strength, functional mobility and performance measures related to balance function.[12–14] Previous studies have shown that decreased muscle strength of lower extremities and the balance instability lead to the fall.[15] Most previous findings related to falls risk have been based on both clinical evaluation methods[16] and self-reported confidence to accomplish ADL, but not many of which were gained from the results of actual physical performance tests.[17]

Activities of daily living is a term commonly used in a wide spectrum of disciplines, and there are many factors that may contribute to ADL such as age, functional ability and balance in old age, but its definitions and conceptualization vary from health status to life satisfaction. Conventionally, various instruments such as the Barthel Index (BI)[18] and Functional Independence Measure (FIM)[19] had been used for the assessment of ADL.

Because falls and their consequences have a major impact on functional prognosis in the older population, rehabilitation programs, which aim to reduce the risk of falling by augmenting all contributing factors such as muscle strength, flexibility and balance, have the potential to both decrease the risk of falling and improve ADL of older adults.

It was confirmed that women had a higher risk of falling than men.[20] It has been speculated that there are various intrinsic factors that make women more prone to falls than men, such as history of osteoporotic fracture after menopause, self-confidence on falling, lower muscle strength and worse physical performances. Differences in muscle strength and body composition are known to exist between men and women, and from early adulthood on, women have, on average, 30–40% less muscle strength than men.[21]

In order to propose rehabilitation strategies for the reduction of falls risk, thereby preventing falls in older women, the present study was designed to explore physical and functional factors related to actual incidence of falls during a 6-month follow-up period.

Methods

Subjects

Female patients aged 65 years and older, who were attending the Geriatric Outpatient Clinic of Nagoya University Hospital, participated in this study. The study was performed according to the principles of the Declaration of Helsinki and approved by the Ethics Committee of Nagoya University School of Medicine, Japan, in December 2007.

Exclusion criteria were: (i) hospital admission within 6 months; (ii) uncontrolled hypertension; (iii) dementia (Mini-Mental State Examination [MMSE][22] ≤15); (iv) ischemic heart disease or heart failure; (v) chronic obstructive pulmonary disease; and (vi) acute orthopedic pain and presence of neurological impairments.

Prior to the data collection, a written informed consent was obtained from each patient participating. After having obtained informed consent, all subjects were instructed to complete a questionnaire. It was designed to assess the risk of falls by scoring, and had 22 questions[23] including one asking about history of falls in the previous year (full score, 22). Those who scored 6 and above were regarded as subjects at risk of falls,[24] and were included in the present study. Eventually, 58 female patients (mean age ± standard deviation, 80.5 ± 5.7 years) were subjected to analyses. (Fig. 1)

All the participants had their medical background obtained by asking existing or previous history of illness, type of drugs used, existing physical complaints and geriatric syndromes. All the participants were then subjected to assessments of ADL, gait and balance, and muscle strength. Detailed descriptions of the assessments are provided below.

