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 $\pm$ 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

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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 ($r = -1.42$, $P < 0.01$).

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 ($P = 0.001$).

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)	
⩾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.

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).

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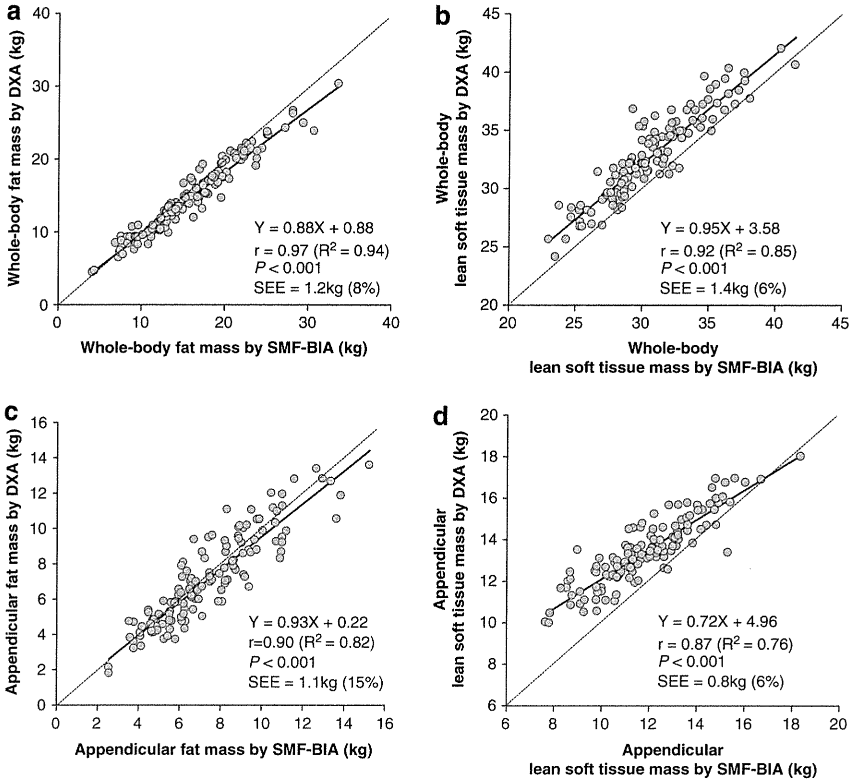

Figure 1. Linear regression between SMF-BIA and DXA. (**a**) Whole-body fat mass, (**b**) whole-body lean soft tissue mass, (**c**) appendicular fat mass and (**d**) appendicular lean soft tissue mass. SEE, s.e. of estimate; solid lines, regression line; dotted lines, identity line.

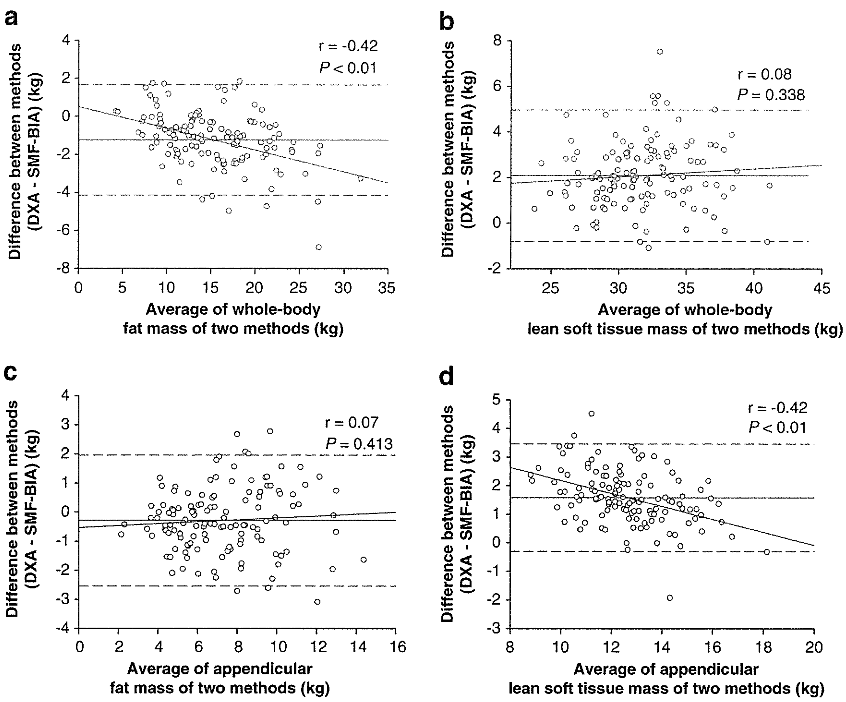

Figure 2. Bland–Altman plots comparing: (**a**) whole-body fat mass, (**b**) whole-body lean soft tissue mass, (**c**) appendicular fat mass and (**d**) appendicular lean soft tissue mass by SMF-BIA and DXA. Solid lines, bias (mean difference); dotted lines, limits of agreement (mean difference ± 2 s.d.).

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

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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 $26.1 \pm 4.4\,kg/m^2$.[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 $\geqslant 0.83$).[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.

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CONFLICT OF INTEREST

The authors declare no conflict of interest.

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ORIGINAL ARTICLE: EPIDEMIOLOGY, CLINICAL PRACTICE AND HEALTH

Effects of a comprehensive intervention program, including hot bathing, on overweight adults: A randomized controlled trial

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Aim: The objective of this study was to evaluate the effects of a comprehensive overweight intervention program, which utilizes hot bathing, on overweight, community-dwelling middle-aged and older adults in a randomized controlled trial.

Methods: The program was carried out in a hot bath facility and included 66 community-dwelling middle-aged and older Japanese adults (mean age 61.6 years, SD 7.5, 77.3% were women). The participants were randomly assigned to an exercise, diet and hot bathing intervention group (group A), exercise and diet intervention group (group B), a hot-bathing intervention group (group C) and a control group (group D). The participants in groups A and B participated in a comprehensive intervention program (including exercise and diet classes) twice a week for 3 months, and groups A and C had hot bathing.

