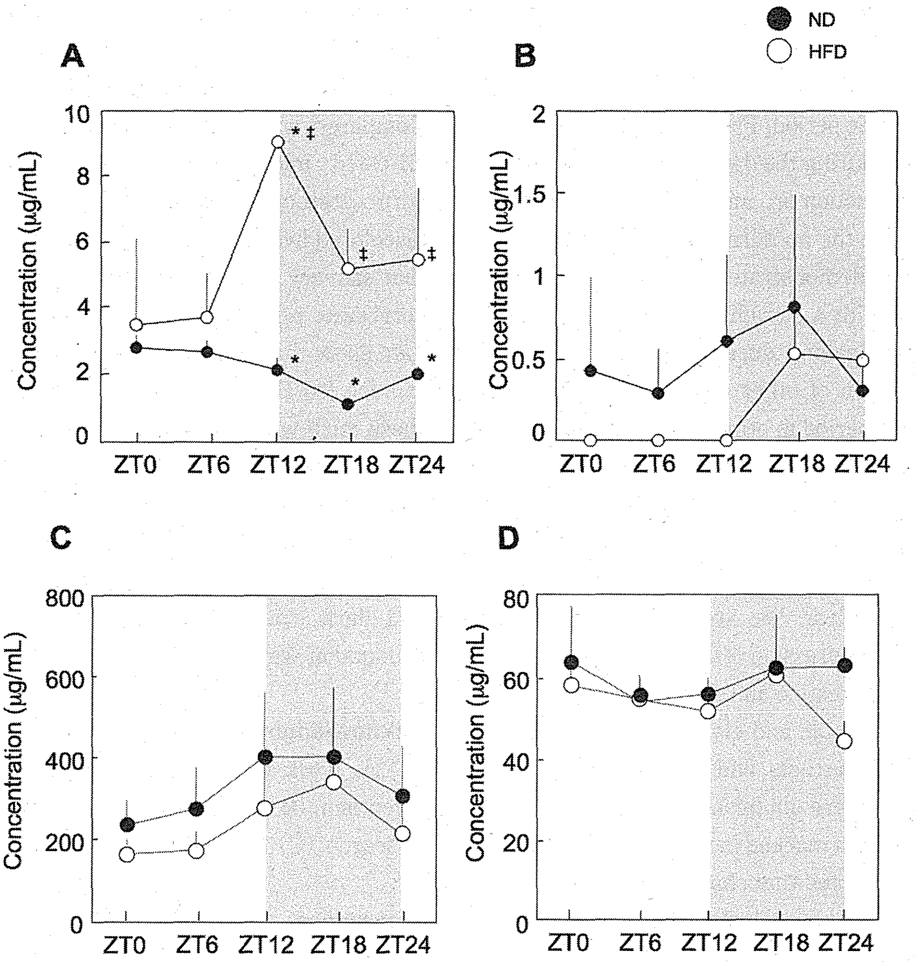

Fig. 5 Circadian fluctuation in S-IgA concentration in fecal extracts (A), saliva (B), plasma IgG (C), and plasma IgA (D) in BALB/c mice fed with HFD for 3 weeks. Concentration of isotype Abs was determined over a 24 hr period using samples collected at 6 hr intervals. Data are mean±SEM. n=6 mice per each time point. * $p<0.05$ vs ZT0, ‡ $p<0.05$ vs ND.

3A). In addition, levels of the stress-associated hormone corticosterone were significantly higher in HFD-fed mice than in ND-fed mice (Fig. 3B).

Feeding with HFD influences the fluctuations in S-IgA levels

To determine whether feeding of HFD affects the Ab isotype in mucosal secretions and plasma, we first analyzed S-IgA levels by ELISA. Significantly elevated levels of S-IgA were observed in FEs of mice fed HFD for 3 weeks (Fig. 4A). In contrast, levels of S-IgA in the saliva of these mice were similar to those in ND-fed mice (Fig. 4B). Moreover, decreased levels of IgG and IgA Abs were observed in HFD-fed mice (Fig. 4C, D). Our findings suggest that production of both IgA and IgG is influenced by dietary components, and we therefore next evaluated the effect of diet on rhythmic fluctuations in Ab levels. Compared with ND-fed mice, significantly elevated levels of S-IgA Ab were observed during the in-dark period (ZT12-ZT24) in FEs of HFD-fed mice. Importantly, markedly increased levels of S-IgA were observed at ZT12, as the transition point between dark and light periods (Fig. 5A). Furthermore, S-IgA was detected in saliva only during the dark period (ZT18-ZT24) in HFD-fed mice (Fig. 5B). In addition, comparable and similar fluctuations in IgG and IgA levels were observed in the plasma of both ND- and HFD-fed mice (Fig. 5C, D).

Discussion

We evaluated daily fluctuations in S-IgA levels in samples collected at 6-h intervals and found that the level of S-IgA in FEs and saliva of mice fluctuates with daily light and dark periods. Furthermore, feeding with HFD affects the daily fluctuations in Ab levels, particularly in mucosal secretions. These results are the first to show daily rhythmic fluctuations in Ab isotype. Notably, the level of S-IgA in FEs was significantly higher during the light period than during the dark period. In contrast, the level of S-IgA in saliva was elevated during the dark period. Plasma levels of both IgG and IgA also increased during the dark period. These results indicate that Ab production in mice follows a circadian rhythm, consistent with the nocturnal habits of mice.

Recent research has demonstrated that mRNA levels of clock genes fluctuate with a circadian rhythm in splenic B cells, with expression peaking during the dark period. In contrast, peak expression of other clock genes reportedly occurs during the light period in other lymphocytes, such as splenic macrophages and dendritic cells. We thus hypothesized that Ab-producing B cells are strictly regulated by clock genes (3, 5, 9, 15). Unfortunately, whether circadian oscillation of clock gene expression occurs in mucosal components remains unclear. We are therefore currently investigating light-dark expression of clock genes in mucosal components of both the intestine and salivary glands of mice. In HFD-fed mice, comparable and elevated Ab levels were observed in both fecal extracts and plasma. Importantly, levels of S-IgA in saliva were diminished in ZT0-ZT12. HFD feeding for 3 weeks led to a marked increase in S-IgA in FEs. Several groups have reported that changes in diet can affect the microbiota and immunoregulation (16). S-IgA production seems quite likely to be regulated by the intestinal environment. However, the precise mechanisms underlying bacterial modulation of the intestinal immune system have yet to be fully elucidated. *Bacteroides*, one of the major commensal bacteria in the murine intestinal microbiota, have been shown to influence IgA production in both the small and large intestine (17, 18). In the present study, significant daily rhythmic fluctuations in specific Ig isotype levels were observed in FEs from HFD-fed mice. Interestingly, dramatically enhanced S-IgA production was observed during the in-dark period, suggesting that the change in circadian rhythm of S-IgA concentration could be due to dysbiosis in these mice. The mechanisms by which the gut microflora affect host homeostasis are not well understood. Modification and fluctuation of the gut microflora may indicate disruption of host homeostasis, as homeostasis and the gut microflora may be correlated. However, our analysis of S-IgA productions revealed that diet created distinct intestinal conditions that may influence immune responses.

Generally, corticosterone is known as a stress maker for physical and mental-related conditions. We therefore performed morphological and immunochemical study to determine the consequences of HFD on body condition. Compared with ND-fed mice, our data clearly show that HFD-fed mice developed significantly higher level of corticosterone in plasma along with a hypertrophic and discolored liver. Importantly, recent studies have suggested that salivary IgA represents a potential stress marker and correlates negatively with stress conditions (19-21). Our data show that similar levels of salivary IgA were detected in mice fed HFD for 3 weeks, even though salivary IgA in these mice was diminished in the light period (ZT0-ZT12), suggesting that HFD-fed mice show stress condition compared to ND-fed mice.

In conclusion, productions of immunoglobulin in both plasma and mucosal secretion were dependent on 24-h light and dark cycles. Moreover, these fluctuations in S-IgA production were clearly influenced by diet.

Acknowledgments

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References

1. Mohawk JA, Green CB, Takahashi JS: Central and peripheral circadian clocks in mammals. Annu Rev Neurosci, 35: 445-462, 2012.
2. Roberts JE: Light and immunomodulation. Ann N Y Acad Sci, 917: 435-445, 2000.
3. Arjona A, Sarkar DK: Circadian oscillations of clock genes, cytolytic factors, and cytokines in rat NK cells. J Immunol, 174: 7618-7624, 2005.
4. Esquifino AI, Selgas L, Arce A, Maggiore VD, Cardinali DP: Twenty-four-hour rhythms in immune responses in rat submaxillary lymph nodes and spleen: effect of cyclosporine. Brain Behav Immun, 10: 92-102, 1996.
5. Arjona A, Sarkar DK: The circadian gene mPer2 regulates the daily rhythm of IFN-gamma. J Interferon Cytokine Res, 26: 645-649, 2006.
6. Holzheimer RG, Curley P, Saporoschetz IB, Doherty JM, Mannick JA, Rodrick ML: Circadian rhythm of cytokine secretion following thermal injury in mice: implications for burn and trauma research. Shock, 17: 527-529, 2002.
7. Petrovsky N, Harrison LC: The chronobiology of human cytokine production. Int Rev Immunol, 16: 635-649, 1998.
8. Hayashi M, Shimba S, Tezuka M: Characterization of the molecular clock in mouse peritoneal macrophages. Biol Pharm