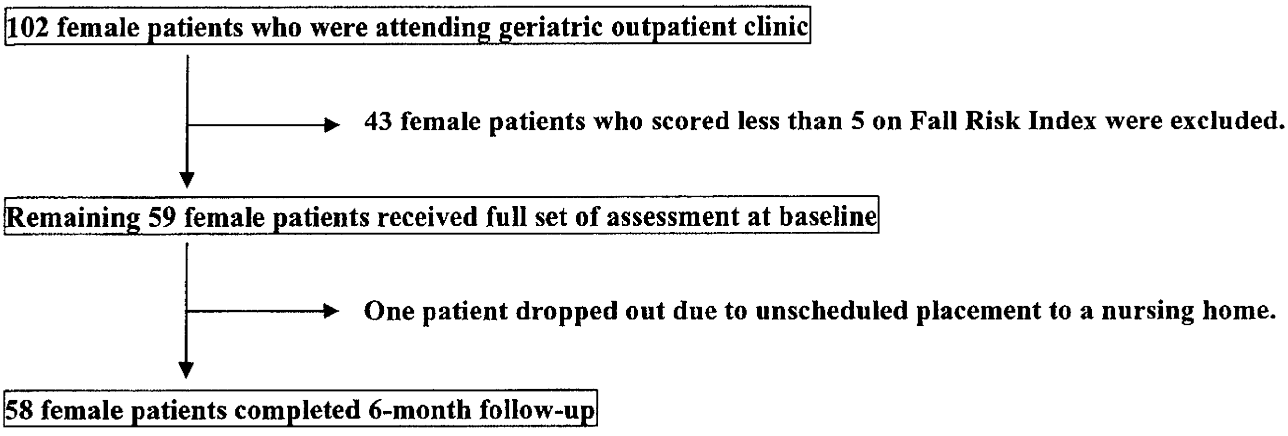

Figure 1 Flowchart showing the selection procedure of participants.

Assessment of ADL

The BI and FIM were used to assess ADL. Specific items in both scales are described elsewhere. In brief, BI is the most commonly used scale to assess one's basic ADL, and it consists of 10 items and scores range 0–100 points, with a higher score indicating greater ability. FIM is an 18-item, seven-level scale of independent performance in self-care, sphincter control, transfers, locomotion, communication and social cognition. The possible total score range from 18 (lowest) to 126 (highest level of independence).

Assessment of gait and balance

The Timed Up and Go test (TUG),[25] Functional Reach test (FR),[26] Berg Balance Scale (BBS)[27] and the Motor Fitness Scale (MFS)[28] were used to evaluate stability, balance and mobility of the participants. We adopted the BBS in the present study rather than the well-acknowledged Tinetti Balance and Gait Evaluation (Performance-Oriented Mobility Assessment [POMA])[29] because POMA is not suitable for analysis of slight differences, given the narrow range of scores in each item as previously suggested.[30]

The TUG test was designed as a quick measure of basic balance and mobility skill in elderly people. The time taken for subjects to rise from a chair, walk 3 m and return to the chair is measured in s, with a shorter time taken indicating better balance ability. Each subject was asked to perform two test trials. The mean score was recorded. The FR was designed to measure the limits of stability in an anterior direction. The score was determined by measuring the maximal distance that subjects can reach forward horizontally while maintaining a fixed base of support, with a greater distance indicating better balance ability. Two trials were performed and the mean score was recorded. The BBS was developed to measure balance impairments in elderly persons and people with neurological disorders. The scale consists of 14 common functional activities which are scored 0–4 (maximum score, 56). The MFS was created by totaling the scores for each item on the questionnaire, consisting of 14 items on motor fitness. This scale has a unidimensional structure with three subscales: mobility, strength and balance. In addition, all subjects were assessed on their postural sway, which was performed on a vertical force platform (Gravicorder GS-10 type C; ANIMA, Tokyo, Japan), fitted with three pressure gauges located in the corners. The subject was required to remain as stable as possible but relaxed, bipedal standing barefoot on the platform with the hands held hanging downwards in a neutral position, arms along the body and breathing normally, staring at a mark placed 2 m away, in a quiet room with artificial lightning. This test lasted 60 s and was performed with eyes open.

Evaluation of self-efficacy

Self-efficacy was evaluated using the Falls Efficacy Scale (FES).[31] The FES was designed to evaluate an individual's confidence in the ability to avoid a fall during each of 10 relatively non-hazardous ADL. The FES consists of questions related to the individual's concern about the possibility of falling when completing 10 specific daily living activities. Respondents are asked to identify, on a 10-point scale, how confident they feel of not falling when performing each activity, with 1 indicating extreme confidence and 10 indicating no confidence at all. The FES score was the sum of scores on each of the 10 activities. Possible scores range 10–100.

Measurement of muscle strength

The muscle strength in hip flexor, knee extensor, ankle extensor and flexor were measured using a hand-held dynamometer (EG-220; SAKAI, Tokyo, Japan) as the strength expressed in Newtons (N). No practice was allowed before measurements except that oral instruction was given prior to the trials. Only one attempt providing verbal encouragement was made for both sides, and the mean of both sides was used for analysis in order to dilute the influence of the dominant side. None of the participants had history of medical conditions that may affect muscle strength such as overt osteoarthritis or stroke.