Results: After 3 months, the participants in group A showed a reduction in weight, abdominal circumference, body mass index and body fat percentage compared with the other intervention groups. And the lower extremity function (i.e. walking speed) had greater improvement in the participants in groups A and B compared with groups C and D. In group C, in which only hot bathing was the intervention, there were no significant improvements in measurement items.

Conclusions: Our study provides preliminary evidence that a comprehensive intervention program, including hot bathing, is useful for community residents with a tendency toward overweight. **Geriatr Gerontol Int 2013; 13: 638–645.**

Keywords: hot bath, intervention program, middle-aged and older adults, overweight, randomized controlled trial.

Introduction

The increasing prevalence of obesity, which might lead to diabetes and cardiovascular disease, is an important global issue in middle-aged and older adults.[1–3] In Japan, 28.6% of men and 20.6% of women are obese or overweight, and the prevalence rate of obesity has increased on a yearly basis.[4] Approximately half of these obese individuals, however, are actively exercising to lose weight.[4] Thus, the development of an effective intervention program could contribute to reduce the prevalence of obesity.

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In recent years, the Most Obesity kNown Are Low In Sympathetic Activity (MONA-LISA) hypothesis has proposed that degeneration of the sympathetic nervous system (SNS) by the effect of long-term inactivity on lipid metabolism and energy consumption systems leads to the onset or progression of obesity.[5,6] As the sympathetic branch of the nervous system contributes significantly to coordinating energy homeostasis, the alteration of SNS activity is widely assumed to promote the onset and development of obesity.[7] Sympathetic activity is also altered by food intake, and a previous study found a highly significant inverse relationship between sympathetic activity and spontaneous food intake.[8] Therefore, it is argued that sympathetic activity is strongly associated with excessive weight gain and the development of obesity.

Additional interventions that activate the SNS could therefore effectively enhance the effects of traditional

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exercise and dietary modifications for weight loss. A relatively simple way to activate the SNS is to take a hot bath at over 42°C or sauna.[9–11] Previous studies have shown that taking a hot bath or sauna has various positive effects on diabetes,[12] autoimmune disease,[13,14] skin disease[15,16] and osteoarthritis[17,18] because of the elevation in body temperature. We therefore hypothesized that an intervention consisting of exercise and dietary modification for weight loss, which also included bathing in hot water, could have synergistic effects on aging obese and overweight individuals. Furthermore, it is unclear that an intervention consisting exclusively of hot bathing independently contributes to the weight reduction in obese and overweight individuals. If so, hot bath regimens might be beneficial for aging obese and overweight individuals who cannot participate in traditional dietary and exercise programs because of physical or psychosocial reasons. Previous studies have reported little regarding the positive effects of comprehensive programs including healthy lifestyle education, exercise, and hot bathing for middle-aged women and white-collar employees using a randomized controlled trial.[19,20] However, it is uncertain if there are synergistic effects of hot bathing on overweight individuals.

Therefore, we carried out a randomized controlled trial to show: (i) the effect of the comprehensive intervention program composed of exercise, diet and hot bathing on overweight individuals with risk factors for cardiovascular diseases, such as metabolic syndrome; and (ii) to test whether hot bath intervention had any independent positive effects on overweight individuals.

Methods

Participants

The participants were recruited from community-dwelling middle-aged and older adults by using a community newsletter; 127 individuals participated in a baseline assessment and agreed to participate in the study. The exclusion criteria prevented the participation of those who: (i) had major severe conditions or injury (e.g. stroke, heart disease or bone fracture) within a 3-month period before the study; (ii) had mental disorders or cognitive impairment; and (iii) showed evidence of use of or addiction to psychoactive substances or tranquilizers. Additionally, individuals who were overweight (a body mass index [BMI] of more than 25)[21] or who showed any two of the following clinical findings were included: (i) raised triglycerides >150 mg/dL or who were receiving treatment for this specific lipid abnormality; (ii) reduced HDL cholesterol <40 mg/dL or who were receiving treatment for this specific lipid abnormality; (iii) raised blood pressure (BP), systolic BP >130 mm Hg or diastolic BP >85 mm Hg, or treatment of previously diagnosed hypertension; and (iv) increased abdominal circumference >85 cm in men and >90 cm in women.[21] We selected 66 participants (mean age 61.6 years, SD 7.5, 77.3% were women).

Written informed consent was obtained from each participant. The study was carried out in accordance with the ethical standards set forth by the Declaration of Helsinki (1983). The study was approved by the ethics committee of Tokyo Metropolitan Institute of Gerontology.

Study design

The study was a four-arm, parallel group, randomized control trial. The participants were randomly assigned to either an exercise, diet and hot bathing intervention group (group A; mean age 59.9 years, SD 8.9); an exercise and diet intervention group (group B; mean age 61.0 years, SD 7.3); a hot bathing intervention group (group C; mean age 64.7 years, SD 7.6); or a monthly health class that served as a control group (group D mean age 61.3 years, SD 6.3). One week after a 3-month intervention period, the participants received a follow-up assessment.

Intervention

All assessments and interventions were held in a hot bath facility. The participants in groups A and B exercised for 75 min twice a week for 3 months under the supervision of exercise, health and medical staff (consisting of a training instructor, physical therapist and nurse). Before exercise, the participants were assessed for BP and health conditions using a health check sheet. If any of the checklist items were positive, the participants were prohibited from joining the exercise class. The participants who had a systolic BP above 180 mm Hg or a diastolic BP above 110 mm Hg were also prohibited from participating in the exercise class.

