Variable Changes Compared with Baseline		Cured of Urine Leakage n(%)	Cochran's Q value	p- value	Post-hoc †
3-month exercise (n=33)					
BMI	Decreased (D)	16 (48.5)	7.091	0.029	D,N>I
	No change (N)	13 (39.4)			
	Increased (I)	4 (12.1)			
Maximum walking speed	Increased	17 (51.5)	6.545	0.038	I>D
	No change	11 (33.3)			
	Decreased	5 (15.2)			
Adductor muscle strength	Increased	11 (33.3)	4.545	0.103	
	No change	6 (18.2)			
	Decreased	16 (48.5)			
1-Year Follow-up (n=20)					
BMI	Decreased	10 (50.0)	3.700	0.157	
	No change	3 (15.0)			
	Increased	7 (35.0)			
Maximumn walking speed	Increased	10 (50.0)	6.100	0.047	I>D
	No change	8 (40.0)			
	Decreased	2 (10.0)			
Adductor muscle strength	Increased	9 (45.0)	3.100	0.212	
	No change	8 (40.0)			
	Decreased	3 (15.0)			

Table 5. Cured of urine leakage according to body mass index (BMI), maximum walking speed, and adductor muscle strength tertiles. (Kim, H.; Suzuki, T.; Yoshida, Y. & Yoshida, H. (2007). Effectiveness of multidimensional exercises for the treatment of stress urinary incontinence in elderly community-dwelling Japanese women: a randomized, controlled, crossover trial. *Journal of the American Geriatrics Society*, Vol.55, No.12, pp. 1932-1939, with permission from the American Geriatrics Society.)

While the details of the beneficial effects that exercise may have on the different types of urinary incontinence is not entirely clear, the current literature seems to suggest that PFM and fitness exercises are beneficial for all three types of urinary incontinence after a training period of three months. However, the effects of exercise training are maintained more in those with stress incontinence compared with those urge or mixed incontinence (Kim et al., 2011a) (Table 6).

Recently, other treatment methods including abdominal and lower back heating have been introduced. The heating may have positive effects on renal function such as renal sympathetic nerve activity suppression, promotion of bladder voiding, and increasing frequency of urination.

The heat and steam generating sheet (HSGS) can be any thin, flexible filmed sheet that generates heat and steam immediately after unsealing. When the sheet is placed on the body, the temperature of the skin surface rises to 38 to 40℃and it continues to generate heat

Variables^a	G^b	Baseline	3-month exercise	7-month follow-up	ANOVA^c G×T	p Value
Body Weight (kg)	I	52.0 ± 8.9	51.9 ± 8.8	50.9 ± 8.9	F=5.78	0.018
	C	53.9 ± 8.2	53.9 ± 8.2	53.9 ± 8.1		
BMI (kg/m^2)	I	23.7 ± 3.4	23.5 ± 3.0	23.2 ± 3.1	F=11.49	0.001
	C	24.1 ± 2.9	24.0 ± 2.7	24.4 ± 3.4		
WC (cm)	I	78.8 ± 10.3	77.8 ± 9.7	77.7 ± 9.9	F=4.06	0.041
	C	79.3 ± 10.4	79.2 ± 10.5	78.9 ± 9.6		
UWS (m/sec)	I	1.2 ± 0.2	1.2 ± 0.2	1.2 ± 0.2	F=2.79	0.099
	C	1.1 ± 0.3	1.1 ± 0.3	1.1 ± 0.2		
MWS(m/sec)	I	1.7 ± 0.4	1.8 ± 0.4	1.8 ± 0.4	F=5.10	0.027
	C	1.7 ± 0.4	1.6 ± 0.3	1.6 ± 0.4		
GS (kg)	I	19.0 ± 4.7	20.7 ± 5.0	19.8 ± 5.7	F=0.37	0.547
	C	19.0 ± 4.2	20.2 ± 3.5	19.5 ± 3.8		
AMS (kg)	I	20.5 ± 7.1	24.1 ± 7.7	24.3 ± 7.9	F=11.00	0.001
	C	21.2 ± 4.8	22.1 ± 4.8	21.8 ± 4.9		
ULS (point)	I	5.0 ± 1.0	3.0 ± 2.0	3.6 ± 2.2	F=7.64	0.007
	C	5.1 ± 1.0	4.4 ± 1.6	4.8 ± 1.6		
Cure of urine leakage	I	0.0	44.1	39.3	21.96	<0.001
	C	0.0	1.6	1.6		
Cure of urine leakage in intervention group	Stress	0.0	63.2^d	66.7^e	15.77	<0.001
	Urge	0.0	35.0^d	26.1^e	7.49	0.032
	Mixed	0.0	40.0^d	30.0^e	9.56	0.016

[a] Data are presented as mean and standard deviation.
WC=waist circumference; UWS=usual walking speed; MWS=maximum walking speed; GS=Grip strength; Ams=adductor muscle strenght; ILS=urine leaking score.
[b] G=group, I=intervention group, C=control group
[c] ANOVA=analysis of variance, T=time.
Chi-square and p values are from generalized estimating wquation.
Cochran's Q-value.
[d] Kruskal-Wallis test : chi-square=1.99, p=0.391
[e] Kruskal-Wallis test : chi-square=10.28, p=0.008
(Scheffe's *post-hoc*=stress >urge, mixed urinary incontinence)

Table 6. Cured of urine leakage after the 3-month exercise between the intervention and control groups. (Kim, H.; Yoshida, H. & Suzuki, T. (2011a). The effects of multidimensional exercise treatment on community-dwelling elderly Japanese women with stress, urge, and mixed urinary incontinence: A randomized controlled trial. *International Journal of Nursing Studies*, doi:10.1016/j.ijnurstu.2011.02.016, with permission from Elsevier.)

and steam for over 5 hours. Research has suggested that the HSGS in combination with exercise yields the highest cure rates of urinary incontinence compared with exercise or the HSGS alone. The HSGS also has beneficial effects for the different urinary incontinence types. Research reveals higher cure rates in those with stress urinary incontinence with the combination of both exercise and heat; however, there is strong evidence that the HSGS can be used as a supplementary treatment method in order to enhance the effects of exercise on those with urge, mixed, and stress urinary incontinence (Kim et al., 2011b) (Table 7).

	Ex+HSGS	Ex	HSGS	GE		
Type of UI	n=37	n=35	n=37	n=34	χ^2 value	*P*-value*
Stress UI, %(n)	61.5(8)	53.8(7)	25.0(3)	9.1(1)	8.94	0.030
Urge UI, %(n)	50.0(7)	16.7(2)	13.3(2)	0.0(0)	12.88	0.005
Mixed UI, %(n)	40.0(4)	30.0(3)	30.0(3)	0.0(0)	3.02	0.389
Total cure rate	51.4(19)	34.3(12)	21.6(1)	2.9(1)	21.89	<0.001

UI=urinary incontinence; Ex=exercise group; HSGS=heat and steam generating sheet group; GE=general education group.
*Kruskal-Wallis test.

Table 7. Cure rate of urinary incontinence according to urinary incontinence type and intervention group. (Kim, H.; Yoshida, H. & Suzuki, T. (2011b). Effects of exercise treatment with or without heat and steam generating sheet on urine loss in community-dwelling Japanese elderly women with urinary incontinence. *Geriatrics and Gerontology International*, doi: 10.1111/j.1447-0594.2011.00705.x, with permission from the Japan Geriatrics Society.)