The maximum grip strength of the dominant hand was recorded with a Smedley's dynamometer (Matsuyoshi, Nagoya, Japan), expressed in kg. Participants were allowed to rest between the tests as necessary. Time to complete the interview and testing procedures ranged 40–60 min.

Falls record

Based on a definition of falls as "an unintentional change in body position resulting in contact with the ground or with another lower level, however, not as a result of a major intrinsic event (e.g. stroke, syncope) or an overwhelming hazard (e.g. car accident)",[32] history of incident falls and their frequency in a previous year was obtained from all participants. Also, they were given a "falls diary" and were asked to record fall events at the time they occurred during the 6-month follow-up period. The diary was collected at the end of the follow-up period for counting the number of falls subjected for analysis. All falls were recorded by the participants or their informants.

Statistics

Statistical analyses were performed using PASW (ver. 18.0) to investigate the association between the parameters examined and actual incidence of falls. Continuous variables between fallers and non-fallers were compared using the Mann–Whitney *U*-test.

Bivariate correlations on the cross-sectional data in both groups (fallers and non-fallers) were assessed using Spearman's rank of order correlation analysis to investigate the association between the functional scales and muscle strength.

Bivariate odds ratios (OR) with their 95% confidence intervals (CI) of the physiological variables at baseline were calculated for fallers who were defined as those who fell at least once or more during the 6-month observation period versus non-fallers who were defined as those who did not fall during the 6-month observation period.

Before constructing a multivariable model for the prediction of falls, univariate analysis was performed across all the variables. They were combined in a binary logistic stepwise regression analysis in which fallers and non-fallers formed a group criterion.

All the medical and pharmaceutical information were supplied by participants' attending geriatricians, and all the assessments were carried out by the same physiotherapist.

Results

The characteristics of the participants at baseline and the results of group comparison for continuous variables and of logistic univariate analysis are presented in Table 1. There were no statistically significant differences in all the continuous variables examined between fallers and non-fallers by Mann–Whitney *U*-test (Table 1).

Correlation analysis investigating associations between the scores of assessment scales and actual measurement of muscle strength and balance showed that there were significant correlations between handgrip strength and FES, FR, TUG, BBS, MFS and motor FIM in fallers and non-fallers. On the other hand, while significant correlations were found between muscle strength of hip flexor, knee extensor and cognitive FIM in non-fallers, it was muscle strength of the ankle dorsiflexor and plantar flexor that were significantly correlated with cognitive FIM in fallers (Table 2).

Because we only had a limited number of variables that gained *P*-values less than generally acceptable for the entrance to multiple logistic models, variables that met the increased threshold *P*-values ($P < 0.3$) in the univariate analysis, which were FES, mean of antero-posterior sway, BBS and handgrip strength, and those of our interest, which were age, muscle strength (hip flexor, knee extensor, ankle dorsiflexor and plantar flexor), functional measures (FR, TUG), ADL scales (motor FIM, cognitive FIM, BI) and sub-items of MFS, were forced into a binary logistic regression analysis (Table 3). A binary logistic stepwise regression analysis incorporating all the possible variables into the model revealed that only inability to "to go up and down the staircase" in MFS remained a significant variable to predict falls during the period of observation (Table 4).

Discussion

In the current study, we explored the factors of physical performances and self-claimed assessment scales related to actual incidence of falls in older female patients who were attending a geriatric outpatient clinic. Because all the participants of the present study were attending the clinic due to chronic medical conditions, which may have increased the risk of falls, the results obtained cannot necessarily be generalized to healthy community-dwelling older adults.