The exercise period consisted of several stages. First, the participants did warm-up exercises for a period of 10 min. Then, the participants carried out a muscle-strengthening routine (10 different resistance training, 2 sets of 12 repetitions) and exercise using resistance bands (Thera-Band, Hygenic Corporation, Akron, OH, USA) for a period of 40 min. Afterwards, the participants did balance and aerobic exercise training for a period of 20 min. Finally, the participants were instructed to cool down for a period of 5 min. During the exercise, the participants were asked to carry out a subjective intensive exercise (ratings of perceived exertion [RPE]), and we confirmed that participants' intensive exercise corresponded to a rating of "somewhat hard" to "hard" (13–15) according to the Borg conventional (6–20 points) scale.[22] Exercise classes comprised a total of 17 lessons.

Dietary modification consisted of a series of four 75-min nutrition guidance classes that were carried out

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under the supervision of a nationally registered dietitian. The classes involved a comparison of the participants' dietary intake with a healthy, balanced dietary intake, and encouraged the participants' to increase their awareness of a healthy diet through using a food model. In addition, the participants discussed problems of dietary habits and settled issues in a group setting. Nutrition guidance classes comprised a total of five lessons.

In group A, the participants took an artificial hot bath for 20 min (bath temperature at 42°C in a half bath; water level at the chest while seated)[19,20] after exercise or dietary modification. As a safety precaution, their blood pressure was monitored before and after the bath to ensure safe management.

The participants belonging to groups C and D took classes that had little conceptual relationship to the present study, such as geriatric diseases once a month. The members of group C were also given a hot bath twice a week for 3 months, similar to group A.

Measurement items

Morphometric assessment (main outcomes)

The body weight, body fat percentage and BMI were measured using a Body Composition Analyzer using the impedance method (InBody 720; Biospace, Seoul, Korea).[23] Abdominal circumference (AC) was measured using two separate measurers level with the umbilicus using an anthropometric tape. A casual BP was determined on the right arm after 3 min of seated rest.

Medical histories, physiological data and blood tests

Participants were interviewed to assess their medical history (use of outpatient care, history of hospitalization, medication use and history of chronic medical conditions were used for exclusion criteria). Non-fasted blood samples were collected from the seated participants. Blood cell counts were obtained and routine tests of biochemical markers,[24] nearly unaffected by a meal (excluding blood glucose or triglyceride), were carried out using a sequential autoanalyzer.

Physical ability

The peak grip strength of the dominant hand was measured twice with a handheld Smedley-type dynamometer, and the highest value was recorded as the participant's maximum grip strength. In the Timed Up & Go test (TUG), the participants were asked to sit on a chair and were then asked to stand up from the chair, walk forward to a marker at a distance of 3 m from the chair, turn around the marker, return to the chair and sit down as fast as possible. The elapsed time of the completion of this procedure of standing, walking and finally sitting on the chair was measured in seconds. This test was carried out twice, and the fastest speed was recorded.[25] In the Multiple-Sit-To-Stand test (MSTS), the participants were asked, while sitting at the front of a chair, to rise until they reached full-knee extension and then sit back down five times as fast as possible. This test was carried out twice, and the fastest time was recorded.[26] The Stepping Test for 20 s (ST) was carried out using bilateral back and forth alternate stepping. The participants stood behind a line, then stepped over the line (forwards) and then stepped back alternately for 20 s as fast as possible. This test was carried out once. The number of steps taken in 20 s was recorded.

Quality of life measurements

Quality of life (QOL) was measured using the psychometrically sound Medical Outcomes Study Short-Form (SF-8; range: 0 worst, −100 best) with norm-based scoring methods used to calculate the mental and physical QOL summary scores.[27] The WHO-Five Well-being Index (WHO-5) was used to measure health-related conditions. The WHO-5 scale contains five items, which are all positively worded. A maximum score of "25" indicates optimal well-being, whereas a score of "0" indicates minimal well-being.[28]

Statistical analysis

The measurement variables are shown in terms of means and SD or percentages, as appropriate according to each variable. On the basis of the status of the four groups at baseline, multivariate analysis of variance and χ^2-tests were carried out to compare the results of the outcome measures among the four groups. The intervention effects were assessed by repeated measure analysis of variance (ANOVA), adjusted for age and sex. ANOVA analyses were carried out in accordance to the intention-to-treat principle; that is, all the randomized participants were included in the analyses, with missing values substituted with carried baseline measured variables. The Kolmogorov–Smirnov test and logarithmic transformation were used to test the normality of distributions and convert non-normal distributions to normal distribution. When significant interaction was identified, we carried out post-hoc analysis. All statistical analyses were computed using the PC-compatible version of SPSS 17.0 (SPSS, Chicago, IL, USA).

Results

A scheme of the study design is presented in Figure 1, and Table 1 shows the results of baseline measurements of the four groups. The groups were not significantly

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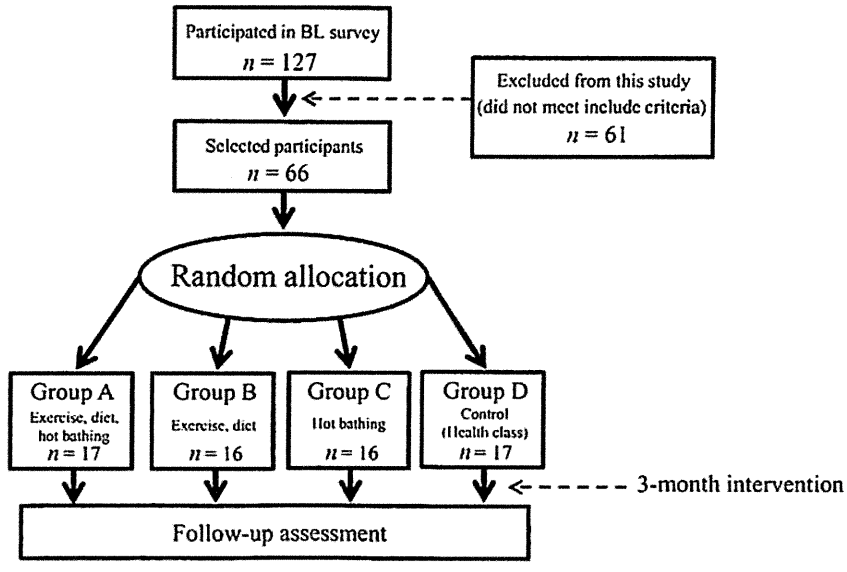