Bull, 30: 621-626, 2007.
9. Silver AC, Arjona A, Hughes ME, Nitabach MN, Fikrig E: Circadian expression of clock genes in mouse macrophages, dendritic cells, and B cells. Brain Behav Immun, 26: 407-413, 2012.
10. Woof JM, Kerr MA: The function of immunoglobulin A in immunity. J Pathol, 208: 270-282, 2006.
11. van Ginkel FW, Jackson RK, Yoshino N, Hagiwara Y, Metzger DJ, Connell TD, Vu HL, Martin M, Fujihashi K, McGhee JR: Enterotoxin-based mucosal adjuvants alter antigen trafficking and induce inflammatory responses in the nasal tract. Infect Immun, 73: 6892-6902, 2005.
12. Kobayashi R, Kohda T, Kataoka K, Ihara H, Kozaki S, Pascual DW, Staats HF, Kiyono H, McGhee JR, Fujihashi K: A novel neurotoxoid vaccine prevents mucosal botulism. J Immunol, 174: 2190-2195, 2005.
13. Kataoka K, McGhee JR, Kobayashi R, Fujihashi K, Shizukuishi S: Nasal Flt3 ligand cDNA elicits CD11c+CD8+ dendritic cells for enhanced mucosal immunity. J Immunol, 172: 3612-3619, 2004.
14. Sekine S, Kataoka K, Fukuyama Y, Adachi Y, Davydova J, Yamamoto M, Kobayashi R, Fujihashi K, Suzuki H, Curiel DT, Shizukuishi S, McGhee JR: A novel adenovirus expressing Flt3 ligand enhances mucosal immunity by inducing mature nasopharyngeal-associated lymphoreticular tissue dendritic cell migration. J Immunol, 180: 8126-8134, 2008.
15. Keller M, Mazuch J, Abraham U, Eom GD, Herzog ED, Volk HD, Kramer A, Maier B: A circadian clock in macrophages controls inflammatory immune responses. Proc Natl Acad Sci U S A, 106: 21407-21412, 2009.
16. Wiśniewski JR, Friedrich A, Keller T, Mann M, Koepsell H: The Impact of High-Fat Diet on Metabolism and Immune Defense in Small Intestine Mucosa. J Proteome Res, 14: 353-365, 2014.
17. Yanagibashi T, Hosono A, Oyama A, Tsuda M, Suzuki A, Hachimura S, Takahashi Y, Momose Y, Itoh K, Hirayama K, Takahashi K, Kaminogawa S: IgA production in the large intestine is modulated by a different mechanism than in the small intestine: Bacteroides acidifaciens promotes IgA production in the large intestine by inducing germinal center formation and increasing the number of IgA + B cells. Immunobiology, 218: 645-651, 2013.
18. Yanagibashi T, Hosono A, Oyama A, Tsuda M, Hachimura S, Takahashi Y, Itoh K, Hirayama K, Takahashi K, Kaminogawa S: *Bacteroides* induce higher IgA production than *Lactobacillus* by increasing activation-induced cytidine deaminase expression in B cells in murine Peyer's patches. Biosci Biotechnol Biochem, 73: 372-377, 2009.
19. Guéguinou N, Bojados M, Jamon M, Derradji H, Baatout S, Tschirhart E, Frippiat JP, Legrand-Frossi C: Stress response and humoral immune system alterations related to chronic hypergravity in mice. Psychoneuroendocrinology, 37: 137-147, 2012.
20. Deinzer R, Schüller N: Dynamics of stress-related decrease of salivary immunoglobulin A (sIgA): relationship to symptoms of the common cold and studying behavior. Behav Med, 23: 161-169, 1998.
21. Ng V, Koh D, Chan G, Ong HY, Chia SE, Ong CN: Are salivary immunoglobulin A and lysozyme biomarkers of stress among nurses? J Occup Environ Med, 41: 920-927, 1999.
22. Wetherell MA, Hyland ME, Harris JE: Secretory immunoglobulin A reactivity to acute and cumulative acute multi-tasking stress: relationships between reactivity and perceived workload. Biol Psychol, 66: 257-270, 2004.

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ORIGINAL ARTICLE: EPIDEMIOLOGY, CLINICAL PRACTICE AND HEALTH

Construct validity of posture as a measure of physical function in elderly individuals: Use of a digitalized inclinometer to assess trunk inclination

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Aim: The first aim of the present study was to determine the construct validity of evaluating posture as a measure of physical function in elderly individuals. The second aim was to determine reference values for sternum inclination in elderly individuals when measured using a digitalized inclinometer.

Methods: We included 834 community-dwelling elderly individuals (350 men and 484 women) in this study. We used a digital inclinometer for measuring sternum inclination angle. We evaluated physical functions, including muscle strength, static balance, gait ability and the functional mobility of our study participants. To assess the construct validity of sternum inclination in elderly people, Pearson's correlation coefficient between sternum inclination and participant characteristics was calculated. To determine a reference value of sternum inclination by age, *P* for trend was calculated.

Results: In men, the sternum inclination angle and sternum inclination index were significantly associated with all anthropometric measures, except static balance. In women, the sternum inclination index was significantly associated with all measures, whereas the sternum inclination angle was associated with all measures except for balance and the Timed Up and Go test. Trend of sternum inclination index by age was significant.

Conclusions: Our results show that the sternum inclination as a measure of physical function in elderly men and women has construct validity. We determined reference values for sternum inclination of which trend by age was considered. **Geriatr Gerontol Int ••; ••: ••–••.**

Keywords: construct validity, elderly individuals, inclinometer, posture, trunk inclination.

Introduction

Elderly people often assume that a forward bending posture is an excessive anterior concavity of the thoracic spine. Age-related hyperkyphosis affects an estimated 20–40% of elderly individuals.[1,2] Kyphosis is common among elderly people, and the degree of hyperkyphosis is thought to be related to an increase in age. Kyphosis increases the risk of fracture and mortality,[2] and it is associated with impaired physical performance,[3] health and quality of life.[4] Furthermore, hyperkyphosis is associated with physical function, including muscle strength,[3,5] balance,[3] gait ability,[3,6–9] activity of daily living (ADL) and self-reported physical activity.[5] It is thought that the evaluation and intervention strategies to conserve posture could have a beneficial effect on care prevention. However, several studies have reported a negative association between kyphosis and physical activity.[10,11] The association between hyperkyphosis, physical function and physical activity is not yet fully understood.

Studies carried out, thus far, have used various methods to evaluate kyphosis. Radiography, which is considered the gold standard method for assessing the degree of kyphosis, was used in some studies, but this method is limited by the need for radiography. The Debrunner kyphometer and flexicurve ruler are often available in clinical settings, but these methods evaluate spinal alignment during standing rather than trunk

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forward bending posture, and it is also not possible to measure the inclination of trunk forward bending using these instruments. In their study, Kamitani *et al.* used a computer-assisted device for measuring spinal shape, named the Spinal Mouse, and found that spinal inclination in elderly people, but not thoracic curvature, lumber curvature and sacral-hip angle, was associated with future dependence for ADL.[12]

Recently, inclinometers have been used for the evaluation of posture. Inclinometers are easy to use and a relatively inexpensive tool for measuring trunk inclination in elderly individuals in a standing posture. MacIntyre *et al.* found a significant association between physical function and activity and spine inclination whose measurement was used with inclinometer for elderly individuals in a standing posture. Furthermore, the inclination of the thoracic standing posture was associated with both ADL and the Timed Up and Go (TUG) test.[13] In contrast, validity, between sternum inclination used with an inclinometer and trunk inclination analyzed with a photograph of the sagittal plane, had been tested in a previous study.[14] The detection of sternum inclination was easier than the spinal landmark; for example, the interspace between the 12th thoracic vertebra and the first lumbar vertebra. The association between measurements by a physical and occupational and speech therapist had a high correlation coefficient. The evaluation whose detection of landmarks was easy might have wide clinical application. However, the relationship between posture measured using digital inclinometers and physical function is not yet clear, and the construct validity of the evaluation of posture using a digital inclinometer in elderly individuals in a standing posture is not known.

Therefore, the first aim of the present study was to determine the construct validity of evaluating posture as a measure of physical function in elderly individuals. We evaluated posture by measuring sternum inclination in standing individuals, using a digitalized inclinometer. The second aim of the present study was to determine reference values for sternum inclination in elderly individuals when measured using a digitalized inclinometer.

Methods

Participants

In the present study, we analyzed data of 834 participants of "*Itabashi Cohort Study 2011*" who were able to receive all health checkups: 350 men with a mean ± SD age, height, and weight of 73.7 ± 5.5 years, 163.5 ± 6.1 cm and 50.8 ± 7.9 kg, respectively, and 484 women with a mean age, height, and weight of 72.7 ± 4.9 years, 150.5 ± 5.6 cm and 50.8 ± 7.9 kg, respectively.

Itabashi Cohort Study 2011 (New Otassya Examination 2011). In the ITABASHI11 study, 7162 residents aged 65–84 years living in nine residential areas surrounding the Tokyo Metropolitan Institute of Gerontology were recruited in 2011. After excluding 463 people who were institutionalized or overlapped from previous studies, 6699 invitations for health checkups were sent out. In October 2011, 913 ambulatory residents received health checkups (participation rate 13.6%).

All participants provided written informed consent. The present study was approved by the institutional review board and ethics committee of the Tokyo Metropolitan Institute of Gerontology.

Posture evaluation

To evaluate standing posture, the inclination angle of the trunk was measured using a digital inclinometer (Horizon; Yuki Trading, Inc. Tokyo, Japan; Fig. 1). This

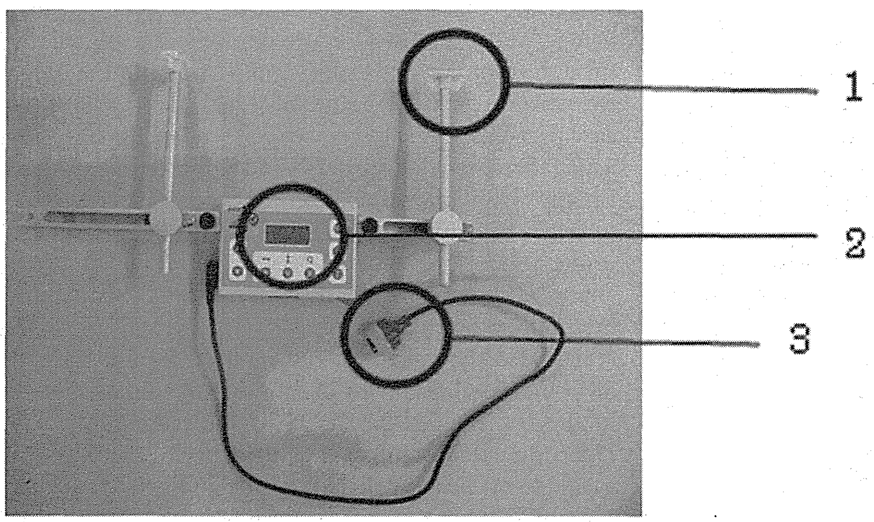

Figure 1 Digital inclination meter for evaluating sternum inclination in standing position. The digital inclinometer used in the present study is shown, and each component of the device is shown. 1. Arm for indicating anatomical landmarks. 2. Display for showing the result. 3."HOLD" button for capturing the inclination angle.

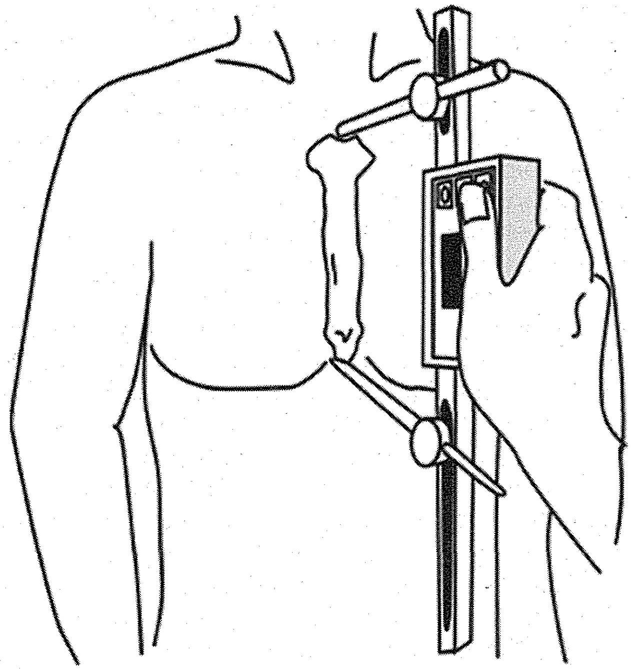

Figure 2 Evaluation of the sternum inclination with a digital inclination meter. Use of the digital inclinometer is shown. 1. Ask subject for standing posture. 2. Indicate anatomical landmarks by two arms. 3. Push the "HOLD" button to capture the trunk inclination angle. 4. Show result on display.

instrument has two arms that are placed on anatomical landmarks when the inclination angles of the trunk are measured. Measures that were taken include the forward inclination angles of the trunk in a standing posture. The instructor responsible for measuring the inclination angle of the trunk placed the two arms of the digital inclinometer on two anatomical landmarks as follows: the forward inclination angle of the trunk was measured using the superior and inferior margins of the sternum as landmarks (Fig. 2). Measurements were accurate to 1°. Because the digital inclinometer measured the inclination of the sternum, we calculated a sternum inclination index according to Equation 1:

$$\text{trunk inclination index} = \frac{\text{trunk inclination angle}}{\text{BMI}} \quad (1)$$

Measurements of physical function

To assess the construct validity of sternum inclination, we assessed physical functions, including muscle strength, static balance, gait ability and the functional mobility of our study participants.