The analysis showed that the sub-item in MFS "being able to go up and down the staircase" has a possibility of

Table 1 Descriptive characteristics at baseline and logistic regression univariate analysis between fallers (F: $n = 25$) and non-fallers (NF: $n = 33$)

Category	Variable	All ($n = 58$) proportion (%) or mean ± SD	F ($n = 25$) proportion (%) or mean ± SD	NF ($n = 33$) proportion (%) or mean ± SD	*P*-value*	OR	95% CI	*P*-value
General	Previous falls (%)	65.5%	72.0%	60.6%	0.370 n.s.	1.67	0.55–5.11	0.37
	Falls (follow up) (%)	43.1%	100.0%	0.0%		–	–	–
	Age (years)	80.5 ± 5.7	80.5 ± 4.9	80.6 ± 6.3	0.795 n.s.	0.98	0.90–1.08	0.77
	Body mass index (BMI) (kg/m^2)	22.8 ± 4.0	22.5 ± 4.3	23.1 ± 3.8	0.451 n.s.	0.96	0.84–1.10	0.55
Medical	Polypharmacy (%)†	6.7 ± 3.5	6.8 ± 3.9	6.5 ± 3.2	0.906 n.s.	1.03	0.88–1.19	0.75
Psychological	Falls Efficacy Scale (FES) (range 1–100)	30.5 ± 20.7	35.1 ± 24.6	26.9 ± 16.7	0.303 n.s.	1.02	0.99–1.05	0.14
	Cognitive FIM	32.7 ± 3.0	32.3 ± 3.5	32.9 ± 2.6	0.604 n.s.	0.93	0.78–1.12	0.46
Postural	Length (cm)	133.3 ± 54.0	138.7 ± 69.9	129.4 ± 39.5	0.974 n.s.	1.00	0.99–1.01	0.52
	Mean of mediolateral direction sway (cm)	0.08 ± 1.5	0.27 ± 0.9	-0.06 ± 1.8	0.265 n.s.	1.17	0.81–1.70	0.41
	Mean of anteroposterior direction sway (cm)	−1.94 ± 3.1	−1.0 ± 3.9	−2.6 ± 2.2	0.078 n.s.	1.26	0.98–1.63	0.07
	Functional Reach test (FR) (cm)	18.5 ± 8.2	17.9 ± 8.2	19.0 ± 8.2	0.741 n.s.	0.98	0.92–1.04	0.60
	Berg Balance Scale (BBS) (score)	39.4 ± 9.2	37.9 ± 10.5	40.5 ± 8.1	0.566 n.s.	0.97	0.92–1.03	0.29
Physical	Handgrip strength (kg)	13.9 ± 4.9	13.0 ± 4.9	14.6 ± 4.9	0.278 n.s.	0.93	0.84–1.04	0.22
	Hip flexion strength (N)	17.4 ± 6.8	17.6 ± 6.4	17.3 ± 7.1	0.783 n.s.	1.01	0.93–1.09	0.84
	Knee extension strength (N)	9.6 ± 4.5	9.8 ± 4.1	9.5 ± 4.8	0.671 n.s.	1.02	0.90–1.14	0.79
	Ankle dorsiflexion strength (N)	19.6 ± 5.4	19.4 ± 4.5	19.7 ± 6.1	0.994 n.s.	0.99	0.90–1.09	0.84
	Ankle plantar flexion strength (N)	22.9 ± 14.7	21.7 ± 11.8	23.9 ± 16.7	0.962 n.s.	0.99	0.95–1.03	0.57
	Timed Up and Go test (TUG) (s)	15.3 ± 8.4	16.0 ± 7.1	14.7 ± 9.4	0.227 n.s.	1.02	0.96–1.08	0.58
	Motor Fitness Scale (MFS) (range 1–14)	5.8 ± 3.6	5.2 ± 3.8	6.2 ± 3.4	0.347 n.s.	0.93	0.80–1.08	0.32
ADL	Barthel Index (BI) (score 0–100)	93.9 ± 9.1	92.8 ± 10.7	94.8 ± 7.7	0.404 n.s.	0.98	0.92–1.03	0.41
	Motor FIM	84.3 ± 8.6	83.0 ± 9.7	85.4 ± 7.7	0.267 n.s.	0.97	0.91–1.03	0.33

*Difference of continuous variables between fallers (F) and non-fallers (NF) by Mann–Whitney *U*-test. †Polypharmacy is defined as a state of patients who were taking more than five medications. CI, confidence interval; n.s., non-significant; OR, odds ratio; SD, standard deviation.