	After 3-month exercise			After 7-month follow-up		
Variable	Adjusted OR *	95%CI	*p* Value	Adjusted OR *	95%CI	*p* Value
Amount of urine leakage	0.69	0.39-0.98	0.049	0.78	0.26-1.88	0.600
Frequency of urine leakage	1.16	0.24-5.79	0.856	1.63	0.73-4.01	0.248
Compliance to exercise	1.03	1.01-1.16	0.048	1.13	1.02-1.29	0.031
Decreased of BMI	0.67	0.48-0.89	0.011	0.78	0.60-0.96	0.028
Increased of walking speed	0.97	0.91-1.04	0.414	0.99	0.94-1.06	0.913
Period of urine leakage	1.01	0.91-1.13	0.919	1.01	0.91-1.14	0.913

Table 8. Adjusted odds ratios for cure of urine leakage after intervention and the 7-month follow-up. (Kim, H.; Yoshida, H. & Suzuki, T. (2011a). The effects of multidimensional exercise treatment on community-dwelling elderly Japanese women with stress, urge, and mixed urinary incontinence: A randomized controlled trial. *International Journal of Nursing Studies*, doi:10.1016/j.ijnurstu.2011.02.016, with permission from Elsevier.)

3.3.3 Predictor variables

Multiple characteristics that may influence the treatment outcome such as age, gender, urine loss frequency and amount, incontinence type, duration of urinary incontinence, chronic conditions, medications, and functional fitness as well as adherence to the prescribed exercise regimen have been examined. Many previous studies have emphasized that compliance to exercise is the key factor to long-term success (Lagro-Janssen & van Weel., 1998; McDowell et al., 1999), and confirmed that BMI reduction have positive influences on urge, mixed and stress UI treatment (Kim et al., 2011a) (Table 8).

4. Conclusion

Geriatric syndromes are highly prevalent and associated with substantial morbidity and poor outcomes. Various factors cause frailty, falls, and urinary incontinence in elderly people including chronic disease, lack of physical activity, malnutrition, and aging itself, some of which are unpreventable. Exercise and nutritional supplementation are among the beneficial treatments promoting healthy and independent lifestyles in the elderly.

Evidence reveals that exercise targeted at reducing risk factors is an effective strategy for treating geriatric syndromes in elderly people. Progressive and moderate-intensity exercise should be encouraged among elderly people to minimize the degenerative physical and mental function that occurs with aging.

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ORIGINAL ARTICLE

Accuracy of segmental multi-frequency bioelectrical impedance analysis for assessing whole-body and appendicular fat mass and lean soft tissue mass in frail women aged 75 years and older

M Kim and H Kim

BACKGROUND/OBJECTIVE: We aimed to examine the accuracy of segmental multi-frequency bioelectrical impedance analysis (SMF-BIA) for the assessment of whole-body and appendicular fat mass (FM) and lean soft tissue mass (LM) in frail older women, using dual-energy X-ray absorptiometry (DXA) as a reference method.
SUBJECTS/METHODS: All 129 community-dwelling Japanese frail older women with a mean age of 80.9 years (range, 75–89 years) from the Frailty Intervention Trial were recruited. The agreements between SMF-BIA and DXA for whole-body and appendicular body composition were assessed using simple linear regression and Bland–Altman analysis.
RESULTS: High coefficients of determination (R^2) for whole-body FM ($R^2 = 0.94$, s.e. of estimate (SEE) = 1.2 kg), whole-body LM ($R^2 = 0.85$, SEE = 1.4 kg), and appendicular FM ($R^2 = 0.82$, SEE = 1.1 kg) were observed between SMF-BIA and DXA. The R^2 coefficient for appendicular LM was moderate ($R^2 = 0.76$, SEE = 0.8 kg). Bland–Altman plots demonstrated that there was systematic (constant) bias (that is, DXA minus SMF-BIA) with overestimation of whole-body FM (bias = − 1.2 kg, 95% confidence interval (CI) = − 1.5 to − 0.1) and underestimation of whole-body LM (bias = 2.1 kg, 95% CI = 1.8–2.3) by SMF-BIA. Similar, the appendicular measurements also demonstrated systematic bias with overestimation of appendicular FM (bias = − 0.3 kg, 95% CI = − 0.5 to − 0.1) and underestimation of whole-body LM (bias = 1.5 kg, 95% CI = 1.4–1.7) by SMF-BIA. In addition, the individual level accuracy demonstrated a non-proportional bias for whole-body LM ($r = 0.08$, $P = 0.338$) and appendicular FM ($r = 0.07$, $P = 0.413$).
CONCLUSIONS: SMF-BIA had acceptable accuracy for the estimation of whole-body and appendicular FM and LM in frail older women, although SMF-BIA underestimated LM and overestimated FM relative to DXA.

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Keywords: body composition; bioelectrical impedance analysis; sarcopenia; frailty

INTRODUCTION

Frailty is an important and common geriatric syndrome that is described as a status of increased vulnerability resulting from the loss of complexity in resting dynamics involving multiple physiological systems with advancing age.[1] The prevalence of frailty increases with age, from 3.9% at 65–74 years to 11.6% at 75–84 years and to 25% in people older than 85 years. In addition, frailty is more prevalent in women than in men.[1] Sarcopenia is a loss of skeletal muscle mass and size that occurs with aging.[2] Although many definitions of sarcopenia have been reported,[3–5] current definitions focus on loss of appendicular skeletal muscle mass as well as low muscle strength and low physical performance.[6] The European Working Group on Sarcopenia in Older People consensus definition of sarcopenia is based on three stages: the presarcopenia stage involves low muscle mass with normal muscle strength and physical performance; the sarcopenia stage involves low muscle mass and either diminished muscle strength or physical performance; and severe sarcopenia combines all three factors.[6] Several pathophysiological overlaps between sarcopenia and frailty have been observed.[7] Thus, age-related loss in muscle mass and strength are a major component in the development of frailty in the elderly.[8,9] Moreover, frailty is associated with a decline in muscle mass and quality and a parallel increase in fat mass (FM).[10] Measurement of body composition, including FM and muscle mass in older populations provide important information about their nutritional status. Therefore, the understanding of the body composition of frail elderly populations is an important part of clinical assessment with a goal of optimal prevention and treatment strategies.

Dual-energy X-ray absorptiometry (DXA) is an accepted method for the estimation of whole-body and segmental body fat and fat-free mass (FFM), which includes lean soft tissues and bone minerals.[11–13] However, DXA has disadvantages for use in clinical settings, such as the high cost of equipment, risk of radiation exposure and lack of access to instruments. For clinical use, bioelectrical impedance analysis (BIA) has been used as an attractive alternative method.[4,14,15] BIA is a portable, non-invasive, easy to use and convenient method for the patient, and it is also relatively inexpensive compared with other methods.[16] Of the BIA devices developed over the years, segmental multi-frequency (SMF)-BIA devices have advantages

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over single-frequency BIA devices (50 kHz).[17–19] SMF-BIA avoids the problems encountered in single-frequency BIA by employing both low- and high-frequency electric currents.[20] In recent years, SMF-BIA has been shown to be valid in the estimation of body composition using DXA as a reference standard.[21–23] However, these results were obtained from analysis of healthy populations.