To evaluate muscle strength, grip strength and knee extension torque were measured using a handheld dynamometer. For grip strength measurements, participants were asked to stand with their arms hanging naturally by their sides and the grip size of the dynamometer was adjusted so that participants could hold it comfortably in their dominant hand. Participants were then asked to squeeze the dynamometer with maximal strength. Grip strength was measured only once for each participant. For knee extension torque measurements, participants were asked to sit on a chair with their arms crossed over their chest and the length of a participant's lower thigh was measured for the torque calculation. The handheld dynamometer was then fastened on the ankle of the dominant leg and participants were asked to extend their knee as far as possible.

To evaluate static balance, participants were asked to stand with their hands on their waist and then to lift one leg, while keeping their eyes open and fixed on a mark on the wall in front of them. Participants were asked to stand on one leg for as long as possible. The one-leg standing time was measured until they lost their balance or until they achieved 60 s. The one-leg standing measurement was carried out during two trials, and the longest time was recorded.

To evaluate gait ability, the 10-m gait time was measured. Participants were asked to walk at a comfortable and then at fast speed on a 10-m gait course that consisted of acceleration and deceleration phases of 3 m each. A participant's comfortable gait speed was measured once. Maximum gait speed was measured twice, and the faster of the two measurements was recorded.

The TUG test was used to evaluate functional mobility. Participants were asked to sit upright and with their backs against the back of a chair that had arms. A marker was placed on the floor 3 m away from the chair and participants were asked to stand up from the chair, to walk to and around the marker, and then to walk back to the chair and to sit in the chair as fast as possible, once the instructor had given the "Go" command. Participants carried out the TUG test twice and the fastest of the times was recorded.

Statistical analysis

Construct validity requires one or more predefined hypotheses, and a positive rating for construct validity is given if 75% of the results in a group of at least 50 participants correspond with such a hypothesis.[15]

Based on a previous study, we hypothesized that the sternum inclination or sternum inclination index would be greater in elderly individuals who were: (i) older; (ii) had weaker muscle strength; (iii) had lower static balance; (iv) had lower gait ability; and (v) had lower functional mobility. We defined grip strength and knee extension torque as muscle strength, one-leg standing with open eyes as static balance, the 10-m gait time (comfortable and fast pace) as gait ability and the TUG as functional mobility.

To assess the construct validity of sternum inclination in elderly people, Pearson's correlation coefficient between sternum inclination and participant characteristics was calculated. To determine a reference value of sternum inclination by age, participants were categorized as follows according to their age: 65–69 years, 70–74 years, 75–79 years, 80–84 years and older than 85 years. *P* for trend was calculated. All data were analyzed with SPSS 19.0 (IBM Japan, Tokyo, Japan).

Results

The demographic characteristics of participants are summarized in Table 1. The associations between sternum inclination and various anthropometric measures are summarized in Table 2. In men, the sternum inclination angle was significantly associated with every anthropometric measure except for balance; therefore, we rejected the associated hypothesis, but accepted all the other hypotheses. In women, the sternum inclination angle was significantly associated with every anthropometric measure except for balance and TUG; therefore, we rejected hypotheses (i) and (v), but accepted the other hypotheses. In men, the sternum inclination index was significantly associated with every anthropometric measure except for balance. We therefore rejected hypothesis (iii), but accepted all the other hypotheses. In women, the sternum inclination index was significantly associated with all anthropometric measures, and we could therefore accept all of the related hypotheses.

In both men and women, the correlation coefficient between the sternum inclination angle as well as the sternum inclination index and body mass index (BMI) was significantly stronger than that for any other characteristic. As a reference value, trends of sternum inclination by age are shown in Table 3. In both men and women, the sternum inclination angles increased as the age increased from 65–69 years to 80–84 years ($P < 0.01$). Similarly, in both men and women, the sternum inclination index increased as the age increased from 65–69 years to 80–84 years ($P < 0.01$).

Table 1 Characteristics of participants in this study

	Men	Women
n	350	484
Age (years)	73.7 ± 5.5	72.7 ± 4.9
Height (cm)	163.5 ± 6.1	150.5 ± 5.6
Body weight (kg)	63.3 ± 9.4	50.8 ± 7.9
Body mass index	23.7 ± 3.0	22.5 ± 3.5
Grip (kg)	31.1 ± 7.1	19.3 ± 4.7
Lower strength (kgf · m)	92.6 ± 26.9	61.5 ± 17.5
One leg stance (s)	37.2 ± 23.7	45.5 ± 21.4
10-m gait time (s)		
Normal	7.7 ± 1.7	7.8 ± 2.3
Fast	5.1 ± 1.3	5.6 ± 1.7
TUG (s)	5.4 ± 2.1	6.0 ± 3.3

Discussion

The aim of the present study was to test the construct validity of posture as an indication of physical function in elderly individuals. Posture was assessed using a digital inclinometer to measure the sternum inclination of elderly individuals in a standing posture. The construct validity of the sternum inclination angle and

Table 2 Association between trunk inclination and participant characteristics

	Men						Women					
	Trunk inclination angle			Trunk inclination index			Trunk inclination angle			Trunk inclination index		
	n	*r*	*P*-value	*n*	*r*	*P*-value	*n*	*r*	*P*-value	*n*	*r*	*P*-value
Age (years)	350	0.21	<0.01*	346	0.19	<0.01*	484	0.19	<0.01*	481	0.21	<0.01*
Height (cm)	350	0.02	0.73	346	0.01	0.85	484	0.02	0.70	481	−0.07	0.15
Body weight (kg)	346	−0.44	<0.01*	346	−0.23	<0.01*	481	−0.50	<0.01*	481	−0.23	<0.01*
BMI	346	−0.53	<0.01*	346	−0.28	<0.01*	481	−0.52	<0.01	481	−0.21	<0.01*
Grip (kgf)	335	−0.16	<0.01*	331	−0.12	<0.05*	458	−0.17	<0.01*	456	−0.17	<0.01*
Leg strength (kgf/m)	332	−0.25	<0.01*	328	−0.21	<0.01*	452	−0.31	<0.01*	450	−0.29	<0.01*
One-leg stand (s)	348	0.01	0.91	344	−0.02	0.70	483	−0.03	0.46	480	−0.14	<0.01*
10-m gait time (s)												
Normal	343	0.25	<0.01*	339	0.30	<0.01*	476	0.09	<0.01*	473	0.19	<0.01*
Fast	333	0.20	<0.01*	329	0.25	<0.01*	457	0.09	0.05	455	0.16	<0.01*
TUG (s)	332	0.26	<0.01*	328	0.30	<0.01*	455	0.02	0.61	453	0.11	0.02*

*Significance of Pearson's correlation coefficient ($P < 0.05$)

Table 3 Trends of the trunk inclination angle and index by the age categories

Age (years)	Trunk inclination angle (degrees)		Trunk inclination index		Trunk inclination angle (degrees)		Trunk inclination index	
	n	mean ± SD	*n*	mean ± SD	*n*	mean ± SD	*n*	mean ± SD
65–69	97	−15.1 ± 6.2	96	−0.62 ± 0.23	143	−17.3 ± 6.8	142	−0.76 ± 0.26
70–74	95	−15.2 ± 6.6	94	−0.61 ± 0.23	167	−16.3 ± 6.6	167	−0.72 ± 0.26
75–79	92	−12.4 ± 6.2	92	−0.53 ± 0.26	136	−14.9 ± 7.3	135	−0.65 ± 0.29
80–84	59	−12.2 ± 7.1	57	−0.53 ± 0.29	34	−13.4 ± 7.3	33	−0.59 ± 0.29
85–	7	−11.1 ± 6.3	7	−0.49 ± 0.27	4	−9.3 ± 5.6	4	−0.42 ± 0.22
P-value		0.001*		0.002*		<0.001*		<0.001*

*Significance of trend ($P < 0.01$)

the sternum inclination index was assessed in relation to age, muscle strength, static balance, gait ability and functional mobility. There was sufficient evidence to prove construct validity of the truck inclination angle as an indicator of muscle strength, gait ability and functional mobility in men, but not in women. Furthermore, Pearson's correlation coefficient between the sternum inclination angle and BMI was significantly stronger than that for other characteristics, and it was evident that the sternum inclination angle is affected the most by BMI. Although the sternum inclination angle is related to age and physical function, it was thought that posture evaluation should be independent of the physical frame. We also assessed the construct validity of the sternum inclination index, which was adjusted by BMI. Our findings also supported construct validity of the sternum inclination index as a measure of physical function in both men and women.

In a previous study, it was shown that thoracic inclination measurement with a digital inclinometer had a higher association with physical function and ADL.[13] However, the sample size was insufficient to allow for definite conclusions regarding the associations. In the present study, although we measured not spine inclination, but sternum inclination, we assessed an association between sternum inclination and several physical functions with sufficient sample size. It was shown that sternum inclination significantly associated physical functions. Furthermore, detecting landmarks for measurement of sternum inclination was easier than detecting lumber or thoracic spine. We were able to clearly show that measurement with a digital inclinometer was available.

A digital inclinometer was able to measure sternum inclination in a standing posture for evaluation of trunk inclination. Trunk inclination was able to be measured with a computer-assisted device; for example, Spinal Mouse and so on. It was shown that spinal inclination measured with a Spinal Mouse was associated with future dependence of ADL.[12] However, to show the result, we needed to analyze the data with a personal computer and software. A simple image analysis system using a personal computer and digital camera was also able to measure trunk inclination, but approximately 5–10 min was spent achieving the result. It was not popular that the computer-assisted device or simple image analysis system was used readily in a clinical setting. The digital inclinometer used in the present study was able to measure trunk inclination easily. The evaluation with this device took less than 1 min, including measurement and procedure for the inclinometer, to show a result. Therefore, the methods to evaluate sternum inclination in the present study had usability.

Further reference values for sternum inclination by age group were reported in the present study. The reference value would help therapists assess the measurement value in clinical practice. Although the importance of thoracic inclination was reported, the reference value had never been shown in previous studies with inclinometers.[12,13] In the present study, in both men and women, the sternum inclination angles and sternum inclination indexes increased as the study population aged; and the reference value for sternum inclination in elderly people was shown according to age group. Therefore, the reference value according to age would be clinically useful for assessment of whether subjects had normal posture or not. The evaluation used in the present study would be a method with wide clinical application.