Figure 1 Scheme of the study design. BL, baseline

Table 1 Characteristics of study participants at baseline

Variables	Group A $n = 17$	Group B $n = 16$	Group C $n = 16$	Group D $n = 17$	*P*-value
Sex (% female)	62.5	80.0	81.0	81.0	0.521
Age (years)	59.9 ± 8.9	61.0 ± 7.3	64.7 ± 7.6	61.3 ± 6.3	0.328
Height (cm)	158.8 ± 6.9	153.9 ± 7.0	155.3 ± 7.7	155.0 ± 6.1	0.226
Abdominal circumference (cm)	90.1 ± 7.2	90.3 ± 9.2	91.5 ± 9.3	92.6 ± 8.4	0.832
Weight (kg)	63.6 ± 12.5	60.7 ± 11.4	61.8 ± 7.8	60.8 ± 6.8	0.838
BMI	25.1 ± 3.5	25.5 ± 4.1	25.7 ± 3.5	25.3 ± 2.6	0.962
Body fat percentage (%)	31.5 ± 7.4	33.3 ± 8.5	34.0 ± 9.5	33.9 ± 5.0	0.776
Systolic blood pressure (mmHg)	122.9 ± 14.3	128.5 ± 17.8	133.9 ± 13.8	128.6 ± 21.1	0.355
Diastolic blood pressure (mmHg)	72.0 ± 9.8	74.7 ± 11.4	81.8 ± 12.5	76.3 ± 10.1	0.094
Heart rate (no. times)	71.7 ± 11.7	70.9 ± 8.6	70.3 ± 10.5	71.9 ± 9.9	0.969
Grip strength (kg)	28.6 ± 10.7	26.3 ± 5.8	26.7 ± 6.3	27.3 ± 7.2	0.851
Timed Up & Go test (s)	5.94 ± 0.95	5.42 ± 0.36	5.91 ± 0.72	5.57 ± 0.73	0.132
Multiple-Sit-To-Stand test (s)	8.1 ± 4.6	7.3 ± 1.9	7.7 ± 1.2	7.2 ± 1.1	0.787
Step Test for 20 s (no. times)	13.6 ± 3.1	13.7 ± 2.0	12.6 ± 2.2	13.6 ± 2.0	0.549
WHO-5	17.6 ± 5.0	17.4 ± 4.1	17.2 ± 5.5	16.4 ± 5.4	0.912
SF-8: physical QOL summary scores	47.6 ± 6.3	47.3 ± 7.2	47.0 ± 7.9	48.3 ± 5.7	0.960
SF-8: mental QOL summary scores	50.5 ± 6.1	51.9 ± 5.6	52.7 ± 6.2	50.7 ± 5.8	0.690
Gamma-GTP (IU/L)	24.0 ± 12.7	29.4 ± 19.8	35.2 ± 28.4	32.8 ± 29.8	0.575
Total cholesterol (mg/dL)	211.5 ± 33.3	204.7 ± 34.4	215.6 ± 41.0	205.4 ± 31.4	0.793
HDL cholesterol (mg/dL)	50.1 ± 14.8	52.0 ± 8.1	58.6 ± 17.5	61.9 ± 12.4	0.062
LDL cholesterol (mg/dL)	130.3 ± 23.5	129.8 ± 32.3	134.1 ± 43.1	125.8 ± 32.6	0.919

Values are mean ± SD or percentage of them in the group. Multivariate analysis of variance and χ^2-tests. BMI, body mass index; GTP, glutamyl transpeptidase; HDL, high-density lipoprotein; LDL, low-density lipoprotein; QOL, quality of life; WHO-5, WHO-Five Well-being Index.

different in age, sex, current disease, medication use or other measurement items. One participant who was in group A dropped out for personal reasons, and two participants in group B and C, respectively, were absent from the follow-up assessment.

Figure 2 shows the results of effects at 3 months in the main outcomes. Participants in group A had significantly greater improvements in the main outcome measures, including weight (group A 63.6 ± 12.5 *vs* 61.2 ± 11.5, $P < 0.01$; group B 60.7 ± 11.4 *vs* 60.1

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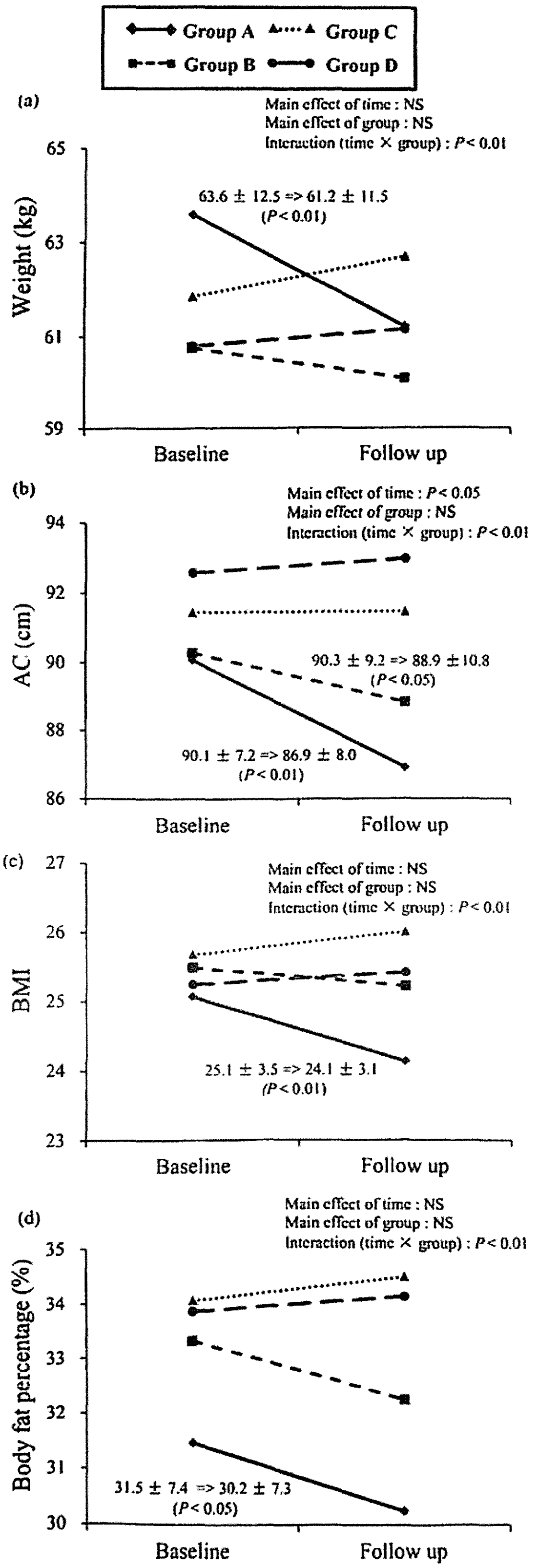