To our knowledge, SMF-BIA has not been evaluated in the assessment of total and appendicular body composition in a specifically targeted frail elderly population. Therefore, the aim of this study was to examine the accuracy of SMF-BIA for the assessment of whole-body and appendicular body composition using DXA as a reference method in frail Japanese women aged 75 years and older.

MATERIALS AND METHODS

Subjects

The subjects were 129 community-dwelling Japanese frail older women with a mean age of 80.9 years (range, 75–89 years). The study population was recruited from participants in the Frailty Intervention Trial (clinical trials registry, number: JMA-IIA00069). The baseline assessment was conducted on 1835 women aged 75 and older at the Tokyo Metropolitan Institute of Gerontology. Three hundred thirty-one were defined as frail, according to Fried's frailty phenotype with the presence of three or more of following criteria: weight loss, weakness, exhaustion, slowness and low physical activity.[1] In the present study, the five different components of the frailty indicators were evaluated as: (1) weight loss: either, answering 'yes' to the question, 'In the last 6 months, have you lost $>2\sim3$ kg unintentionally?' or a body mass index (BMI) <18.5; (2) weakness: hand grip strength <19.0 kg; (3) slowness: usual walking speed <1.10 m/s; (4) exhaustion: answering 'yes' to at least one of two questions, 'I felt that everything I did was an effort' or 'I could not get going'; (5) low physical activity: answering 'true' to at least three of the following four statements, 'I regularly take walks less than once a week,' 'I do not exercise regularly,' 'I do not actively participate in hobbies or lessons of any sort,' and 'I do not participate in any social groups for elderly people or volunteering.' Two hundred (60.4%) of the frail older women were excluded because they were classified into the exclusion criteria or declined participation. The exclusion criteria were: (1) severe knee or back pain; (2) severely impaired mobility; (3) impaired cognition (Mini-Mental State Examination score <24); (4) missing baseline data; and (5) unstable cardiac conditions, such as ventricular dysrhythmias, pulmonary oedema or other musculoskeletal conditions. Of a total of 131 frail older women who participated in the intervention study, body composition was measured in 129 subjects, using SMF-BIA and DXA. The anthropometric assessment of the subjects was conducted at the Tokyo Metropolitan Institute of Gerontology. The participants read and signed the informed consent forms that were approved by the institutional review board before testing. The Clinical Research Ethics Committee of the Tokyo Metropolitan Institute of Gerontology approved the study protocol.

Experimental design

The study model was a cross-sectional analysis of baseline data from the Frailty Intervention Trial. The subjects were instructed to refrain from exercise for 12 h and to refrain from eating for 3 h and drinking for 1 h bfore the measurements.[24] Subject body composition was measured by SMF-BIA and DXA. Both investigations were performed on the same day 2 h apart.

Anthropometric measurements

With the subjects wearing light clothes and no shoes, body weight was measured to the nearest 0.01 kg using DXA equipment, and height was determined to the nearest 0.1 cm using a fixed-wall-scale measuring device. BMI was calculated as body weight in kilograms divided by height in metres squared. The calf circumference was measured at the point of greatest circumference.

Dual-energy X-ray absorptiometry (DXA)

As a reference method, DXA (QDR-4500 A scanner; Hologic, Waltham, MA, USA) was used for the measurement of whole and regional body composition, including FM, lean soft tissue mass (LM), bone mineral content and bone mineral density. The subjects were positioned for whole-body scans according to the manufacturer's protocol. The subjects lay in a supine position on the scanner table with their limbs close to their bodies. Their body compositions were analysed manually using DXA analysis software (version 9.03 D; Hologic, Waltham, MA, USA). The segmental analyses of the total body into arm, leg and trunk segments were separated manually with anatomical landmarks by the DXA analysis software. Appendicular skeletal muscle mass[25] was calculated as the sum of the LM of both the right and left arms and legs, with the assumption that all non-fat and non-bone tissue was skeletal muscle. Appendicular muscle index was defined as ASM/body height.[23] The subjects were measured while wearing only a standard light cotton shirt to minimise clothing absorption. The DXA machine was calibrated daily against a spine phantom supplied by the manufacturer before testing. In addition, weekly calibration procedures were performed on a density step phantom. The precision error for bone mineral density and bone mineral content were 0.20–0.77% for the spine phantom. Our laboratory assessment of seven subjects demonstrated that the coefficients of variation for FM, LM and bone mineral content with repeated examinations were $<3.0\%$.

Segmental multi-frequency bioelectrical impedance analysis (SMF-BIA)

SMF-BIA was performed with a body composition analyser (InBody 720, Biospace Co. Ltd, Soul, Korea). A tetra-polar 8-point tactile electrode system was used. The system separately measured the impedance of the subjects' right arm, left arm, trunk, right leg and left leg at six different frequencies (1, 5, 50, 250, 500 and 1000 kHz) for each body segment. In accordance with the manufacturer's guidelines, subjects wiped the bottom of their feet with a proprietary electrolyte tissue before standing on the electrodes embedded in the scale platform of the respective analysers. The subjects were instructed to stand upright and to grasp the handles of the analyser, thereby providing contact with a total of eight electrodes (two for each foot and hand). In our study, the within-day coefficient variances for six different frequencies evaluated in nine subjects were 0–1.9%. Proprietary equations from the manufacturer were used to estimate whole and regional body composition variables.

Statistical analysis

The data are expressed as means, s.d. , and range (minimum-maximum). A paired Student's *t*-test was used to compare the difference in body composition measurements between the SMF-BIA and DXA. To assess the agreement in body composition parameters of whole-body measurements of FM and LM and appendicular measurements of FM and LM as measured by SMF-BIA and DXA, linear regression and Bland–Altman analyses were conducted. Simple linear regression analyses were performed with DXA body composition parameters as the dependent variable to determine whether the regression line differed significantly from the line of identity. In the Bland–Altman plots,[26] the systematic bias was calculated as the mean difference between methods, and the 95% limits of agreement were calculated as the bias ± 2 s.d. of the differences between methods. As there was evidence of proportional bias for body composition parameters, a Pearson's correlation was performed to quantify the bias observed in the Bland–Altman plots. Multiple regression analysis was performed to determine physical variables that influenced the bias of appendicular LM between DXA and SMF-BIA. The independent variables were age, body weight, height and appendicular LM as determined by DXA. Statistical analyses were performed using the IBM SPSS software version 20 (SPSS Inc., Chicago, IL, USA) and the SigmaPlot software version 12.0 (Systat Software Inc., Chicago, IL, USA). For all tests, statistical significance was set at $P<0.05$.

RESULTS

The characteristics of the frail older women subjects are described in Table 1 with means ± s.d. and ranges. Table 2 describes the body composition parameters obtained by using SMF-BIA and DXA. The means of the body composition parameters estimated by SMF-BIA and DXA were significantly different ($P<0.01$), except for the segmental FM in both legs ($P>0.05$).