In several studies, the association between excessive kyphosis and physical performance had been researched.[4] Kado *et al.* showed that hyperkypotic posture of older adults, some of whom had activity limitations, was associated with physical function.[5] MacIntyre *et al.* showed in a study of self-independent participants that inclinometer-based measures of standing posture were not associated with ADL.[13] Because, in these studies, the participants were elderly with hyperkyphosis or with limitation of abilities of daily living, the association between standing posture of self-independent subjects and their physical function was unclear. However, the posture evaluation used in the present study had an association with the physical function of self-independent subjects. Therefore, this posture evaluation with a trunk inclination meter would be applicable as a health check in care prevention projects for community-dwelling elderly individuals who did not have limitations of ADL.

As conclusion, posture evaluation with a digital inclinometer was certainly available, usable and had a reference value. The evaluation method could be used in wide clinical application.

We did not assess the association between sternum inclination and ADL, physical activity or future adverse events in elderly individuals. Therefore, our reference values should not be used as a diagnostic method, but they should rather be used for the evaluation of age-related changes in an individual. The association between spinal inclination and sternum inclination was also unclear. The evaluation for posture with the measurement of sternum inclination is a new method. Future studies to assess the association between sternum inclination and ADL, nursing care, future adverse events, spinal inclination and so on should be considered.

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References

1 Kado DM, Huang MH, Karlamangla AS, Barrett-Connor E, Greendale GA. Hyperkyphotic posture predicts mortality in older community-dwelling men and women: a prospective study. *J Am Geriatr Soc* 2004; **52**: 1662–1667.
2 Takahashi T, Ishida K, Hirose D *et al.* Trunk deformity is associated with a reduction in outdoor activities of daily living and life satisfaction in community-dwelling older people. *Osteoporos Int* 2005; **16**: 273–279.
3 Sinaki M, Brey RH, Hughes CA, Larson DR, Kaufman KR. Balance disorder and increased risk of falls in osteoporosis and kyphosis: significance of kyphotic posture and muscle strength. *Osteoporos Int* 2005; **16**: 1004–1010.
4 Katzman WB, Wanek L, Shepherd JA, Sellmeyer DE. Age-related hyperkyphosis: its causes, consequences, and management. *J Orthop Sports Phys Ther* 2010; **40**: 352–360.
5 Kado DM, Huang MH, Barrett-Connor E, Greendale GA. Hyperkyphotic posture and poor physical functional ability in older community-dwelling men and women: the rancho bernardo study. *J Gerontol A Biol Sci Med Sci* 2005; **60**: 633–637.
6 Ryan SD, Fried LP. The impact of kyphosis on daily functioning. *J Am Geriatr Soc* 1997; **45**: 1479–1486.
7 Hirose D, Ishida K, Nagano Y, Takahashi T, Yamamoto H. Posture of the trunk in the sagittal plane is associated with gait in community-dwelling elderly population. *Clin Biomech (Bristol, Avon)* 2004; **19**: 57–63.
8 Lombardi I Jr, Oliveira LM, Monteiro CR, Confessor YQ, Barros TL, Natour J. Evaluation of physical capacity and quality of life in osteoporotic women. *Osteoporos Int* 2004; **15**: 80–85.
9 Antonelli-Incalzi R, Pedone C, Cesari M, Di Iorio A, Bandinelli S, Ferrucci L. Relationship between the occiput-wall distance and physical performance in the elderly: a cross sectional study. *Aging Clin Exp Res* 2007; **19**: 207–212.
10 Ryan PJ, Blake G, Herd R, Fogelman L. A clinical profile of back pain and disability in patients with spinal osteoporosis. *Bone* 1994; **15**: 27–30.
11 Cortet B, Houvenagel E, Puisieux F, Roches E, Garnier P, Delcambre B. Spinal curvatures and quality of life in women with vertebral fractures secondary to osteoporosis. *Spine* 1999; **24**: 1921–1925.
12 Kamitani K, Michikawa T, Iwasawa S *et al.* Spinal posture in the sagittal plane is associated with future dependence in activities of daily living: a community-based cohort study of older adults in japan. *Osteoporos Int* 2005; **16**: 273–279.
13 MacIntyre NJ, Lorbergs AL, Adachi JD. Inclinometer-based measures of standing posture in older adults with low bone mass are reliable and associated with self-reported, but not performance-based, physical function. *Osteoporos Int* 2014; **25**: 721–728.
14 Suzuki Y, Kamide N, Mizuno K, Takahashi-Narita K, Hiraga Y, Fukuda M. Validity and reliability of evaluation of posture using a digital inclinometer. *J Phys Ther Sci* 2011; **23**: 431–435.
15 Terwee CB, Bot SD, de Boer MR *et al.* Quality criteria were proposed for measurement properties of health status questionnaires. *J Clin Epidemiol* 2007; **60**: 34–42.

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ORIGINAL ARTICLE: EPIDEMIOLOGY, CLINICAL PRACTICE AND HEALTH

Classification of frailty using the Kihon checklist: A cluster analysis of older adults in urban areas

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Aim: Frailty is an important predictor of the need for long-term care and hospitalization. Our aim was to categorize frailty in community-dwelling older adults.

Methods: The present study was carried out in 2011–2013, and consisted of 1380 individuals over 65 years of age. Participants completed the Kihon checklist, which is widely used to assess frailty in Japan, and their physical, cognitive and social function was evaluated. Non-hierarchical cluster analysis was used to statistically categorize frailty. The optimum number of clusters was determined as the point at which the external reference values (instrumental activity of daily living score, grip power, 10-m walk time, body mass index, portable fall risk index, occlusal force and Mini-Mental State Examination score) differed.

Results: According to the Kihon checklist, 369 (26.7%) of the 1380 study participants were considered frail. When the cluster number was increased from two to six, the scores in each subdomain of the Kihon checklist significantly differed. The estimated minimum number of clusters was five, and each of the five cluster groups had distinct characteristics. The numbers of participants in cluster groups 1–5 were 105, 78, 62, 71 and 53, respectively.

Conclusions: We identified five types of frailty in community-dwelling older adults in Japan: "experience of falling," "pre-frailty," "oral frailty," "housebound" and "severe frailty." **Geriatr Gerontol Int 2016; ••: ••–••.**

Keywords: cluster analysis, frail, Japan, phenotype, urban population.

Introduction

The aging of society has caused serious problems in Japan. In 2013, individuals over 65 years of age comprised more than 25% of the Japanese population for the first time.[1] The rate of increase in the size of the elderly population in Japan is the highest in the world, and the percentage of older adults in Japan is expected to exceed 35% in 2050.[2] Medical and long-term care costs will also steeply increase in the future, and we must be prepared for this eventuality.

Frailty is an important predictor of the need for long-term care and medical treatment.[3] Although its definition is controversial,[4] a recent study defined frailty as a medical condition with multiple causes characterized by reduced strength, endurance, and physiological function that promotes dependency and death.[5] In other words, frailty is a precursor of mental and physical decline requiring medical care.

The Kihon checklist is widely used to identify frail individuals in Japan.[6] It assesses the instrumental activity of daily living, physical function, nutrition, eating, social interactions, memory and depression, and whether individuals carry out certain activities rather than simply being able to do so. A total of 31% of older adults in Japan have been tested for frailty using the Kihon checklist, making it the de facto screening tool for frailty in Japan.[7] Its sensitivity and specificity for predicting the need to insure older adults for long-term care after 1 year from evaluation are 55.7% and 90.3%, respectively.[8]

Frailty includes physical, social and cognitive or mental subcategories, and the predictive value of each in terms of the need for long-term care or hospitalization differs. In the study by Garre-Olmo *et al.*, physical and social frailty were associated with mortality, whereas mental frailty was not.[4] Classifying frailty according to

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its symptoms and functional defects, and consideration of frailty subgroups might help predict the need for long-term care. The aim of the present study was to identify frailty subgroups on the basis of non-hierarchical clusters and to characterize each subgroup. Our hypotheses were: (i) the Kihon checklist can be used to statistically classify frailty groups; and (ii) physical, social and mental frailty can affect physical strength, and social and cognitive function.

Methods

Study population

We have been carrying out a physical and mental health research project named "OTASYA KENSHIN." This project involves older adults living in nine regions in Tokyo, Itabashi-ku. In 2011, 913 individuals (363 men and 550 women) were enrolled. Enrollees did not include nursing home occupants or past participants. In 2012 and 2013, 499 older adults (214 men and 285 women) were recruited; of these, 32 did not completely fill out the Kihon checklist and were excluded. The project now contains 1380 older adults, all of whom were included in our study. All participants provided informed consent. This study was approved by the Ethical Committee of the Tokyo Metropolitan Institute of Gerontology (approval number H48).

Kihon checklist

The Kihon checklist is a questionnaire consisting of five subdomains with five items each.[9] The questions are simple; the participants respond by answering "Yes" or "No." Each response indicative of the potential need for preventive care receives a point; this might be a "Yes" to a "negative" question or a "No" to a "positive" question. When the Kihon checklist excludes the five questions in the depression subdomain, as done in the present study, the cut-off point is 5, sensibility is 72.2% and specificity is 80.0%.[10] In the present study, participants with five or more points were considered frail.

Measurement of anthropometric parameters

The height and weight of each participant were measured and used to calculate body mass index (BMI). Body composition was determined via bioelectrical impedance analysis using the WELL-SCAN 500 system (Canon Lifecare Solutions, Tokyo, Japan) in 2011 and the InBody 720 system (Biospace, Seuol, Korea) in 2012 and 2013. Individuals with pacemakers were excluded from this analysis, and the test value was recorded as "missing." Bone density was measured using an ultrasound bone densitometer CM-200 (Furuno, Tokyo, Japan). The speed of sound was used as the index of bone density.

Measurement of physical performance

The 10-m walk test, the Timed Up & Go (TUG) test,[11] and the single-leg standing test were used to measure locomotion and balance. For the 10-m walk test, an indoor course with a 3-m path for acceleration, a 10-m path for measurement and a 3-m path for deceleration was assembled. Participants were asked to walk at their usual pace for 10 m and at maximal speed for 10 m. The former was measured twice, and the faster time was accepted. Speed was measured to one-tenth of a second.

TUG was measured on a 3-m path. Participants sat in a chair with their hands on their knees. They were asked to stand up, walk over a cone and sit down as quickly as possible. Time was measured from the point at which the participant began to rise from the chair (loss of contact with the back of the chair) to the point at which his or her hip touched the seat of the chair after walking over the cone. The TUG test was carried out twice, and the shorter time was accepted.

In the single-leg standing test, a marker was set on the wall at eye level. Participants were asked to stand on either leg (their choice) while watching the marker without touching or bending the supporting leg. Time was measured from the start of the single-leg stand (determined by the participant) to the point at which the participant's leg touched the floor or moved from the starting point. When participants were unable to stand on one leg, the time recorded was 1 s. Measurements were stopped when the standing time exceeded 60 s.