Figure 2 Comparison of main outcome measures (a) weight, (b) abdominal circumference (AC), (c) body mass index (BMI) and (c) body fat percentage before and after intervention among the four groups (the baseline and follow up are shown only for groups that were significantly different between baseline and follow up). NS, not significant.

± 11.9, not significant; group C 61.8 ± 7.8 *vs* 62.7 ± 8.1, not significant; group D 60.8 ± 6.8 *vs* 61.1 ± 6.9, not significant), AC (group A 90.1 ± 7.2 *vs* 86.9 ± 8.0, $P < 0.01$; group B 90.3 ± 9.2 *vs* 88.9 ± 10.8, $P < 0.05$; group C 91.5 ± 9.3 *vs* 91.5 ± 9.6, not significant; group D 92.6 ± 8.4 *vs* 93.0 ± 8.4, not significant), BMI (group A 25.1 ± 3.5 *vs* 24.1 ± 3.1, $P < 0.01$; group B 25.5 ± 4.1 *vs* 25.2 ± 4.2, not significant; group C 25.7 ± 3.5 *vs* 26.0 ± 3.5, not significant; group D 25.3 ± 2.6 *vs* 25.4 ± 2.6, not significant), body fat percentage (group A 31.5 ± 7.4 *vs* 30.2 ± 7.3, $P < 0.05$; group B 33.3 ± 8.5 *vs* 32.3 ± 7.6, $P < 0.1$; group C 34.0 ± 9.5 *vs* 34.5 ± 9.2, not significant; group D 33.9 ± 5.0 *vs* 34.1 ± 5.5, not significant) compared with the other groups (post-hoc analysis that compare before with after intervention). In measures of physical ability, there was a significant time by group interaction for grip strength ($P < 0.05$), TUG ($P < 0.01$), MSTS ($P < 0.01$) and ST ($P < 0.01$). In particular, the TUG, MSTS and ST had greater improvement in groups A and B compared with groups C and D, although groups C and D also improved their physical performance (Table 2). Groups A and B also improved the mean of total cholesterol and gamma-glutamyl transpeptidase (GTP), respectively ($P < 0.05$). Group C had significantly higher levels of total cholesterol compared with the measurements taken before the intervention ($P < 0.05$), and group D had significantly higher levels of gamma-GTP ($P < 0.05$). In group C, in which hot bathing was the only intervention, there were no significant improvements in measurement items.

Discussion

After a 3-month intervention, group A, in which the intervention program consisted of exercise, diet and hot bathing, positively influenced weight reduction more than the interventions in the other three groups. One possible reason for this result is sympathetic activation by the hot bathing, which resulted in body temperature elevation and facilitation of blood circulation and metabolism. A previous study reported that a 12-week exercise intervention improved heart rate recovery and blood pressure associated with SNS activation.[29,30] Thus, exercise intervention could have a beneficial

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Table 2 Comparison of various outcome measures before and after intervention among the four groups