Figure 1 displays the results of simple linear regression analyses for whole-body FM and LM, in addition to the appendicular FM and LM parameters as determined by SMF-BIA and DXA. The correlations between SMF-BIA and the body composition parameters estimated by DXA for whole-body FM and LM and appendicular FM were high ($r > 0.9$, all $P < 0.001$). High coefficients of determination (R^2) for whole-body FM ($R^2 = 0.94$, s.e. of estimate (SEE) = 1.2 kg or 8%), whole-body LM ($R^2 = 0.85$, SEE = 1.4 kg or 6%) and appendicular FM ($R^2 = 0.82$, SEE = 1.1 kg or 15%) between SMF-BIA and DXA were observed. The R^2 coefficient for appendicular LM was moderate ($R^2 = 0.76$, SEE = 0.8 kg or 6%).

In addition, agreements between the two methods were assessed using Bland–Altman plots at the individual level (Figure 2). There was a narrow limit of agreement on the Bland–Altman plots for the whole-body FM and LM and the appendicular FM and LM measurements. Almost all individual plots were within the 95% limit of agreement (mean difference ± 2 s.d.). There was systematic (constant) bias (that is, DXA minus SMF-BIA) with the overestimation of whole-body FM (bias = − 1.2 kg, 95% confidence interval (CI) = 1.5 to − 0.1) and the underestimation of whole-body LM (bias = 2.1 kg, 95% CI = 1.8–2.3) by SMF-BIA. Proportional bias was noted for whole-body FM measurement, with overestimation of the whole-body FM (SMF-BIA) increasing with increasing whole-body FM ($r = -1.42$, $P < 0.01$). However, the Bland–Altman plots indicated no significant proportional bias in whole-body LM measurement ($r = 0.08$, $P = 0.338$). Similarly, the appendicular parameters were systematically biased, with the overestimation of appendicular FM (bias = − 0.3 kg, 95% CI = − 0.5 to − 0.1) and the underestimation of whole-body LM (bias = 1.5 kg, 95% CI = 1.4–1.7) by SMF-BIA. In contrast, the Bland–Altman plots indicated no significant proportional bias in appendicular FM measurement ($r = 0.07$, $P = 0.413$). In addition, proportional bias was noted for appendicular LM measurement, with SMF-BIA tending to underestimate the appendicular LM in the lower range ($r = -1.42$, $P < 0.01$).

Table 1. Characteristics of the subjects

	Mean ± s.d.	*Range*
Age, years	80.9 ± 2.9	75.0–89.0
Body weight, kg[a]	48.5 ± 8.2	29.2–72.4
Height, cm	146.4 ± 6.0	132.2–161.8
BMI, kg/m^2	22.6 ± 3.5	15.6–31.4
<18.5	32 (24.8)	
18.5–24.9	80 (62.0)	
$\geqslant 25.0$	17 (13.2)	
Calf circumference, cm	32.4 ± 3.0	25.7–41.3
<31.0	46 (35.7)	
Whole-body bone mineral content, g	1111.1 ± 254.0	978.1–1880.1
Whole-body bone mineral density, g/cm^2	0.75 ± 0.10	0.59–1.37

Abbreviation: BMI, body mass index.
Values are means ± s.d., number (%).
[a]Weight derived from whole-body mass measurement by dual X-ray absorptiometry.

In a multiple regression analysis, age ($\beta = 0.051$), body weight ($\beta = -0.055$), height ($\beta = -0.091$) and appendicular LM as determined by DXA ($\beta = 0.302$) were significant contributors to the appendicular LM bias between DXA and SMF-BIA (all, $P < 0.05$) (data not shown). The R^2 in the multiple regression model was 0.421, indicating that 42.1% of the variability in the appendicular LM bias was explained by all variables ($P = 0.001$).

DISCUSSION

To our knowledge, this is the first investigation to compare the assessment of whole-body and appendicular body composition from SMF-BIA to DXA device-based measurements in a community-dwelling elderly population of frail women Japanese aged 75 years and older. In particular, our study examined the accuracy of SMF-BIA in the heterogeneous population. Our findings indicate that there was good agreement between the two methods for the estimation of whole-body and appendicular body composition in frail older women subjects, but SMF-BIA underestimated LM and overestimated FM relative to DXA. Moreover, the Bland–Altman plots at the individual level demonstrated non-proportional bias for whole-body LM and appendicular FM.

Table 2. Body composition parameters as determined by DXA and SMF-BIA

Body composition parameters	*DXA*		*SMF-BIA*		*Difference*[a]	
	Mean ± s.d.	*Range*	*Mean ± s.d.*	*Range*	*Mean ± s.d.*	*P-value*[b]
Whole-body measurement						
FM, kg	14.7 ± 5.1	4.4–30.3	16.0 ± 5.7	4.2–33.6	− 1.2 ± 1.5	0.001
LM, kg	32.7 ± 3.6	24.1–42.0	30.6 ± 3.5	23.0–41.5	2.1 ± 1.4	0.001
Percentage of FM, %	29.6 ± 5.9	13.2–41.8	32.0 ± 7.0	12.6–49.7	2.5 ± 2.8	0.001
Segmental body mass measurement						
Right arm FM, kg	1.0 ± 0.4	0.3–2.6	1.7 ± 0.5	0.4–3.0	− 0.2 ± 0.2	0.001
Left arm FM, kg	1.0 ± 0.4	0.3–2.5	1.2 ± 0.5	0.4–3.1	0.2 ± 0.2	0.001
Trunk FM, kg	6.7 ± 2.7	1.6–15.5	7.6 ± 3.1	0.9–17.1	− 0.8 ± 1.0	0.001
Right leg FM, kg	2.6 ± 2.0	0.6–5.0	2.9 ± 0.8	0.9–4.7	0.1 ± 0.5	0.177
Left leg FM, kg	2.6 ± 0.9	0.6–4.9	2.6 ± 0.8	0.9–4.7	0.0 ± 0.5	0.816
Appendicular FM, kg	7.2 ± 2.6	1.8–13.6	7.5 ± 2.5	2.6–15.2	0.3 ± 1.1	0.001
Right arm LM, kg	1.6 ± 0.2	1.1–2.2	1.4 ± 0.3	0.7–2.1	0.2 ± 0.2	0.001
Left arm LM, kg	1.6 ± 0.2	1.0–2.2	1.4 ± 0.3	0.70–2.1	0.2 ± 0.2	0.001
Trunk LM, kg	16.4 ± 2.0	11.7–21.7	13.7 ± 2.0	9.0–18.2	2.7 ± 1.0	0.001
Right leg LM, kg	5.1 ± 0.6	3.8–6.9	4.5 ± 0.8	2.9–7.0	0.6 ± 0.4	0.001
Left leg LM, kg	5.1 ± 0.6	3.7–7.1	4.5 ± 0.8	3.0–7.2	0.6 ± 0.4	0.001
Appendicular LM, kg	13.4 ± 1.6	10.0–18.0	11.9 ± 2.0	7.7–18.3	1.6 ± 0.9	0.001
Appendicular skeletal muscle index, kg/m^{2}[c]	6.3 ± 0.7	4.8–8.1	5.5 ± 0.7	4.0–7.9	0.8 ± 0.5	0.001

Abbreviations: DXA, dual X-ray absorptiometry; FM, fat mass; LM, lean soft tissue mass; SMF-BIA, segmental multi-frequency bioelectrical impedance analysis. Values are means ± s.d. [a]Mean difference between DXA and BIA (that is, DXA minus SMF-BIA), mean (s.d.) [b]*P*-values for paired *t*-test between DXA and SMF-BIA. [c]Appendicular lean soft tissue mass (kg)/height (m^2).