Occlusal force was measured using a dental prescale 50H Type R (Fuji Photo Film, Tokyo, Japan) and Occluzer pressure-sensitive sheets (Fuji Photo Film). Participants were asked to bite down on the sheet as forcefully as possible while sitting.[12] Grip power was measured using a Smedley-type hand dynamometer (Yagami, Nagoya, Japan).

Evaluation of social and cognitive function

The Tokyo Metropolitan Institute of Gerontology Index of Competence (TMIG-IC)[13] was used to survey daily activities. Depression was evaluated using the Zung self-rating depression scale (SDS), the Mini-Mental State Examination (MMSE), which was administered by a psychologist, and the Japanese version of the Montreal Cognitive Assessment (MoCA-J).[14] The incidence of falling was assessed using data collected from one of the subdomains of the Kihon checklist, and the portable fall risk index was determined.[15] To evaluate lifestyle, we asked the participants eight questions about mobility and community activity.

Data analysis

Participants completed four subdomains of the Kihon checklist: lifestyle part 1 (items 1–5), physical strength (items 6–10), nutrition and eating (items 11–15), and lifestyle part 2 (items 16–20). The depression subdomain (items 21–25) was excluded from the analysis, because determination of frailty only requires 20 checklist items. The scores for the four subdomains were translated to Z-scores. Non-hierarchical cluster analysis was used to group the participants according to subdomain score. We assumed that the optimal number of clusters was between two and six. One-way ANOVA was used to determine cluster number and to compare the subdomain scores in each cluster. The following parameters were used as external references to determine the number of clusters: the TMIG-IC score, grip power, 10-m walk time, BMI, occlusal force, portable fall risk index and the MMSE score. We searched for conditions that produced the highest number of significantly different items (based on the Kruskal–Wallis test) in a cluster. The Kruskal–Wallis and post-hoc tests were used to compare the scores of the subdomains of the Kihon checklist, and physical, psychological and social function among the cluster groups and a non-frailty group. The χ^2-test was used for categorical variables. Significance was defined as $P < 0.05$. SPSS software, version 21 (IBM, Chicago, IL, USA) was used for statistical analysis.

Results

Among the 1380 older adults in the present study, 369 (26.7%) were classified as frail according to the Kihon checklist. When the cluster number was increased from two to six, the scores in all subdomains of the checklist differed significantly as determined by using ANOVA. As external references, grip power, 10-m walk time, BMI, TMIG-IC score, portable fall risk index and MMSE score differed significantly when the number of clusters was five or six. Occlusal force was similar in all cluster groups (Table 1). We chose a cluster number of at least five as the optimal cluster number, and continued to use the cluster numbers chosen by the program. The participants were divided into five cluster groups, with 105, 78, 62, 71, and 53 participants in cluster groups 1–5, respectively.

The point totals for each item on the Kihon checklist for each cluster group are listed in Table 2. There were significantly more women than men in all five cluster groups. The total and subdomain scores for each cluster group are listed in Table 3. The responses to the questions in all subdomains of the checklist differed significantly among the cluster groups. "Lifestyle, part 1" had the most points (i.e., responses indicative of frailty) in groups 4 and 5. "Physical strength" had the most points in groups 1 and 5, and the fewest points in group 2. "Nutrition and eating" had the most points in groups 3 and 5, and the fewest points in groups 1 and 4. "Lifestyle part 2" had the most points in groups 2 and 5, and the fewest points in groups 1 and 4.

Tables 3 and 4 present the anthropometric, and physical and psychological function data. Body fat mass and BMI differed significantly among the five cluster groups, whereas the other anthropometric parameters did not. Muscle strength (grip power and knee extension), gait time (10-m walk test), balance (TUG and single-leg standing tests) and psychological function (SDS, MMSE and MoCA-J scores) also differed significantly among the groups. Of the five groups, group 5 was the worst in terms of muscle strength, gait time and balance, whereas groups 2 and 3 were the best. Cluster group 5 ranked last in the cognitive function category (evaluated using the MMSE and MoCA-J), whereas cluster group 1 ranked first. Overall, the non-frailty group had better physical and physiological function than the frailty groups.

The responses to items related to lifestyle are summarized in Table 5. Higher point totals indicate worse health. Cluster groups 4 and 5 had more points than the non-frailty group in items assessing mobility, leaving the house and hobbies (items 1, 4, and 7 respectively). Cluster group 5 had more points than the non-frailty group in item 3 (smoking). Cluster groups 1

Table 1 Results of the various tests for each cluster number

	Cluster number 2	3	4	5	6
TMIG-IC	<0.001	<0.001	<0.001	<0.001	<0.001
Grip power	NS	NS	<0.05	0.033	0.008
10-m walk time	<0.001	<0.001	<0.001	<0.001	<0.001
BMI	NS	<0.05	N.S.	0.026	0.008
Portable fall risk index	NS	<0.05	<0.001	<0.001	<0.001
Occlusal force	NS	NS	NS	NS	NS
MMSE score	0.006	0.001	<0.001	0.002	<0.05

BMI, body mass index; MMSE, Mini-Mental State Examination; Numeral is P value; NS, not significant; TMIG-IC, Tokyo Metropolitan Institute of Gerontology Index of Competence.

Table 2 Number of points for each item on the Kihon checklist

Men/women	Non-frailty	Frailty cluster group					χ^2-test
	1011	1	2	3	4	5	
	423/588	35/70 (−1.6)	23/55 (−2.1)	18/44 (−1.9)	37/34 (2.0)	26/27 (1.3)	=0.007
Lifestyle, part 1							
1. Do you use public transport (bus or train) when you go out?	0	9 (−1.8)	0 (−4.0)	0 (−3.5)	27 (6.6)	15 (3.3)	<0.001
2. Do you shop for daily necessities?	12	4 (−2.5)	0 (−3.3)	1 (−2.4)	15 (3.5)	17 (5.8)	<0.001
3. Do you manage financial matters such as savings accounts or deposits by yourself?	29	7 (−2.2)	3 (−2.7)	3 (−2.0)	21 (4.7)	13 (2.8)	<0.001
4. Do you visit the homes of friends?	112	27 (−4.3)	23 (−2.7)	6 (−5.8)	62 (8.4)	41 (5.4)	<0.001
5. Do you give advice to friends or family members?	136	9 (−4.8)	6 (−4.2)	3 (−4.2)	48 (8.9)	30 (5.5)	<0.001
Physical strength							
6. Are you able to climb stairs without using handrails or the wall for support?	401	92 (7.2)	34 (−3.0)	21 (−4.3)	33 (−2.3)	36 (1.5)	<0.001
7. Are you able to stand up from a sitting position without support?	40	63 (6.5)	12 (−4.0)	10 (−3.3)	18 (−1.8)	24 (1.8)	<0.001
8. Are you able to walk continuously for 15 min?	20	23 (1.8)	6 (−2.4)	4 (−2.3)	15 (1.2)	13 (1.7)	<0.001
9. Have you fallen in the past year?	141	60 (4.2)	19 (−3.2)	24 (−0.2)	17 (−3.1)	28 (2.0)	<0.001
10. Do you feel anxious about falling when you walk?	285	88 (3.2)	50 (−1.7)	40 (−1.4)	42 (−2.6)	45 (2.3)	<0.001
Nutrition & eating							
11. Has your weight declined by 2 kg or more in the past 6 months without dieting?	117	21 (−2.6)	18 (−1.5)	38 (5.9)	14 (−2.1)	19 (1.0)	<0.001
12. Is your BMI less than 18.5?	108	6 (−2.7)	8 (−0.9)	14 (2.4)	5 (−1.7)	16 (3.9)	<0.001
13. Is it more difficult to chew tough foods now than 6 months ago?	135	37 (−3.2)	26 (−3.0)	48 (5)	26 (−2.2)	42 (4.8)	<0.001
14. Do you ever choke or cough when drinking soup or tea?	136	31 (−2.8)	30 (−0.5)	49 (6.7)	14 (−4.0)	27 (1.6)	<0.001
15. Do you feel uncomfortable feelings of thirst or dry mouth?	237	58 (−2.1)	45 (−1.2)	60 (6.0)	30 (−4.1)	41 (2.3)	<0.001
Lifestyle part 2							
16. Do you go out at least once a week?	37	7 (−2.1)	13 (1.3)	0 (−3.3)	10 (0.5)	16 (4.2)	<0.001
17. Do you go out less often now than you did last year?	101	44 (−2.1)	45 (1.4)	24 (−2.1)	29 (−1.8)	45 (5.4)	<0.001
18. Do others point out your forgetfulness or tell you that you always ask the same thing?	64	19 (−4.3)	48 (5.5)	21 (−0.2)	7 (−4.9)	34 (4.8)	<0.001
19. When you want to make a phone call, do you usually search for the number and call on your own?	57	8 (−3.0)	20 (2.4)	2 (−3.1)	12 (0.0)	20 (4.4)	<0.001
20. Do you sometimes not know what the date is?	363	41 (−3.1)	57 (4.2)	33 (0.2)	22 (−4.0)	39 (3.4)	<0.001

Data are expressed as the number of points and adjusted residual. The frailty groups were compared using the χ^2-test. The reference for the English version of the Kihon checklist is: Sewo Sampaio PY, Sampaio RA, Yamada M, Ogita M, Arai H. Validation and translation of the Kihon Checklist (frailty index) into Brazilian Portuguese. Geriatr Gerontol Int 2014;14:561–569 doi: 10.1111/ggi.12134.

Table 3 Results of the Kihon checklist survey and the mental and psychological function tests

	Frailty cluster group						*P*-value
	Non-frailty (n = 1011)	1 (n = 105)	2 (n = 78)	3 (n = 62)	4 (n = 71)	5 (n = 53)	
Kihon checklist							
Total score	2.0 ± 1.3	6.2 ± 1.3*	5.9 ± 1.2*	6.5 ± 1.2*	6.6 ± 1.5*	10.6 ± 2.2*	<0.001
Lifestyle part 1	0.2 ± 0.5	0.5 ± 0.5*	0.4 ± 0.5***	0.2 ± 0.4	2.4 ± 0.7*	2.2 ± 1.0*	<0.001
Physical strength	0.7 ± 0.8	3.1 ± 0.8*	1.6 ± 0.7*	1.6 ± 0.9*	1.8 ± 1.2*	2.8 ± 1.2*	<0.001
Nutrition & eating	0.7 ± 0.8	1.5 ± 0.8*	1.6 ± 0.6*	3.4 ± 0.5*	1.3 ± 0.9*	2.7 ± 0.8*	<0.001
Lifestyle part 2	0.4 ± 0.6	1.1 ± 0.7*	2.3 ± 0.8*	1.3 ± 0.8*	1.1 ± 0.8*	2.9 ± 0.9*	<0.001
TMIG-IC score	12.6 ± 0.8	12.0 ± 1.4*	12.2 ± 1.1**	12.2 ± 1.2	10.5 ± 2.1*	9.6 ± 2.8*	<0.001
Portable fall risk index	5.6 ± 2.7	9.9 ± 2.9*	8.6 ± 2.9*	8.6 ± 2.8*	8.3 ± 3.5*	12.0 ± 3.2*	<0.001
SDS score	32.8 ± 8.2	39.0 ± 8.8*	38.4 ± 7.6*	38.9 ± 8.7*	39.0 ± 8.8*	44.2 ± 10.3*	<0.001
MMSE score	27.9 ± 2.1	27.6 ± 2.4	27.1 ± 3.3	27.5 ± 1.9	26.0 ± 3.6	25.6 ± 3.9*	0.002
MoCA-J score	23.8 ± 3.4	23.0 ± 3.7	21.8 ± 4.4	22.4 ± 3.1	21.0 ± 4.6	19.7 ± 4.4*	<0.001

Data are expressed as mean ± standard deviation. Frailty groups were compared using the Kruskal–Wallis test. The *P*-values compare the non-frailty group with each cluster group. ***$P < 0.05$. **$P < 0.01$. *$P < 0.001$.
MMSE, Mini-Mental State Examination; MoCA-J, Montreal Cognitive Assessment (Japanese version); SDS, self-rating depression scale; TMIG-IC; Tokyo Metropolitan Institute of Gerontology Index of Competence.

and 5 had more points than the non-frailty group in item 6 (light gymnastics). Cluster groups 1 and 5 had more points than the non-frailty group in item 7 (hobbies).