Variables		Group A $n = 17$	Group B $n = 16$	Group C $n = 16$	Group D $n = 17$	Time	*P*-value Group	Interaction
Systolic blood pressure (mmHg)	Baseline	122.9 ± 14.3	128.5 ± 17.8	133.9 ± 13.8	128.6 ± 21.1	0.866	0.704	0.630
	Follow up	121.8 ± 14.2	121.7 ± 14.6	126.3 ± 9.9	125.6 ± 16.6			
Diastolic blood pressure (mmHg)	Baseline	72.0 ± 9.8	74.7 ± 11.4	81.8 ± 12.5	76.3 ± 10.1	0.245	0.240	0.051
	Follow up	73.1 ± 10.9	67.7 ± 8.8	75.3 ± 9.7	75.3 ± 10.6			
Heart rate (no. times)	Baseline	71.7 ± 11.7	70.9 ± 8.6	70.3 ± 10.5	71.9 ± 9.9	0.011	0.630	0.156
	Follow up	71.6 ± 7.9	69.4 ± 9.4	66.6 ± 11.2	72.3 ± 8.3			
Grip strength (kg)	Baseline	28.6 ± 10.7	26.3 ± 5.8	26.7 ± 6.3	27.3 ± 7.2	0.617	0.555	0.015
	Follow up	28.7 ± 10.3	28.2 ± 6.5*	26.8 ± 5.8	25.9 ± 7.5*			
Timed Up & Go test (s)	Baseline	5.94 ± 0.95	5.42 ± 0.36	5.91 ± 0.72	5.57 ± 0.73	0.560	$p < 0.01$	$p < 0.01$
	Follow up	3.70 ± 0.65**	3.92 ± 0.55**	5.40 ± 0.71*	5.34 ± 0.65			
Multiple-Sit-To-Stand test (s)	Baseline	8.1 ± 4.6	7.3 ± 1.9	7.7 ± 1.2	7.2 ± 1.1	0.731	0.460	$p < 0.01$
	Follow up	5.4 ± 2.1**	4.8 ± 1.0**	6.9 ± 1.1	6.4 ± 1.2			
Step Test for 20 s (no. times)	Baseline	13.6 ± 3.1	13.8 ± 2.0	12.7 ± 2.2	13.6 ± 2.0	0.078	0.011	$p < 0.01$
	Follow up	17.9 ± 3.8**	18.9 ± 3.0**	14.0 ± 2.9*	14.2 ± 2.2			
WHO-5	Baseline	17.6 ± 5.0	17.4 ± 4.1	17.2 ± 5.5	16.4 ± 5.4	0.497	0.186	0.281
	Follow up	19.6 ± 5.5	16.4 ± 4.9	17.8 ± 3.0	16.2 ± 6.0			
SF-8: physical QOL summary scores	Baseline	48.2 ± 6.1	47.3 ± 7.2	47.0 ± 7.9	48.3 ± 5.7	0.974	0.988	0.153
	Follow up	48.6 ± 4.9	49.6 ± 6.1	51.3 ± 5.0	47.9 ± 6.3			
SF-8: mental QOL summary scores	Baseline	50.8 ± 6.2	51.9 ± 5.6	52.7 ± 6.2	50.7 ± 5.8	0.533	0.892	0.275
	Follow up	53.8 ± 6.7	50.4 ± 7.8	51.5 ± 6.9	50.8 ± 4.6			
Gamma-GTP (IU/L)	Baseline	24.0 ± 12.7	29.4 ± 19.8	35.2 ± 28.4	32.8 ± 29.8	0.749	0.452	0.037
	Follow up	21.7 ± 13.4	24.5 ± 10.1*	34.6 ± 23.9	38.1 ± 39.9*			
Total cholesterol (mg/dL)	Baseline	211.5 ± 33.3	204.7 ± 34.4	215.6 ± 41.0	205.4 ± 31.4	0.331	0.502	0.007
	Follow up	201.0 ± 38.5*	199.8 ± 37.8	229.0 ± 47.0*	205.3 ± 27.5			
HDL cholesterol (mg/dL)	Baseline	50.1 ± 14.8	52.0 ± 8.1	58.6 ± 17.5	61.9 ± 12.4	0.877	0.112	0.084
	Follow up	55.9 ± 14.7	53.5 ± 10.4	60.6 ± 17.2	62.3 ± 12.1			
LDL cholesterol (mg/dL)	Baseline	130.3 ± 23.5	129.8 ± 32.3	134.1 ± 43.1	125.8 ± 32.6	0.866	0.753	0.058
	Follow up	122.7 ± 30.0	121.7 ± 35.7	142.2 ± 50.8	122.3 ± 29.7			

Values are mean ± SD. Repeated measures ANOVA adjusted for age and sex. $^*P < 0.05$, $^{**}P < 0.01$: within group. GTP, glutamyl transpeptidase; HDL, high-density lipoprotein; LDL, low-density lipoprotein; QOL, quality of life; WHO-5, WHO-Five Well-being Index effect because of sympathetic involvement. From the standpoint of the MONA-LISA hypothesis, sympathetic activation or maintained sympathetic activation by 42°C baths immediately after exercise would lead to hypermetabolism and thus facilitate weight reduction. In fact, previous studies suggest that 42°C baths enhanced activity of the SNS because of body temperature elevation and increasing circulatory blood flow.[31,32]

These results could also be attributed to increased aspiration activity because of water pressure, and to rising calorie consumption induced by body temperature elevation.[9] In contrast, group C showed no effects on weight reduction or mental and physical function. Although hot bathing has a lot of positive effects as an alternative medicine, our results suggest that hot bathing twice a week for 3 months did not have an independent effect on overweight community-dwelling adults.

Additionally, after a 3-month intervention, groups A and B showed a reduced level of total cholesterol or gamma-GTP. A previous study has reported that exercise might improve saccharometabolism, lipid metabolism and hepatic function.[33] Therefore, the present results of improved total cholesterol and gamma-GTP would not likely be attributed to any synergistic effect of hot bathing and other interventions, but rather to traditional exercise or diet effects.

Groups A and B also showed significant improvement in physical abilities, such as TUG, MSTS and ST, compared with groups C and D. Individuals who are overweight or obese tend to have a reduced frequency of exercise (sedentary lifestyle) and thus might show a decline in their physical abilities.[34,35] Such a decline in physical abilities could cause these individuals to fall into an inactive lifestyle and cause systemic disorders in energy consumption. Conversely, improvement of physical ability could lead to a fitness habit and also reduce the risk of inactivity. However, group A did not show any synergistic effects of hot bathing on physical ability in comparison with group B. Thus, the synergistic effects of hot bathing would likely prove to be of limited effect on weight reduction because of the changes in metabolism.

Japan has a scattering of hot bath (hot spring) facilities that serve as regional resources. Hot bath facilities are also closely related to multifaceted fields of health, medicine and community centers in Japan. Use of a hot bath facility, which contains these diverse aspects and is accessible to the community residents, might promote health self-awareness, similar to the way in which the intervention program was carried out in the present study. It is argued that such kinds of intervention programs would be widely accepted all over Japan.

The present study had some potential limitations. First, considering program generalization, the present study's sample size might be considered small. Despite its small size, however, the present results show that hot bathing had a dependent effect on weight reduction in middle-aged and older individuals. To the best of our knowledge, these results provide the first evidence of the effects of hot bathing on weight reduction. Our similar pilot study of older adults also suggested a comparable result; therefore, an intervention program that utilizes hot bathing is considered useful for health promotion among all ages.[36] Second, we used an artificial hot bath for convenience of location, and the present study did not compare the effect of spring quality. Currently, little is known regarding the effects of spring quality on weight reduction and other health effects. However, even an artificial hot bath had a dependent effect on weight reduction in the present study, and our results suggest that other bathing styles (e.g. jacuzzi spa) would also provide similar benefits.