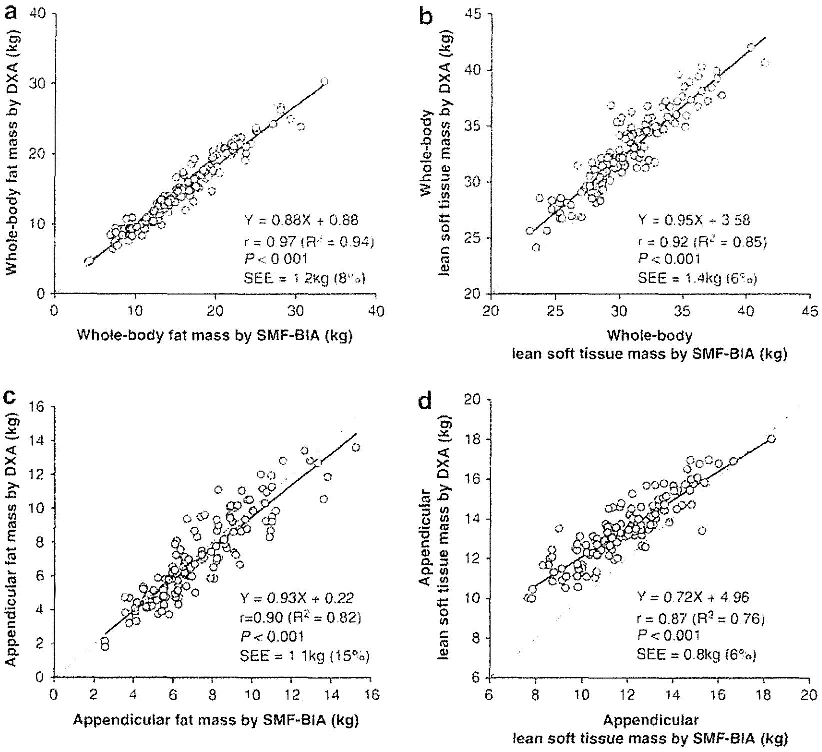

Figure 1. Linear regression between SMF-BIA and DXA. (**a**) Whole-body fat mass, (**b**) whole-body lean soft tissue mass, (**c**) appendicular fat mass and (**d**) appendicular lean soft tissue mass. SEE, s.e. of estimate; solid lines, regression line; dotted lines, identity line.

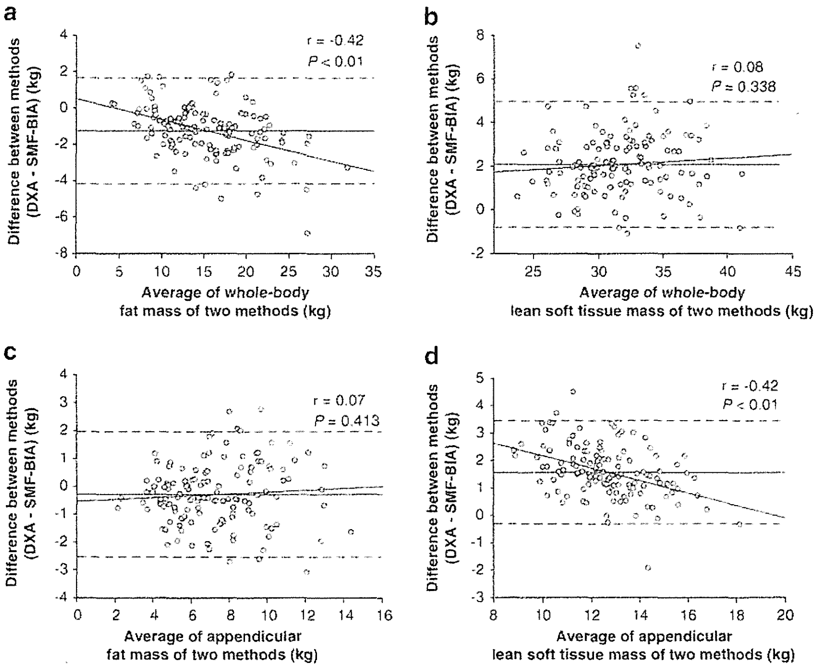

Figure 2. Bland–Altman plots comparing: (**a**) whole-body fat mass, (**b**) whole-body lean soft tissue mass, (**c**) appendicular fat mass and (**d**) appendicular lean soft tissue mass by SMF-BIA and DXA. Solid lines, bias (mean difference); dotted lines, limits of agreement (mean difference ± 2 s.d.).

Previous studies have demonstrated that SMF-BIA provides a valid estimation of body composition using DXA as a reference standard.[21–23] Ling *et al.*[22] reported that SMF-BIA (InBody 720, Biospace Co. Ltd) had a good agreement with DXA (the same device as used in this study, the Hologic QDR-4500A) in the assessment of total body composition of 484 general middle-aged

Dutch subjects. In that study, the coefficients of determination for whole-body FM ($R^2 = 0.94$) and whole-body FFM ($R^2 = 0.95$) in linear regression equations with adjusted gender was significantly greater. Anderson *et al.*[18] found that whole-body FM ($R^2 = 0.95$) and LM ($R^2 = 0.88$) measured with SMF-BIA in 25 women aged 18–45 years had a high correlation and small SEE when using DXA (Lunar DPX-iQ2288) as a reference standard. Houtkouper *et al.*[27] reported that an SEE of 2.0–2.5 kg in men and 1.5–1.8 kg in women is considered ideal in the FFM as calculated by the BIA equations. Whole-body LM, as measured by DXA, is bone mineral-free LM (total FFM − total bone mineral content). Previous studies have reported good correlations between DXA-derived LM and skeletal muscle mass when MRI was used as the criterion ($r = 0.94$–0.97).[11,28–30] Chen *et al.*[11] reported that DXA-derived LM was highly correlated with MRI-derived whole-body skeletal muscle mass ($r = 0.94$) in 101 older women aged 50–79 years. Our study found that the Bland–Altman plots indicated no significant proportional bias in whole-body LM measurement. Therefore, SMF-BIA may provide a valid method for assessing whole-body body composition, particularly for the whole-body skeletal muscle mass, assuming that the LM from DXA is skeletal muscle mass in the frail older women.