Discussion

Older adults with impaired mental and physical functions are divided into seven care groups according to the amount of long-term care required, as based on evaluations by the Certification Committee for Long-term Care Need in Japan.[16] Older adults requiring long-term preventive care can be identified using the Kihon checklist, which consists of 25 items. Excepting the five items related to depression, this checklist provides a good indication of the need for future long-term care.[17] Although the Fried frailty index is commonly used to operationally define frailty, it requires specialized equipment and operators to evaluate grip power and gait speed. The Kihon checklist, in contrast, identifies frailty by using only a questionnaire. Because it is the simpler of the two methods, we used it as our frailty indicator in the present study. As determined by use of receiver operating characteristic curves and the Youden index, the cut-off point for the frailty phenotype described by Fried *et al.*[3] is between four and five when 20 items of the Kihon checklist are analyzed.[6] Therefore, in the present study, we defined older adults as frail when the point total was more than five. However, this cut-off point resulted in the inclusion of pre-frail individuals in the frailty group.

Operational definitions of frailty include the frailty index by Rockwood *et al.*,[18] the frail scale by Rolfson *et al.*[19] and the frail phenotype by Fried *et al.*[3] These indices include domains that can be used to identify health deficits. Components describing physical frailty are shrinking (weight loss), weakness, exhaustion (poor endurance), slowness and low activity. The Tilburg Frailty indicator is used to evaluate social frailty.[20] Almost all evaluations determine frailty by the number of points. Because the components of frailty are interrelated, frail individuals should share a common combination of attributes indicative of declining function. However, what these combinations are is unclear. To address this issue, we examined the response patterns to items on the Kihon checklist using cluster analysis. Use of the checklist allowed us to divide frail older adults into groups (n = 5), as predicted by our first hypothesis.

Most individuals in cluster group 1 fell (i.e., showed physical weakness) during the past year and felt anxious about falling. We termed cluster group 1 the "experience of falling" group. However, their physical function was only slightly reduced compared with that of nonfrail individuals. In terms of social function, they went out less and exercised less. Although the number of points in the physical strength subdomain of the Kihon checklist was high in cluster group 1, there was a consistent mismatch between participant self-evaluation and the results of performance tests. It is not clear whether occasional falling indicates a decline in physical function or a fall affects a person's perception of physical function. One study reported that self-evaluation was more accurate than external evaluation,[21] whereas another found that older adults with low perceived health tended to exaggerate disabilities.[22] In the present study, frailty was underreported in cluster group 1 in contrast to the results in a previous report.[21]

Table 4 Results of the anthropometry and physical function tests

	Non-frailty	Frailty cluster group 1	2	3	4	5	p value
	(*n* = 423/588)	(*n* = 35/70)	(*n* = 23/55)	(*n* = 18/44)	(*n* = 37/34)	(*n* = 26/27)	
Age (years)	71.9 ± 5.1	75.2 ± 5.7*	73.1 ± 5.6	73.3 ± 5.1	74.4 ± 5.7**	75.8 ± 4.4*	0.009
	(72.1 ± 5.5/71.7 ± 4.9)	(76.1 ± 5.6*/74.7 ± 5.7*)	(73.1 ± 5.1/73.1 ± 5.9)	(73.2 ± 5.7/73.3 ± 4.9)	(73.7 ± 4.9/75.1 ± 6.4***)	(75.7 ± 4.3**/75.9 ± 4.5*)	(<0.001/ < 0.001)
Height (cm)	156.5 ± 8.6	154.5 ± 9.0	154.5 ± 8.2	155.2 ± 8.3	155.1 ± 9.4	154.8 ± 8.9	N.S.
	(163.9 ± 6.2/151.1 ± 5.4)	(163.8 ± 6.5/149.8 ± 5.8)	(164.1 ± 4.9/150.5 ± 5.6)	(163.9 ± 6.1/151.6 ± 6.0)	(161.5 ± 7.4/148.2 ± 5.8)	(161.8 ± 4.9/148.0 ± 6.0)	(N.S./ 0.005)
Weight (kg)	56.3 ± 10.2	56.2 ± 9.5	54.2 ± 10.3	52.5 ± 10.6	55.8 ± 11.2	54.4 ± 13.1	N.S.
	(63.3 ± 9.1/51.2 ± 7.5)	(60.4 ± 10.4/54.1 ± 8.3***)	(63.5 ± 6.6/50.2 ± 9.1)	(61.9 ± 10.8/48.7 ± 7.8)	(61.6 ± 9.9/49.4 ± 8.9)	(60.6 ± 8.9/48.5 ± 13.9)	(N.S./<0.001)
Lean body mass (kg)	40.5 ± 7.8	39.3 ± 7.3	38.4 ± 7.3	38.4 ± 7.8	39.9 ± 8.2	39.1 ± 7.7	N.S.
	(47.9 ± 5.9/35.3 ± 3.7)	(46.6 ± 7.0/35.7 ± 4.1)	(47.7 ± 3.5/34.6 ± 4.3)	(47.9 ± 6.1/34.5 ± 4.4)	(46.0 ± 5.6/33.3 ± 4.6)	(45.4 ± 4.5/33 ± 4.7)	(N.S./ 0.006)
Soft lean mass (kg)	37.6 ± 7.3	36.4 ± 6.6	35.7 ± 7.0	35.7 ± 7.5	37.2 ± 7.7	36.7 ± 8.0	N.S.
	(44.6 ± 5.5/32.7 ± 3.4)	(43.2 ± 6.0/33.0 ± 3.7)	(44.7 ± 3.5/31.9 ± 3.9)	(44.8 ± 5.6/32.0 ± 4.1)	(43.0 ± 5.2/30.8 ± 4.2)	(42.2 ± 4.0/31.5 ± 7.4)	(N.S./ 0.005)
Body fat mass (kg)	15.7 ± 5.0	17.0 ± 6.1	15.7 ± 5.2	14.1 ± 4.7	15. 9 ± 6.6	15.8 ± 7.9	0.047
	(15.5 ± 5.0/15.9 ± 5.0)	(14.2 ± 6.2/18.5 ± 5.6**)	(15.8 ± 4.4/15.7 ± 5.6)	(14.0 ± 5.6/14.2 ± 4.4)	(15.6 ± 7.6/16.1 ± 5.4)	(15.4 ± 5.7/16.2 ± 9.6)	(N.S./ < 0.001)
BMI (kg/m^2)	22.9 ± 3.1	23.5 ± 3.4	22.6 ± 3.4	21.7 ± 3.2	23.1 ± 3.8	22.6 ± 4.9	0.027
	(23.5 ± 2.9/22.5 ± 3.2)	(22.4 ± 3.2/24.1 ± 3.4)	(23.6 ± 2.1/22.2 ± 3.8)	(23.0 ± 3.8/21.1 ± 2.8)	(23.7 ± 3.8/22.5 ± 3.8)	(23.1 ± 3.1/22.1 ± 6.2)	(N.S./ < 0.01)
Grip power (N)	264.8 ± 81.4	226.5 ± 62.5*	237.6 ± 70.6***	238.1 ± 77.8	234.9 ± 72.0	198.8 ± 78.4*	<0.001
	(333.2 ± 6.9/215.6 ± 47.0)	(275.4 ± 51.0*/201.9 ± 51.0)	(321.4 ± 70.6/203.8 ± 32.3)	(320.5 ± 73.5/202.9 ± 47.0)	(282.2 ± 57.8*/181.3 ± 43.1*)	(251.9 ± 73.5*/149.9 ± 44.1*)	(<0.001/ < 0.001)
Knee extension (Nm)	76.5 ± 28.7	63.0 ± 20.3*	65.6 ± 25.0***	62.3 ± 25.4**	62.2 ± 28.8*	52.1 ± 22.9*	0.020
	(95.5 ± 30.1/62.9 ± 17.7)	(73.4 ± 25.1*/57.8 ± 15.3)	(90.3 ± 24.4/55.6 ± 17.3)	(83.3 ± 27.7/53.4 ± 18.2***)	(78.7 ± 29.2***/44.8 ± 14.9*)	(64.6 ± 24.3*/40.5 ± 13.8*)	(<0.001/ < 0.001)
10-m gait, usual pace (s)	7.3 ± 1.2	9.4 ± 3.5*	8.0 ± 1.7*	8.0 ± 1.7**	9.9 ± 4.2*	10.2 ± 3.2*	<0.001
	(7.4 ± 1.3/7.2 ± 1.2)	(9.4 ± 2.8*/9.4 ± 3.8*)	(8.3 ± 2.1/7.9 ± 1.5**)	(8.0 ± 1.2/8.0 ± 1.9)	(8.5 ± 2.2**/11.4 ± 5.2*)	(9.8 ± 3.3*/10.6 ± 3.1*)	(<0.001/ < 0.001)
10-m gait, maximum speed (s)	5.3 ± 1.0	6.9 ± 3.0*	5.8 ± 1.2**	5.8 ± 1.5	7.0 ± 2.5*	7.8 ± 3.1*	<0.001
	(5.1 ± 1.0/5.5 ± 1.0)	(6.6 ± 2.3*/7.0 ± 3.3*)	(5.6 ± 1.1/5.9 ± 1.2).	(5.3 ± 0.9/6.1 ± 1.6)	(6.0 ± 1.4*/8.0 ± 3.0*)	(7.5 ± 3.4*/8.2 ± 2.9*)	(<0.001/ < 0.001)
TUG (s)	5.9 ± 1.4	7.6 ± 3.5*	6.5 ± 1.5**	6.5 ± 2.0	8.5 ± 4.1*	10.4 ± 8.6*	<0.001
	(5.7 ± 1.5/6.0 ± 1.3)	(7.8 ± 3.6*/7.6 ± 3.5*)	(6.1 ± 1.6/6.6 ± 1.4***)	(5.8 ± 1.3/6.8 ± 2.2)	(6.9 ± 2.1**/10.3 ± 5.0*)	(8.4 ± 3.3*/12.3 ± 11.3*)	(<0.001/ < 0.001)
Time standing on 1 foot (s)	43.8 ± 22.0	27.2 ± 23.3*	39.8 ± 22.6	41.8 ± 23.1	33.0 ± 24.4**	19.3 ± 20.5*	<0.001
	(39.6 ± 23.3/46.8 ± 20.4)	(23.0 ± 22.4**/29.2 ± 23.6*)	(38.3 ± 24.7/40.5 ± 21.9)	(34.3 ± 24.3/44.9 ± 22.1)	(36.4 ± 24.0/29.5 ± 24.7*)	(14.3 ± 16.7*/24 ± 22.9*)	(<0.001/ < 0.001)
Occlusal force (N)	530.8 ± 351.3	467.8 ± 337.5	416.8 ± 288.5	427.5 ± 295.6	379.5 ± 271.9	310.5 ± 235.6*	<0.001
	(570.5 ± 396.6/503.3 ± 313.8)	(365.5 ± 271.1/522.3 ± 359)	(616.9 ± 421.4/363.1 ± 218.5)	(427.8 ± 411.5/427.5 ± 256.3)	(401.3 ± 294.8/356.7 ± 250.8)	(378.7 ± 270.2/238.6 ± 171.8**)	(<0.011/ < 0.001)

Data are expressed as mean ± standard deviation. The first and second numbers in parentheses are the values for men and women, respectively. Frailty groups were compared using the Kruskal–Wallis test. The *P*-values compare the non-frailty group with each cluster group. ***$P < 0.05$. **$P < 0.01$. *$P < 0.001$. BMI body mass index; TUG, Timed Up & Go test.