In conclusion, the present study provides preliminary evidence that a comprehensive intervention program, consisting of exercise, diet and hot bathing improved participants' weight, AC, BMI and body fat percentage, in comparison with the other intervention groups. Thus, the synergistic effect of hot bathing could lead to hypermetabolism and then facilitate weight reduction. Comprehensive intervention programs in hot bath facilities can be considered useful for community residents.

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Disclosure statement

The authors declare that there are no conflicts of interest.

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Chapter 6

Behavioral Therapy for Urinary Incontinence

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Abstract

Background

Urinary incontinence among the elderly is a common problem that leads to loss of independence, decreased quality of life, social restrictions, and increased risk of hospitalization. Several treatments are currently available for elderly people with urinary incontinence including surgery, drug therapies, and behavioral interventions. Recently, much attention has been placed on the behavioral treatments for UI, including pelvic floor muscle (PFM) exercise and bladder training, weight loss exercise, and thermal therapy, as they have few risks, no side effects, and are effective.

Treatment

Pelvic floor muscle exercise: PFM exercises, which were first initiated by Kegel in 1948, has been found to be effective in reducing stress urinary incontinence with improvement rates ranging from 17%-80%. However, current focus has extensively been on treatment of stress urinary incontinence with little attention on the effects of behavioral treatments on other types of urinary incontinence, such as urge or mixed urinary incontinence. Previous research has found that PFM exercise reduced urine leakage in people with urge and mixed urinary incontinence because of the inhibition of the bladder reflex associated with PFM contractions. While further investigation is still needed, there is evidence indicating that exercise interventions may be equally effective in treating stress, urge, and mixed urinary incontinence.

Weight loss exercise: Several factors such as obesity and high body mass index (BMI) have been associated with higher risk of urinary incontinence. Surgically induced weight loss in morbidly obese women has been found to reduce stress and urge urinary

incontinence. Hence, fitness exercises focused on strengthening the abdominal muscles and reducing abdominal fat as well as BMI may also decrease the risk of urinary incontinence in the elderly. An 8% weight reduction in obese women has been reported to decrease weekly incontinence episodes by 47%. In light of such recent information, weight loss has been suggested as a first-line treatment for obese women with urinary incontinence.

Thermal therapy: Recent studies have expanded the focus of urinary incontinence interventions to thermal therapy as well. Previous research has indicated that abdominal and lower back heating may have positive effects on renal function via renal sympathetic nerve activity suppression, promotion of bladder voiding, and increasing urination frequency. Moreover, the combination of both heat therapy and exercise has shown to be effective in the treatment of stress, urge, and mixed urinary incontinence.

Conclusions

Behavioral treatments for urinary incontinence, especially PFM and fitness exercises along with combinations of other therapies, are effective in reducing incontinence in the elderly population. These treatments are often recommended as first line treatment because they are considerably safe with no risks and no side effects.

This chapter will discuss the benefits of behavioral treatments on different types of urinary incontinence, as well as the rationale behind how and why weight loss can reduce the risk of urinary incontinence. The chapter will present and examine in detail the effects of PFM exercise, biofeedback, pelvic floor electrical stimulation, vaginal cones, and thermal therapy on improving urine leakage episodes in people with urinary incontinence. While further research is still necessary, the combinations of behavioral interventions seem to be promising in the treatment of urinary incontinence.

1. Introduction

Urinary incontinence, particularly in the elderly, is considered to be an important determining factor for admission into long-term care and has been associated with loss of independence, reduced quality of life, restricted social activities, and increased anxiety and social isolation. Thus, prevention and treatment of urinary incontinence in its early stages are important strategies in maintaining health and independence among the elderly.

There is general agreement on the multifactorial nature of incontinence. Permanent incontinence is typically the result of neurological damage, intrinsic bladder or urethral pathology. However, incontinence is also associated with several potentially reversible conditions. Lower urinary tract function, environmental factors, physical and cognitive function, psychological distress, mobility, manual dexterity, medical conditions, and medications may all have an effect on urinary incontinence status in the elderly (Landi et al., 2003). The incidence of urinary incontinence is typically higher in women than men, and those who experience incontinence are usually older with a lower functional fitness level for both sexes. Although there is a large amount of information regarding the mechanisms and treatment options for urinary incontinence, little is known about the potentially reversible causes of this condition in community-dwelling elderly people. Several of the known causes that may be reversible include urinary tract infections, as they can cause the urge to void quite frequently, physical restraints and drastic limits of mobility, and environmental hazards.

Obesity, lifestyle (such as smoking status and social activity), and functional fitness are significantly associated with the onset of urinary incontinence in community-dwelling elderly people (Kim et al., 2004) (Table 1).

Table 1. Multiple logistic regression model of risk factors associated with the onset of urinary incontinence

Sex	Variable		OR	95%CI
Male	Age (per 1 yr)		1.23	1.11-1.38
	Plasma albumin (per 0.1 g/dl)		0.70	0.54-0.88
	Smoking status	non-smoker	1.00	
		previous smoker	1.53	0.56-4.59
		current smoker	2.33	0.82-7.61
Female	Grip strength (per 1 kg)		0.92	0.86-0.98
	Social role (per 1 point)		1.81	1.19-2.73
	BMI (per 1 kg/m^2)		1.10	1.01-1.20
	Smoking status	non-smoker	1.00	
		current smoker	7.53	1.36-41.63

2. Treatment

Urinary incontinence is often differentiated into stress, urge, and mixed urinary incontinence. Stress incontinence is defined as urine leakage associated with coughing, sneezing, laughing, heavy lifting, standing, running, or other types of physical activity that increase abdominal pressure. Leakage associated with running water or an urge to void and not being able to reach the toilet in time is urge incontinence. Mixed urinary incontinence shows symptoms of both stress and urge incontinence.