We found in our study that SMF-BIA underestimated whole-body LM and overestimated whole-body FM relative to DXA (see Figure 1). In our study, a subanalysis of the FFM indicated that SMF-BIA underestimated the whole-body FFM (bias, 1.2 kg, 95% CI, 0.9–1.5) (data not shown). These results are consistent with a previous study. The method's bias indicated that SMF-BIA underestimated whole-body FFM and overestimated whole-body FM in women with a mean age of 61.2 ± 6.4 years and a mean BMI of 26.1 ± 4.4 kg/m^2.[22] However, Völgyi *et al.*[31] demonstrated the validity of SMF-BIA compared with DXA (GE Lunar Prodig) in 86 Finnish women aged 37–81. These researchers observed that SMF-BIA overestimated FFM in normal and overweight groups by 3.2 and 2.9 kg, respectively. Discrepancies between studies are most likely due to differences in the specificity of subject populations (for example, age, gender, body shape, ethnic groups). In our study, SMF-BIA was used to analyse body composition (InBody 720 device). The measurement of FFM with an InBody 720 device was estimated as TBW/0.73. In addition, FM was calculated as the difference between total body weight and FFM. However, FFM hydration of 0.73 has been shown to be remarkably stable in healthy individuals.[32] The change of FFM hydration has been controversial because of the presence of systematic differences in regards to growth, aging, adiposity, gender, body size and acute or catabolic illness.[33] Heymsfield *et al.*[34] suggest that FFM hydration increases slightly in old age, resulting in a slight, systematic decrease in FFM density. Physiological ageing is associated with several changes that may affect water balance and expose older adults to the risk of dehydration. These changes include a decline in renal function and thirst perception and a reduction of TBW.[35] Thus, SMF-BIA may lead to underestimation of FFM with DXA in the dehydrated state. The extracellular water to intracellular water (ECW/ICW) ratio is a parameter of cellular hydration state. The ECW/ICW ratio ranges from 0.80–1.20 in healthy adults.[33] However, elderly patients displayed chronic cellular dehydration associated with relative extracellular overhydration, which was not evidently related to ageing because healthy elderly volunteers and healthy adults had similar water space distributions.[36] Notably, overhydration is a frequent consequence of organ failures such as kidney impairment, heart failure, chronic obstructive pulmonary disease and liver disease.[37–41] Basrends *et al.*[38] reported that chronic obstructive pulmonary disease patients with extreme FFM wasting are characterised by an increased ECW/ICW ratio despite the relative sparing of FM. Therefore, SMF-BIA is dependent on proprietary regression equations to estimate conductor volume (for example, FFM). As these equations have been formulated from healthy populations, they may contribute to error in body composition measurements in specific populations.

This study measured coefficients of determination for appendicular FM ($R^2 = 0.82$) and appendicular LM ($R^2 = 0.76$) between SMF-BIA and DXA. Our findings are supported by previous studies that indicate SMF-BIA has excellent agreement in the measurement of the segmental LM as both the right and left arms when using DXA as the reference method (interclass correlation coefficient ≥ 0.83).[22] Anderson *et al.*[21] found that the measurement of appendicular LM by SMF-BIA devices (InBody 720 and InBody520) was moderately to strongly associated ($R^2 = 0.62$–0.87) with DXA in men and women aged 18–49. In our study, the appendicular FM was in better agreement between SMF-BIA and DXA than the appendicular LM. To our knowledge, no comparative studies exist that evaluate the accuracy of assessing the segmental body composition at the individual level by SMF-BIA (InBody 720 device) in a population of elderly subjects.

In the present study, despite the significant SMF-BIA overestimation of appendicular FM and the underestimation of appendicular LM with DXA, the Bland–Altman plots indicated a non-proportional bias in appendicular FM measurement. However, we observed a proportional bias in appendicular LM, with SMF-BIA tending to underestimate appendicular LM in the lower range (see Figure 2). These results are in contrast to the results of previous studies evaluating SMF-BIA in healthy adults. Anderson *et al.*[21] found a non-proportional bias for appendicular LM as measured by two types of SMF-BIA devices in 25 women with a mean BMI of 26.1 kg/m^2 and aged 18–45. These different findings are probably the result of methodological differences, with the previous data confined to small subject numbers dispersed over a wide age range. In particular, the findings may be the result of a combination of physical factors such as different body sizes. Bedogni *et al.*[17] found that eight-polar SMF-BIA was precise and gave accurate estimates of TBW in healthy subjects with a BMI range from 18.5–29.9 kg/m^2. In our study population, the prevalence of underweight subjects (BMI values below 18.5 kg/m^2) in the frail older women population was 24%, with a TBW-to-body weight ratio of 44.8%. Thus, the Fried's definition includes weight loss criteria.[1] We found that in multiple regression analysis, the age, body weight, height and appendicular LM determined by DXA were associated with the bias of appendicular LM between DXA and SMF-BIA among the frail older women subjects. Therefore, SMF-BIA may tend to underestimate appendicular LM in the lower range as underweight when using DXA as the reference method.

Our study has some limitations. First, although DXA is a validated 'gold standard' reference method, it is still only an estimate of body composition. Therefore, validation against DXA is not the most accurate analysis possible.[42–44] However, it is included as a reference method because of its wide availability and previous validation. Second, it is likely that the focus of our study on frail older women in communities may not be applicable to populations in nursing homes, hospitals and other institutions. Finally, the hydration status of the study subjects was not determined before the body composition assessment.

In conclusion, the present study confirmed that SMF-BIA had acceptable accuracy in the estimation of whole-body and appendicular FM and LM in frail women subjects aged 75 years and older, although SMF-BIA underestimated LM and overestimated FM relative to DXA. In addition, the individual level accuracy revealed non-proportional bias for whole-body LM and appendicular FM measurement. This may suggest that SMF-BIA can be used in intrapersonal comparisons, with the understanding that SMF-BIA measurements will include errors. Our findings indicate that SMF-BIA would be useful for community-based research in measuring body composition in frail older women populations. Future research efforts should examine the validity of the SMF-BIA models in predicting body composition changes in frail elderly populations with diverse body shapes and compositions.

CONFLICT OF INTEREST

The authors declare no conflict of interest.

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歩行速度

金　憲経

Summary

- **「高齢者は何故つまずきやすくなっているのか」に対する理解が、転倒と歩行機能との関連性を把握するうえで重要である。**
- **歩行速度の低下は転倒の危険要因になる。**

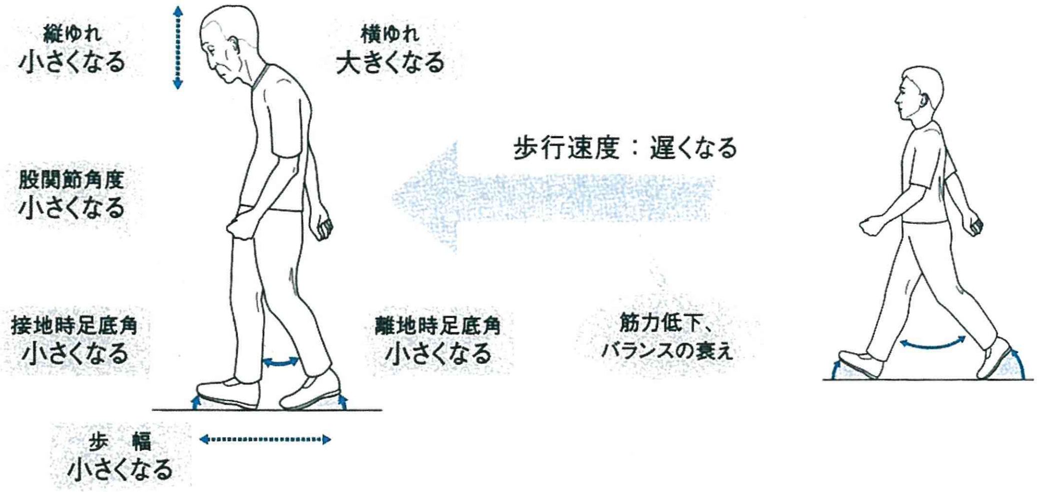
疾病によらない身体機能に関連した転倒の危険因子はいずれも加齢(老化)、生活習慣(不活動)に伴う機能の減衰に基づくものであり、高齢者の転倒原因の大きな割合を占めている。ここでは、歩行機能と転倒との関連性について簡単に記述する。