Table 2 Correlation analysis between fallers ($n = 25$) vs non-fallers ($n = 33$)

	Fallers ($n = 25$)/Non-fallers ($n = 33$)				
	Handgrip strength	Hip flexor	Knee extensor	Ankle dorsiflexor	Ankle plantar flexor
Falls Efficacy Scale	−0.600**/−0.437*	−0.165/−0.169	−0.201/−0.054	−0.319/−0.091	−0.278/−0.107
Functional Reach test	0.596**/0.526**	−0.134/0.258	−0.070/0.191	0.049/0.132	0.255/0.234
Timed Up and Go test	−0.466*/−0.689**	−0.204/−0.136	−0.011/−0.085	−0.300/−0.095	−0.371/−0.202
Berg Balance Scale	0.398*/0.650**	0.147/0.326	0.105/0.228	0.192/0.272	0.248/0.323
Motor Fitness Scale	0.619**/0.690**	0.052/0.057	0.034/0.008	0.099/−0.033	0.186/0.015
Cognitive FIM	0.273/0.356	0.175/0.481**	−0.132/0.370*	0.443*/0.238	0.677**/0.360
Motor FIM	0.622**/0.416*	−0.013/0.304	0.090/0.113	0.199/0.153	0.290/0.232
Barthel Index	0.095/0.289	−0.077/0.100	0.135/0.088	0.108/−0.156	0.291/0.019

*$P < 0.05$ **$P < 0.01$. Correlations between muscle strength of lower extremities and assessment scales were examined using Spearman's coefficient of correlation. FIM, Functional Independence Measure.

being a significant ADL predictor of falls. This finding has clinical relevance, given that many older women with poor physical performance have difficulties in going up and down the staircase, and many falls in fact occur during such movement. It also has important implications for clinicians in view of planning effective rehabilitation for the prevention of falls. In usual clinical settings, on the other hand, clinicians can be advised that asking the simple question of whether the patient has any difficulty in using the staircase or observation of actual movement using a step under careful supervision may both be considered for the initial risk assessment of falls.

From our results, MFS can be recommended as the functional assessment of choice for physiotherapists working with older women. The scale is easy to administer, requires no special equipment and is equally applicable to any older adults. Appropriate falls risk assessment could also have important implications for secondary prevention strategies, where the role of professional guidance of a physiotherapist may be crucial. First, this can be used as a screening tool for the identification of older women at risk of falling. Second, it also provides the necessary information to construct an individualized physical intervention program as it examines general muscle strength, balance, mobility and coordination. We believe in the importance of an individualized rehabilitation program based on the assessment of various domains of physical function in order to identify individual risk of falls for effective interventions.

Training for independence in bathing and climbing stairs was reported to be the most difficult during rehabilitation of the elderly with apoplexy.[33] Nonetheless, the present findings suggest the importance of offering rehabilitation aimed at maintaining the ability of actual daily movement for preventing falls or deterioration in physical function.

As shown by our results concerning the postural sway control, inadequate anteroposterior stability may be an important predictor of falls, which is in agreement with the findings of Shumway-Cook *et al.*[34] Diminished muscle strength and low physical performance may enforce the impairment of postural reflexes and increase the risk of falls. The ability to perform ADL is related to balance and potential falls in older people.[35,36]

The postural sway control research by Nashner and colleagues explored muscle patterns that underlie movement strategies for balance.[37]

The ankle strategy is the first pattern for controlling upright sway to be identified.[37] Muscle activity begins in the distal muscle, the tibialis anterior, followed by activation of the quadriceps femoris and abdominal muscles. Use of the ankle strategy requires muscle strength in the ankles.