Table 5 Comparison of the lifestyles of the non-frailty group and the frailty group

	Non-frailty	Frailty cluster group 1	2	3	4	5	*P*-value
1. Which response best describes your ability to move?†	1.0 ± 0.1	1.1 ± 0.3	1.0 ± 0.1	1.0 ± 0.0	1.2 ± 0.4*	1.4 ± 0.6*	<0.001
2. How often do you drink?‡	3.5 ± 1.7	3.9 ± 1.6	3.9 ± 1.5	3.9 ± 1.6	3.9 ± 1.6	3.8 ± 1.6	<0.001
3. How often do you smoke?§	1.2 ± 0.7	1.2 ± 0.7	1.2 ± 0.6	1.3 ± 0.7	1.4 ± 1.0	1.5 ± 1.0*	<0.001
4. How often do you leave home?¶	1.1 ± 0.3	1.3 ± 0.5***	1.2 ± 0.5	1.2 ± 0.4	1.5 ± 0.6*	1.5 ± 0.8*	<0.001
5. How often do you take a walk?††	2.5 ± 1.7	2.6 ± 1.7	2.8 ± 1.7	2.5 ± 1.6	3.1 ± 1.8	3.0 ± 1.7	<0.001
6. How often do you do light gymnastics?††	2.8 ± 1.8	3.4 ± 1.8***	3.1 ± 1.8	2.8 ± 1.7	3.4 ± 1.7	4.0 ± 1.5*	<0.001
7. Do you have hobby or attend a class?‡‡	1.9 ± 0.9	2.3 ± 0.9***	2.4 ± 0.8*	2.0 ± 0.9**	2.3 ± 0.9**	2.6 ± 0.7*	<0.001
8. How often do you exercise or play sports excluding walking and light gymnastics?††	2.4 ± 0.8	2.3 ± 0.6	2.3 ± 0.7	2.2 ± 0.6	2.1 ± 0.3**	2.1 ± 0.3**	<0.001

Data are expressed as mean ± standard deviation. Groups were compared using the Kruskal–Wallis test. The *P*-values compare the non-frailty group with each cluster group. $***P < 0.05$. $**P < 0.01$. $*P < 0.001$. †Responses are: (1) go out alone on a bicycle or in a car, bus or train; (2) travel near home, but do not go out alone; (3) move only at home (e.g. go into the yard, take care of the bird, do simple sewing); (4) mostly sitting; and (5) always in bed, except to go to the toilet or to eat. ‡Responses are: (1) never; (2) 1 day/week; (3) 2–4 days/week; (4) 5–6 days/week; and (5) every day. §Responses are: (1) never; (2) less than 10 cigarettes/day; (3) 11–20 cigarettes/day; (4) 21–30 cigarettes/day; and (5) more than 30 cigarettes/day. ¶Responses are: (1) every day; (2) 2–3 days/week; (3) 1 day/week; and (4) never. ††Responses are: (1) every day; (2) 5–6 days/week; (3) 2–4 days/week; (4) less than 1 day/week; and (5) never. ‡‡Responses are: (1) often; (2) sometimes; and (3) hardly ever.

Cluster group 2 scored well in the physical strength subdomain of the Kihon checklist and in physical function tests. Social function was also maintained. Few participants in cluster group 2 had experienced a fall in the past year. Although the participants in this group felt that their cognitive function was waning, it was comparable to that of non-frail participants according to MMSE and MoCA-J scores. The participants in cluster group 2 were younger than those in the other cluster groups, and had similar TMIG-IC scores as the non-frail participants. Their physical function was only slightly reduced. We termed cluster group 2 the "pre-frailty" group. However, the women in group 2 had lower gait and TUG times than those in the non-frailty group, whereas the men in group 2 did not. This finding suggests that physical performance declines earlier in women than in men.

Cluster group 3 had more points in the nutrition and eating subdomain of the Kihon checklist than the other cluster groups, and their BMI and body fat mass were lower. However, their social function was unimpaired. Bollwein *et al.* found that pre-frail and frail people had more chewing and swallowing difficulties than did non-frail people, as well as poor dietary quality.[23] Aspiration and dysphagia resulting from swallowing difficulties are risk factors for frailty.[24] Chewing and swallowing difficulties might cause frailty by decreasing intake energy, body fat mass, and skeletal muscle mass. We term cluster group 3 the "oral frailty" group.

Cluster group 4 had the highest number of points in the lifestyle part 1 subdomain of the Kihon checklist. Members of this group did not go out often and had few opportunities to establish social connections. We termed cluster group 4 the "housebound" group. Becoming housebound has been associated with frailty.[18] Because housebound individuals are less active, their physical function and psychological function decline.

Cluster group 5 was the most distinctive of the cluster groups. It had a relatively high number of points overall and in each subdomain of the Kihon checklist. Correspondingly, actual physical function, such as leg muscle strength and gait time (although not occlusal force), was poor, and the SDS score was high in both men and women. The members of cluster group 5 were considered frail, and in need of physical, nutritional, and psychological care. Nishi *et al.* identified several factors indicative of frailty: age, family composition, low BMI and TMIG-IC score, reduced muscle strength, locomotive function, cognitive function, and depression.[25] These factors are descriptive of cluster group 5. We termed this group the "severe frailty" group. Notably, cluster group 5 had the lowest cognitive function. Frailty is associated with loss of cognitive function,[25,26] and dementia severely curtails the performance of the activities of daily living.[27]

The original Kihon checklist contains 25 items addressing physical, social and cognitive function. Because the Fried frailty index focuses on physical frailty (e.g., bodyweight, muscle strength, and performance and activity levels), it would not recognize group 2 (the "pre-frailty" group) or group 4 (the "housebound" group), which are the groups classified on the basis of social function, nor would it recognize group 1 (the "experience of falling" group). Therefore, the Kihon checklist more widely defines frailty. Although previous frailty phenotypes included "mental frailty", the present study did not explicitly examine factors such as mild cognitive impairment. Cluster group 4 had the lowest MSSE and MoCA-J scores and, other than cluster group 5, the highest SDS score. Cluster group 4 might represent the mental frailty phenotype.

Garre-Olmo *et al.* compared the 4-year mortality rates in elderly individuals with different types of frailty (physical, mental, and social), and found that physical and social frailty correlated with increased mortality.[4] Furthermore, individuals with all three frail phenotypes had a higher mortality rate than did those with a single frail phenotype (hazard ratios were 10.4 and 1.9, respectively). The types of frailty in the study by Garre-Olmo *et al.* might apply to cluster group 5.[4]

If operational definitions of phenotypes can predict mortality and functional decline, it is possible that statistical analyses of phenotypes can also do so. A previous study used cluster analysis to determine the degree of obstructive pulmonary disease according to health-related quality of life scores and physical function.[28] Similarly, we characterized frailty in terms of clusters using the Kihon checklist, because the operational definition of frailty is based on the decline of physical and psychological function. The differences in the pattern of decline were reasonable among the cluster groups. The present results suggest that differences in decline patterns might signify a limitation in the population approach for prevention of frailty. In Japan, individuals who might require future long-term care can participate in prophylactic programs that focus on improving skeletal muscle and oral function, and preventing housebound conditions and depression. We were unable to divide our study cohort into physical, social and mental groups in this study. However, we classified frailty as "experience of falling", "pre-frailty," "oral frailty," "housebound" and "severe frailty." We suggest that this characterization might facilitate the design of effective approaches for preventing frailty.

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Disclosure statement

The authors declare no conflict of interest.

References

1 National Institute of Population and Social Security Research. Population Projections for Japan. 2012. [Cited 08 Nov 2015.] Available from URL: http://www.ipss.go.jp/site-ad/index_english/esuikei/h1_1.html

2 U.N. 2015 Revision of World Population Prospects. [Cited 08 Nov 2015.] Available from URL: http://esa.un.org/unpd/popdev/Profilesofageing2015/index.html.

3 Fried LP, Tangen CM, Walston J *et al.* Frailty in older adults: evidence for a phenotype. *J Gerontol A Biol Sci Med Sci* 2001; **56**: M146–M156.

4 Garre-Olmo J, Calvo-Perxas L, Lopez-Pousa S *et al.* Prevalence of frailty phenotypes and risk of mortality in a community-dwelling elderly cohort. *Age Ageing* 2013; **42**: 46–51.

5 Morley JE, Vellas B, van Kan GA *et al.* Frailty consensus: a call to action. *J Am Med Dir Assoc* 2013; **14**: 392–397.

6 Ogawa K, Fujiwara Y, Yoshida H *et al.* The validity of the "Kihon Check-list" as an index of frailty and its biomarkers and inflammatory markers in elderly people. *Nihon Ronen Igakkai Zasshi* 2011; **48**: 545–552.

7 Japan Ministry of Health Labor and welfare. Results of survey on the implementation status of preventive long-term care project, and preventive long-term care total daily living support project (community support project) in 2013. [Cited 08 Nov 2015.] Available from URL: http://www.mhlw.go.jp/stf/seisakunitsuite/bunya/0000075280.html

8 Sone T, Nakaya N, Tomata Y *et al.* Prognostic prediction of the functional capacity and effectiveness of functional improvement program of the musculoskeletal system among users of preventive care service under long-term care insurance. *Nihon Eiseigaku Zasshi* 2013; **68**: 11–21. [Cited 22 Jun 2015.] Available from URL: http://www.ncbi.nlm.nih.gov/pubmed/23358372

9 Japan Ministry of Health Labor and welfare. Manual of services of care prevention benefits. 2014. [Cited 08 Nov 2015.] Available from URL: http://www.mhlw.go.jp/topics/2009/05/tp0501-1.html

10 Ogawa K, Fujiwara Y, Yoshida H *et al.* The validity of the "Kihon Check-list" as an index of frailty and its biomarkers and inflammatory markers in elderly people. *Nippon Ronen Igakkai Zasshi* 2011; **48**: 545–552.