まず、注目すべき点は転倒のほとんどは歩行中に発生することである[1)]。したがって、歩行機能の加齢変化についての理解が必要である。高齢者の歩行パターンの特徴は、歩行速度の低下、歩幅の短縮、両脚支持期の延長、遊脚期での足の挙上の低下、歩隔の増大、腕の振りの減少、不安定な方向転換などにまとめられる(図1)。

一方、転倒者の歩行を分析した研究によれば、転倒経験がある高齢者は転倒経験がない高齢者に比べて歩幅は短くて、歩調の変動は大きくて、歩行速度は遅いという特徴を示し、歩行速度の低下のみならず不安定な歩き方が転倒につながる可能性が示唆されている[2)]。

一方、転倒の主な理由につて調べた調査によれば、「つまずいた44.8%、滑った17.2%、めまい10.3%」である(レベルⅡ)[3)]。「高齢者は何故つまずきやすくなっているのか」に対する理解が、転倒と歩行機能との関連性を把握するうえで重要なポイントである。つまずく、すなわち「すり足」の原因は、歩くときつま先を上げる役割を担っている「前脛骨筋」の衰弱に起因すると考えられる。次に、膝を伸ばすとき、股を上げるとき、椅子から立ち上がったり階段を昇ったりするときに使われる「大腿四頭筋」、股を上げるとき、階段を昇るときに使用する「腸腰筋」、膝を曲げるとき、大きく歩幅をとって歩くときに使われる「ハムストリングス」、つま先立ちするとき、地面を蹴るときに使用する「下腿三頭筋」の筋力の衰えは、歩幅の短縮を招き、ひいては歩行速度の低下に結び付き、転倒の危険要因となる。

図1　高齢者歩行の特徴



歩行速度の計測

歩行速度の計測には5mあるいは10mがよく採用されているが、ここでは5m歩行について説明する。障害物のない平坦な床に3mと8m地点にテープで印を付けた11mの歩行路上で直線歩行を行い、3m地点を体幹の一部（腰または肩）が越えた時点から8mを越えるまでの時間を計測する。通常歩行は「いつも歩いている速さで歩いてください」と被験者に指示する。試行は2回行い、速い値を採用する。

歩行速度のカットオフポイント

歩く速さはさまざまな健康指標として活用され、多数のカットオフポイントが提案されている。アメリカで普段の日常生活で必要とされる歩行速度の目安である横断歩道を渡りきる速さを1.22m/秒で設定し[4]、1.0m/秒以下になると下肢障害や入院、死亡の危険性が上昇することを[5]、0.8m/秒以下はサルコペニアの診断基準の1つとして使用されている（レベルⅡ）[6]。このように、カットオフポイントには差があるものの、歩行速度は高齢者の生活機能の自立や日常生活の良し悪しを判断する指標として幅広く採用されている。

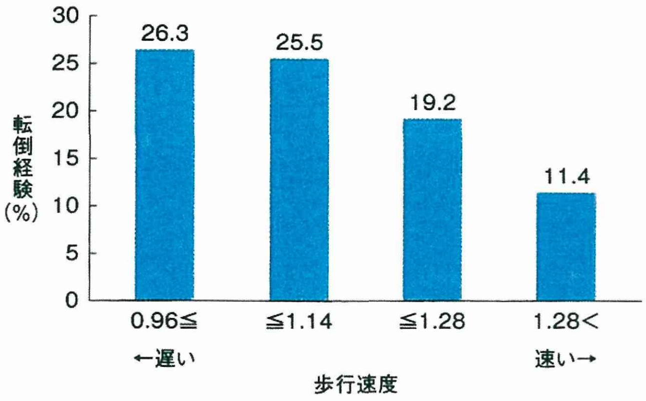
歩行速度と転倒との関連性

歩行速度と転倒との関連性については、さまざまな角度から検討されている。多く

の研究で、**歩行速度の低下は、転倒のみならず再転倒(relative risk ; RR=5.4、95% CI : 2.0−14.3)と密接に関連すると指摘している(レベルⅡ)**7)。

地域在宅高齢者の転倒発生率について調べた追跡調査によれば、5年間2回以上の複数回の転倒発生と関連する要因は、過去1年間の転倒経験(オッズ比[OR]=3.80、95%CI : 2.22−6.49)、通常歩行速度(OR=0.20、95%CI : 0.08−0.52)、皮下脂肪厚(OR=0.97、95%CI : 0.94−0.99)であり、特に自由歩行速度が速い群で転倒発生率が11.4%と低く、遅い群では26.3%と高い傾向が観察されている(**図2**)8)。さらに、歩行速度の低下は大腿骨頸部骨折の予知因子(RR=1.4、95%CI : 1.1−1.6)であることも検証されている9)。

図2　歩行速度と5年間の複数回転倒率



(鈴木隆雄ほか : 地域高齢者の転倒発生に関連する身体的要因の分析的研究−5年間の追跡研究から−. 日老医誌 1999 ; 36 : 472-8. より引用)

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環境因子

金　憲経

Summary

●環境要因のみでは転倒の直接的原因とは言い難く、高齢者の身体機能などとの交互作用として働く側面を捉えることが重要である。

転倒の潜在的危険要因としての環境要因は多数存在する。環境要因のみでは転倒の直接的原因とは言い難く、高齢者の身体機能などとの交互作用として働く側面を捉えるのが重要なポイントである。高齢者の日常生活の場である住宅内外には、転倒に結びつきやすい危険要因が数多く潜んでいる。転倒と関連する環境要因は大きく屋内環境、屋外環境、行動要因、その他に分けられる（表1）[1~4]。一般的に、屋内転倒は虚弱高齢者に、屋外転倒は健常高齢者に多発することが指摘されている[5]。

高齢者の家庭内事故の概要

家庭内で発生している事故の状況を知る資料として「病院危害情報からみた高齢者の家庭内事故」がある[6]。全国20の危害情報収集協力病院から20歳以上の事故が2003年度～2007年度まで21,860件寄せられ、20歳以上65歳未満で15,291件、65歳以上で6,569件である。事故発生場所を年齢層別にみると住宅（敷地内を含む）が最も多く、65歳未満では53.4％（8,163件）、65歳以上では63.3％（4,158件）となっている。65歳以上のうち、65歳以上75歳未満（全体3,051件）では60.4％（1,843件）、75歳以上（全体3,518件）では65.8％（2,315件）と、年齢上昇につれて、住宅内での事故の割合が高くなる傾向を示している（レベルⅠ）。

事故のきっかけにおける転倒・転落の割合は65歳未満で22.9％（1,868件）、65歳以上の高齢者で56.2％（2,337件）と上昇する。高齢者でも、75歳未満47.7％（879件）、75歳以上63.0％（1,458件）と年齢上昇とともに転倒・転落事故が多くなる。高齢者における転倒事故と転落事故を分けると、75歳未満では転倒27.1％（500件）、転落20.6％（379件）、