Table 3 Binary logistic regression analysis to predict risk model of fallers ($n = 25$) vs non-fallers ($n = 33$)

	B	SE	*P*-value	OR	95% CI
Age	0.098	0.103	0.341	1.103	0.902–1.349
FES	0.046	0.040	0.249	1.047	0.969–1.131
Handgrip strength	−0.172	0.178	0.334	0.842	0.594–1.193
Hip flexion strength	0.095	0.165	0.563	1.100	0.797–1.518
Knee extension strength	−0.200	0.244	0.413	0.819	0.507–1.321
Ankle dorsiflexion strength	0.045	0.163	0.783	1.046	0.760–1.440
Ankle plantar flexion strength	−0.050	0.047	0.283	0.951	0.868–1.042
FR	0.059	0.110	0.593	1.061	0.854–1.317
TUG	−0.063	0.082	0.440	0.939	0.800–1.102
Motor FIM	0.022	0.125	0.861	1.022	0.801–1.305
Cognitive FIM	−0.001	0.235	0.996	0.999	0.630–1.538
BBS	−0.171	0.136	0.209	0.843	0.646–1.101
BI	0.076	0.096	0.430	1.079	0.893–1.303
MFS: Being able to go up and down the staircase	3.169	1.746	0.069	23.795	0.777–728.628
No breathlessness when taking staircase	1.399	1.016	0.168	4.053	0.553–29.691
Being able to jump	0.381	1.548	0.805	1.464	0.070–30.435
Being able to run	−3.149	1.703	0.064	0.043	0.002–1.208
Being able to overtake others while walking	2.183	1.383	0.115	8.869	0.589–133.490
Being able to walk for more than 30 min without break	−1.086	1.045	0.299	0.337	0.044–2.617
Being able to carry a bucket filled with water	0.703	1.355	0.604	2.019	0.142–28.745
Being able to lift a 10 kg bag of rice	−3.459	1.723	0.045	0.031	0.001–0.921
Being able to stand a fallen bicycle up	1.371	1.164	0.239	3.941	0.402–38.603
Being able to open the lid of a jar	−0.875	1.099	0.426	0.417	0.048–3.591
Being able to touch the floor without bending the knees	−0.495	1.013	0.625	0.610	0.084–4.443
Being able to wear trousers, socks or skirts without support while standing	−3.115	1.586	0.050	0.044	0.002–0.994
Being able to rise from a chair without support of hands	0.814	1.246	0.514	2.257	0.196–25.949
Being able to stand on toes without support	−1.406	1.278	0.271	0.245	0.020–3.000
Constant	−0.910	16.988	0.957	0.402	

Sub-items of Motor Fitness Scale entered as dichotomous variable "yes" or "no". B, regression coefficient; BBS, Berg Balance Scale; BI, Barthel Index; CI, confidence interval; FES, Falls Efficacy Scale; FR, Functional Reach test; MFS, Motor Fitness Scale; OR, odds ratio; SE, standard error; TUG, Timed Up and Go test.

Table 4 Risk model for the prediction of fallers versus non-fallers obtained by binary logistic stepwise regression ($n = 58$)

	B	SE	*P*-value	OR	95% CI
Being able to go up and down the staircase	1.715	0.859	0.046	5.559	1.031–29.963
Constant	−2.178	1.013	0.032	0.113	

B, regression coefficient; CI, confidence interval; OR, odds ratio; SE, standard error.

The study has also identified another in-place strategy for controlling body sway, the hip movement strategy. This strategy controls motion at the hip joints with anti-phase of the ankles.[37]

Cognition is defined as the ability to process, sort, retrieve and manipulate information.[38] A normally functioning cognitive system is critical to successful interaction with the environment. Thus, impairments in this system affect the patient's ability to move effectively and efficiently.

In this study, there were significant correlations between cognitive FIM and muscle strength of the hip flexor, knee extensor in non-fallers, which may imply that the hip strategy is used to restore equilibrium in response or perturbations when the support surface is smaller than the feet, making their muscles of hip and knee joints adjustable to sudden change of postures.

On the other hand, significant correlations were found between muscle strength of ankle dorsiflexor and plantar flexor and cognitive FIM in fallers.