11 Beauchet O, Annweiler C, Assal F *et al.* Imagined timed up & go test: a new tool to assess higher-level gait and balance disorders in older adults? *J Neurol Sci* 2010; **294**: 102–106.
12 Murakami M, Hirano H, Watanabe Y *et al.* Relationship between chewing ability and sarcopenia in Japanese community-dwelling older adults. *Geriatr Gerontol Int* 2014; doi: 10.1111/ggi.12399.
13 Koyano W, Shibata H, Nakazato K *et al.* Measurement of competence: reliability and validity of the TMIG index of competence. *Arch Gerontol Geriatr* 1991; **13**: 103–116.
14 Suzuki H, Hujiwara Y, Nasreddine Z. MoCA (Montreal cognitive assessment) Japanese version. [Cited 13 May 2015.] Available from URL: http://www.mocatest.org/paper-tests/moca-test-full/
15 Toba K, Okochi J, Takahashi T *et al.* Development of a portable fall risk index for elderly people living in the community. *Nihon Ronen Igakkai Zasshi* 2005; **42**: 346–352.
16 Japan Ministry of Health Labor and welfare. Long-Term Care, Health and Welfare Services for the Elderly. 2013. [Cited 08 Nov 2015.] Available from URL: http://www.mhlw.go.jp/english/policy/care-welfare/care-welfare-elderly/index.html
17 Tomata Y, Hozawa A, Ohmori-Matsuda K *et al.* Validation of the Kihon Checklist for predicting the risk of 1-year incident long-term care insurance certification: the Ohsaki Cohort 2006 Study. *Nihon Koshu Eisei Zasshi* 2011; **58**: 3–13.
18 Rockwood K, Song X, MacKnight C *et al.* A global clinical measure of fitness and frailty in elderly people. *CMAJ* 2005; **173**: 489–495.
19 Rolfson DB, Majumdar SR, Tsuyuki RT *et al.* Validity and reliability of the Edmonton Frail Scale. *Age Ageing* 2006; **35**: 526–529.
20 Gobbens RJJ, Van Assen M. The prediction of quality of life by physical, psychological and social components of frailty in community-dwelling older people. *Qual Life Res* 2014; **23**: 2289–2300.
21 Robinovitch SN, Cronin T. Perception of postural limits in elderly nursing home and day care participants. *J Gerontol A Biol Sci Med Sci* 1999; **54**: B124–B130, discussion B131.
22 Ferrer M, Lamarca R, Orfila F *et al.* Comparison of performance-based and self-rated functional capacity in Spanish elderly. *Am J Epidemiol* 1999; **149**: 228–235.
23 Bollwein J, Diekmann R, Kaiser MJ *et al.* Dietary quality is related to frailty in community-dwelling older adults. *J Gerontol A Biol Sci Med Sci* 2013; **68**: 483–489.
24 Hathaway B, Vaezi A, Egloff AM *et al.* Frailty measurements and dysphagia in the outpatient setting. *Ann Otol Rhinol Laryngol* 2014; **123**: 629–635.
25 Nishi M, Shinkai S, Yoshida H *et al.* Prevalence and characteristics of frailty among community-dwelling older people in Japan. *Nippon Ronen Igakkai Zasshi* 2012; **49**: 344–354.
26 Kulmala J, Nykänen I, Mänty M *et al.* Association between frailty and dementia: a population-based study. *Gerontology* 2013; **60**: 16–21.
27 Sauvaget C, Yamada M, Fujiwara S *et al.* Dementia as a predictor of functional disability: a four-year follow-up study. *Gerontology* 2002; **48**: 226–233.
28 Azarisman MS, Fauzi MA, Faizal MPA *et al.* The SAFE (SGRQ score, air-flow limitation and exercise tolerance) Index: a new composite score for the stratification of severity in chronic obstructive pulmonary disease. *Postgrad Med J* 2007; **83**: 492–497.

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REVIEW ARTICLE

Sarcopenia: Prevalence and associated factors based on different suggested definitions in community-dwelling older adults

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The age-related loss of muscle mass and/or strength and performance, sarcopenia, has been associated with geriatric syndromes, morbidity and mortality. Although sarcopenia has been researched for many years, currently there is a lack of consensus on its definition. Some studies define sarcopenia as low muscle mass alone, whereas other studies have recently combined low muscle mass, strength and physical performance suggested by the European Working Group on Sarcopenia in Older People, as well as the Asian Working Group for Sarcopenia. The arbitrary use of various available sarcopenia definitions within the literature can cause discrepancies in the prevalence and associated risk factors. The application of population-specific cut-off values in any sample population can be problematic, particularly among different ethnicities. Using commonly used cut-off points to define sarcopenia, including solely muscle mass and combined definitions, on a community-dwelling elderly Japanese population, the prevalence of sarcopenia ranged from 2.5 to 28.0% in men and 2.3 to 11.7% in women, with muscle mass measured by dual-energy X-ray absorptiometry, and 7.1–98.0% in men and 19.8–88.0% in women measured by bioelectrical impedance analysis. Body mass index was the most prominent related factor for sarcopenia across the definitions in this Japanese sample. However, other associated hematological and chronic condition factors varied depending on the definition. **Geriatr Gerontol Int 2016; 16 (Suppl. 1): 110–122.**

Keywords: muscle strength, sarcopenia, skeletal muscle mass, walking ability.

Introduction

Sarcopenia, a term proposed by Rosenburg in 1989 referring to the age-related decline in lean body mass, has become a relatively well-known condition among researchers and physicians.[1] Many investigators have attempted to clarify and establish a definition for the estimation of sarcopenia in older adults, as there is still a lack of consensus on components for the diagnosis of sarcopenia and the corresponding cut-off values.[2–8]

While some investigators maintain that sarcopenia should be characterized solely on muscle mass, since the publication of the European Working Group on Sarcopenia in Older People (EWGSOP) definition, more studies have used the combined definition of muscle mass, strength and performance to define sarcopenia.[9] The issue then, is that the reported prevalence of sarcopenia, or any outcome, varies depending on the definition used.[10–13] Furthermore, the differences in cut-off values used for the definition can also greatly affect the outcome of the results depending on the population on which said cut-off value is applied.[2,6,7,10] The different definitions of sarcopenia and their corresponding cut-off points might also have an effect on the risk factors associated with sarcopenia, which is an area that has not yet been explored. Understanding these risk factors can potentially assist in identifying early markers for sarcopenia prevention.

The purpose of the present review was to determine the differences in prevalence and factors associated with sarcopenia based on different definitions found in the literature, and to investigate how different sarcopenia definitions affect prevalence and associated factors

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when applied to a population of community-dwelling Japanese older adults.

Criteria for sarcopenia diagnosis and cut-off points

Muscle mass

The loss of muscle mass and increase in fat mass with aging has been well established in numerous studies.[14–18] The age-related loss of much mass is strongly associated with impaired mobility, greater morbidity and mortality,[7,19,20] and is a principal component in the causal pathway leading to frailty.[21] Therefore, the proper measurement and evaluation of muscle mass in older adults is extremely important.

The most widely used muscle mass cut-off points are those suggested by Baumgartner *et al.*, which used skeletal muscle mass index cut-off points two standard deviations below the mean of a young reference group measured by dual x-ray absorptiometry (DXA), 7.26 kg/m^2 for men and 5.45 kg/m^2 for women.[2] As seen in Table 1, several methods and cut-off points have been used, although many follow Baumgartner's example. The range of cut-off values shown in Table 1 for skeletal muscle index (SMI) or appendicular skeletal muscle mass adjusted by height, was 5.72–8.81 kg/m^2 in men and 4.23–7.36 kg/m^2 in women measured by DXA.[2–6,10,11,14,15,22–36] In addition, although the golden standard method of measurement is dual DXA, bioelectrical impedance analysis (BIA) has also been used, as the method is convenient and cost-effective, making it a more desirable and perhaps appropriate method for large-scale population studies. The range of cut-off values for BIA measurements of muscle mass were 7.00–8.87 kg/m^2 in men and 5.75–6.42 kg/m^2 in women, which are smaller ranges as the number of studies are fewer relative to those using DXA.[7,8,12,19,31,37,38]

It is not uncommon to witness these previously established cut-off points applied to various populations and samples in the literature. However, whether these population-specific cut-points should be used for any sample is questionable.

Muscle strength

Loss of muscle strength can lead to a number of major geriatric syndromes in addition to sarcopenia including frailty, mobility impairment and falls.[20,21,39,44] Low muscle strength is an important public health issue, as it has been associated with poor future health outcomes, and some researchers insist that muscle quality and functionality might be more vital within the elderly population.[39,41,44,48,49] Generally, upper extremity strength is measured using hand grip strength,[20,39,50] and knee flexion or extension is used for lower extremity strength assessments.[37,41] However, leg strength measurements might not be practical for large population studies or in clinical practice, as the equipment can be quite large and inconvenient, and the participants often require practice trials for accurate measurements. Therefore, grip strength is most often used in trials not only for the simplicity, reliability and affordability, but also because grip strength is a valid predictor of physical disability and mobility limitation. Grip strength cut-off points from the literature range from 26.0 to 37.0 kg in men and 18.0 to 21.0 kg in women.[9,13,19–21,31,35,38,39] One study suggested adjusting the cut-off values of grip strength based on body mass index (BMI).[21] Other measures of muscle strength included isokinetic knee extension torque and knee extension strength; however, these are not used as frequently (cut-off values summarized in Table 1).[40,41,48,51]

Physical performance

Among the commonly used available physical performance measures including the Short Physical Performance Battery, usual walking speed, 6-min walk test, timed get-up & go test and the stair climb power test,[52–54] usual walking speed is quick, inexpensive and a reliable measurement of physical function that can be easily implemented in clinical settings.[55] The predictive values of usual walking speed measurements for major health-related outcomes have been well established in the literature.[42,43,55] Determining the cut-off value for walking speed necessary to maintain a healthy, independent lifestyle is very important, which several researchers have investigated (Table 1).

The cut-point of gait speed ranged from 0.65 to 1.22 m/s.[9,19–21,31,38,41–43,45–47,55] Many of the studies found provided the same cut-off value for men and women, which does not take into account the likely height differences between the sexes. Fried *et al.* stratified walking speed by sex and height using the slowest 20% of a 15-ft walk as a cut-point.[21] The cut-points converted into m/s were 0.65 m/s for men ≤173 cm and women ≤159 cm, and 0.76 m/s for men >173 cm and women >159 cm.

Working definition of sarcopenia

The term sarcopenia was originally defined as the age-related loss of muscle mass.[1] Several cut-off points have been used to define sarcopenia based on muscle mass alone. The definition proposed by Baumgartner is the most commonly used definition of sarcopenia based on height-adjusted skeletal muscle mass measured by DXA.[2] Newman suggested a definition with similar cut-off values (7.23 kg/m^2 for men and 5.67 kg/m^2 for women) measured by DXA, defining sarcopenia as those whose muscle mass was in the lowest 20% of the