表1　転倒と関連する環境要因

屋内環境要因

1.居間・寝室など

1）床の面
- カーペットの端
- 滑りやすい敷物、座布団
- 収納されていないコードやケーブル類
- 床上に置かれている新聞紙・本・おもちゃなど
- 滑りやすい床の材質

2）家具
- 不安定な家具・椅子
- 低位置に置かれている家具
- アームレスト、背もたれがない椅子
- 低すぎる、もしくは高すぎるベッド・棚
- 廊下の不適切な物置

3）照明
- 暗い照明
- 反射されやすい床の材質・まぶしい光線
- 不適切なスイッチ位置

2.階段
- 急な階段
- 照明不良（暗い）
- 手すりがない
- 狭い階段
- 最後の段と床との境目の識別が困難
- 踏み面の寸法の不足

3.玄関
- 滑りやすい玄関マット
- 段差が大きいかまち
- 手すりがない
- 整理されてない靴

4.台所
- よく使用する器具の位置：背伸び・しゃがむ必要
- 収納されてない調理器具のコード
- 不安定な台・食卓椅子
- 濡れやすい床・落ち水

5.トイレ・お風呂
- 低い便座の位置、手すりがない
- 寝室から遠いトイレ
- 照明不良
- 入口の段差
- 滑り止めのマットがないお風呂場、手すりがない
- 風呂場でスリッパ使用
- 深い浴槽

屋外環境要因
- 歩道の段差
- 濡れた落ち葉、氷、雪
- デコボコ道、水溜り
- 高さが異なる階段
- 滑り止めのない急坂道（雨天時要注意）

日々の活動要因
- 急な立ち座り・姿勢変換
- 夜中のトイレ
- 不慣れの環境
- 不適切な介護用具
- 危険な活動（両手荷物、急ぐ、走るなど）

他の要因
- 歩道と横断歩道間の段差、信号が変わる間際の横断
- 整備されていない歩行補助道具
- 不適切な靴（滑り止めがない、ヒールが高い、サイズが合わないなど）
- 駅の階段の最終段での踏み外し、バスの乗り遅れ

75歳以上では転倒44.8％（1,037件）と急増傾向を示している。このように、家庭内事故では、75歳以上高齢者の転倒事故が多発することに注目すべきである。

転倒場所と問題点

都市部在宅高齢者における転倒状況を調べた報告によれば[7]、転倒場所は屋内32.2％、屋外41.4％、両方9.2％、不明17.1％である。屋内の転倒場所は、居間46.9％、階段20.4％、廊下10.2％、玄関・その他の部屋8.2％である。屋外は、平らな道47.6％、坂道14.3％、階段12.7％である。転倒時の履物は、屋内ではスリッパ20.4％、靴下12.2％、サンダル10.2％、何も履いていない34.7％、屋外では靴78.8％、草履・サンダル15.2％である（レベルⅡ）。

このように、高齢者が日々の生活を送る場所である居間、階段、玄関、廊下で転倒発生の頻度が高いことに注意喚起が必要であり、これらの場所はなぜ転倒事故と結びつきやすいのかについての考察が必要である（図1）。

◆階段

階段がかなり狭くて急で、曲っている内側の踏み面の寸法が不足しているケースが多い。手すりが途中までで、視力低下や照明不良で階段の最後の１段と床との境界の区別が困難な場合に「踏み外し」の原因となる。階段に手すりがない場合、転倒率の上昇につながることを指摘している。

◆居間

目立った段差がない場所である居間では、カーペットの折れ端、敷居などの1～2cmの小さな段差は気づきにくく、不用心となりやすい。また、滑りやすい床面の材質、床に置かれている電気コード類、雑誌や新聞紙、衣類は転倒につながる障害物である。

◆玄関

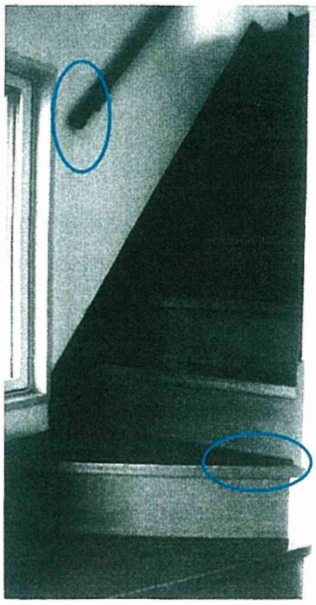
玄関では靴の着脱、上がりかまちの昇降など片足で行動することが多いため、普段は注意していても、荷物を持って上がろうとしたり、急いでいるときに、つまずいたり踏み外し、転落することが多い。

◆その他

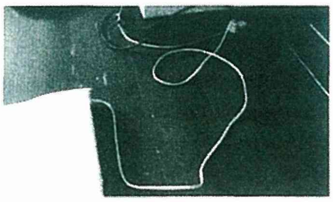
浴室やトイレでの転倒事故も多く報告されている。深い浴槽にまたいで入る動作や水で滑りやすい床面、トイレの便器への立ち座り、入口への段差、夜間利用時の照明不良のため転倒事故が多く発生する場所である。

図1　屋内外の環境

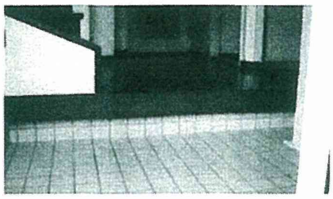
屋内環境



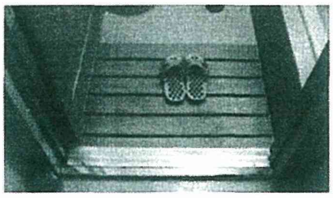
階段：かなり急で手すりも途中まで、曲っているため内側の踏み面の寸法が不足、照明不良



居間：床に置かれているカーペットの端、コード類

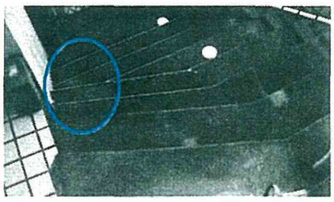


玄関：段差のある上がりかまち、手すりなし



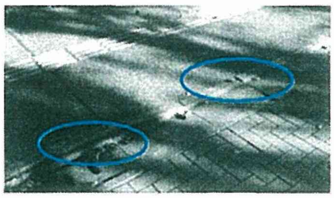
浴室：滑りやすいすのこ・スリッパ、手すりなし、段差と深い浴槽

屋外環境



階段：曲っているため内側の踏み面の寸法が不足、上から見ると2段の階段が1段に見える

道路：整理されてないデコボコ道



外部環境：段差、雨のとき水溜り

環境要因と転倒との関連性

家庭内の危険因子の数と転倒率との関連性は高く、2,304名の高齢者を調べたところ、家庭内に1つ以上の危険要因が存在する場合には転倒に結びつく可能性が高まる[8)]。家庭内には転倒につながりやすい物的要因が、数多く潜んでいるにもかかわらず、転倒のハイリスク者である高齢者自身は気づいていない点が問題である。また、院内転倒の54.0%は異なるさまざまな環境要因と関わり、歩行中の転倒は骨折に結びつく危険性が高いと指摘し、院内の環境整備の重要性を強調している[9)]（レベルⅡ）。