This difference suggests that falls may tend to occur in those who are not capable of using the hip strategy for the initial perception of postural change.

As Daubney *et al.* tested, the ankle dorsiflexors were found to be the best predictor of falling.[39] During gait, the ankle dorsiflexors are involved, together with the hip and knee flexors, in lifting the lower limb during the swing phase to make sufficient clearance of the toes over the ground to prevent tripping. Taken together, lower extremity muscle strength may be an important predisposing factor in the pathogenesis of falls.

Going up and down the staircase is considered to depend mainly on functioning of the lower limbs, hence, the result that lower extremity muscle strength was not selected as significant variables in the logistic regression univariate analysis in the current study may be considered rather contradictory. A possible explanation as to why muscle strength in the lower extremities was not as predictive as handgrip strength might be found in the reliability of strength measures, which tend to be higher for handgrip strength than for leg strength when measured with a hand-held dynamometer, limiting somewhat the predictive value of leg muscle strength towards falling. Handgrip strength is correlated with muscle strength in the lower extremity,[40] and can therefore be a reliable measure of general muscle strength, as confirmed in a recent meta-analysis of prospective cohort studies.[41]

The relationship between reduction of muscle strength and difficulties in ADL may reflect an association with frailty and appears to be important in older women. When people withdraw from outdoor social contact, they become more susceptible to the negative effects of social isolation and physical inactivity.[17,42] The more activities that the older people avoid, the more difficulties they experience in doing these activities. Therefore, it is highly likely that avoidance of activities dramatically speeds up the process of physical frailty because of the devastating consequences of physical inactivity.[43] Avoidance of activities was not only related to the general status of physical frailty, but also to some specific components of physical function, including less muscle strength in the hip and knee, and less handgrip strength. Because the older people who avoid activities have decreased muscle strength, it is likely that they will experience limitations during activities such as shopping, going for a walk, walking around indoors and bending down to pick something up. This may further increase their feelings of insecurity and apprehension.

Maintenance of muscle strength throughout life reduces the prevalence of functional limitations that might closely relate to older persons.[44–47] It may also be expected to increase self-esteem and confidence in one's own abilities to perform physical activities, thereby avoiding social withdrawal. Increasing activity appears to be a simple and effective means of countering fall risk factors such as muscle weakness or functional limitations.

Limitations of the current study are as follows. First, there may be some uncertainties about the validity and reliability of self-reported falls even with a falls diary provided with sufficient instruction for use. The reliability of a fall questionnaire has been discussed by others,[48] and the discrepancy in this study confirms that there may be a recall bias. Therefore the variances in assessments may have affected the results. Second, the sample size was relatively small and the results shown in this study were obtained from a cross-sectional survey. The scale might perform differently in other populations. Longitudinal data are required to address this issue more carefully. Also, a longer period of intervention involving more participants would be warranted. Third, in the current study, subjects with significant depressive symptoms and those scoring lower than 15 on MMSE were excluded in order to endorse the reliability of a series of assessments and falls reports if they ever occurred. Although the physical performance in these subjects remains unknown, it is likely to substantially affect the outcomes if included. Lastly, lower extremity muscle strength was measured by a hand-held dynamometer, which may have resulted in inaccurate assessment of the muscle strength of the lower limbs in the current study. We assumed that the conflicting result we obtained in the present study might be due to a limitation other than small sample size and diverse background of the participants in that we used a hand-held dynamometer for measurements whose accuracy/test-retest reliability can possibly be questioned. The previous studies have reported some limitations of measuring muscle strength using a hand-held dynamometer as follows: consistency of the testing procedure,[49–51] patient effort,[50,52,53] degree of verbal inducements[51] and incentives.[49,53]

In conclusion, despite the limitations raised above, our findings indicate that a standard assessment of ADL may be a useful component in the risk assessment of falls in older women. The results confirmed that the sub-item in MFS has a possibility of being a significant predictor of falls in older women, therefore might prove useful in screening this population at risk of falls.

The results also permit further work investigating the individual effect of specific rehabilitation program on falls prevention in the older population.

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