Surgery, drug and behavioral therapies are common treatments for urinary incontinence. Behavioral treatments such as pelvic floor muscle (PFM) exercises and bladder training are often recommended for the management of stress urinary incontinence, because they are non-invasive, have potential benefits, few risks and no side effects. While until recently, treatments have varied according to incontinence type, with an emphasis on stress incontinence, results of research have suggested that behavioral treatments are not only more effective than drug treatments, they are also safe, effective conservative treatments for urge and mixed incontinence as well (Burgio et al., 1998). The recommended conservative treatments for the prevention of urinary incontinence are behavioral treatments involving PFM exercises and various different combinations of other treatments including bladder training, biofeedback, electrical stimulation, vaginal cones, and/or thermal therapy.

Table 2. Summaries of different interventions targeting reductions in urinary incontinence episodes.

Table 2. Summarizes several research trials that have investigated the effects of these behavioral treatments on urinary incontinence

Study	Participants	Intervention	Outcomes	Conclusion
Kegel (1951)	500+women with stress urinary incontinence (UI)	PFM exercise 20 minutes a day, 3 times a day, or a total of 300 contractions using a Perineometer	Continence improved in 84% of patients with stress UI	Physiological therapy for stress UI is useful and successful
Burns et al. (1993)	123 women, age 55 and older with stress UI	8 week treatment, 3 month, 6 month follow-up Biofeedback(n=40) PFM exercise(n=43) Control(n=40)	Improvement in urine loss frequency Biofeedback=61% PFM exercise=43% Control=6%	Biofeedback and PFM exercise are effective and benefits are maintained for 6 months
Bo et al. (1999)	107 women, age range 24-70 years with stress UI	6 month trial PFM exercise(n=25) Electrical stimulation(ES)(n=25) Vaginal cones(n=27) Control group(n=30)	Reduction in leakage PFM exercise =-30.2g ES=-7.4g Cones=-14.7g Control=-12.7g	PFM exercise is most effective
Goode et al. (2003)	200 women, age range 40-78 with stress UI	8 weeks PFM exercise(n=66) PFM=ES(n=67) Self-help booklet(n=67)	Reduction in weekly episodes PFM exercise=68.6% PFM=ES71.9% Self-help booklet 52.5%	PFM+ES did not increase effectiveness in treating UI
Kim et al. (2007)	70 women, age 70 and older with stress UI	3 month trial, 1 year follow up PFM and fitness (n=35) Control (n=35)	Cure rate of urine leakage Exercise=54.5% Control=9.4%	↓ in BMI and ↑ in walking speed may contribute to improvement of UI
Fantl et al. (1991)	123 women, age 55 and older with UI	6 weeks, 6 months follow up Bladder training(n=60) Control(n=63)	Bladder training reduced UI episodes by 57%. Urine loss volume was reduced by 54%	Bladder training recommended as an intial step in UI treatment
Goode et al. (2011)	208 men, age range 51-84 with UI persisting after radial prostatectomy	8 weeks Behavior(PFM exercise+bladder training(n=70) Behavior+biofeedback and ES(n=70) Control (n=68)	Reduction in weekly UI episodes Behavior=55% Behavior+biofeedback and ES=51% Control=24%	Additional biofeedback and ES did not increase effectiveness in treating post prostatectomy incontinence
Burgio et al. (2002)	222 women, age range 55-92 years with urge or mixed UI	8 weeks PFM exercise(n=74) PFm and Biofeedback(n=73) Self-help booklet(n=75)	Reduction in weekly UI episodes	Improvement in urge UI was seen in all interventions
Kim et al. (2011a)	127 women, age 70 and older with stress urge, and mixed UI	3 month trial, 7 month follow up PFM and fitness(n=63) Control(n=64)	Cure rate of urine leakage PFM and fitness=44.1% Stress UI=63.2% Urge UI=35.0% Mixed UI=40.1% Control=1.6%	Multidemsional exercise may be effective for all tree types of UI
Kim et al. (2011b)	147 women, age 70 and older with stress urge, and mixed UI	3 month trial PFM and fitness +heat and steam generating sheet (HSGS) (n=37) PFM and fitness (n=37) (HSGS) (n=37) Education (n=36)	Cure of urine leakage PFM and fitness+HSGS=54.1% PFM and fitness=34.3% HSGS=21.6 Education=2.9%	HSGS can be used in addition to PFM and fitness exercise to reduce incontinence
Stubak et al. (2005)	40 obese women, age range 46-62, with UI	3 month, 6 months follow-up Liquid diet weight reduction program(n=24) Weight-list control(n=24)	Reduction in weekly UI episodes Weightloss program=60% Control=15%	Weight reduction is effective in treating UI for obese women
Stubak et al. (2009)	338 overweight and obese women with IU	6 months Intervention (diet and excercise weight-loss program with behavior modification) (n=22) Education (n-112)	Reduction in weekly UI episodes Intervention=47% Education=28%	Behavioral intervention targeting weight loss reduced UI episodes among overweight and obese women

2.1. Pelvic Floor Muscle Exercise

PFM exercises (Figure 1), were first initiated by Kegal in 1948. These exercises are hypothesized to enhance urethral resistance by increasing the strength and endurance of the periurethral and perivaginal muscles as well as by improving the anatomic support to the bladder neck and proximal urethra (Kegel, 1948). The effectiveness of PFM exercises for the improvement of urine leakage has been validated by many investigators, with improvement rates ranging widely from 17 to 84% (Bo, 1995). PFM exercises have been the preferred treatment for stress incontinence; however, recently they have been recommended for urge or mixed incontinence as well, due to the reflex bladder inhibition associated with pelvic floor muscle contraction (Kim, 2012).

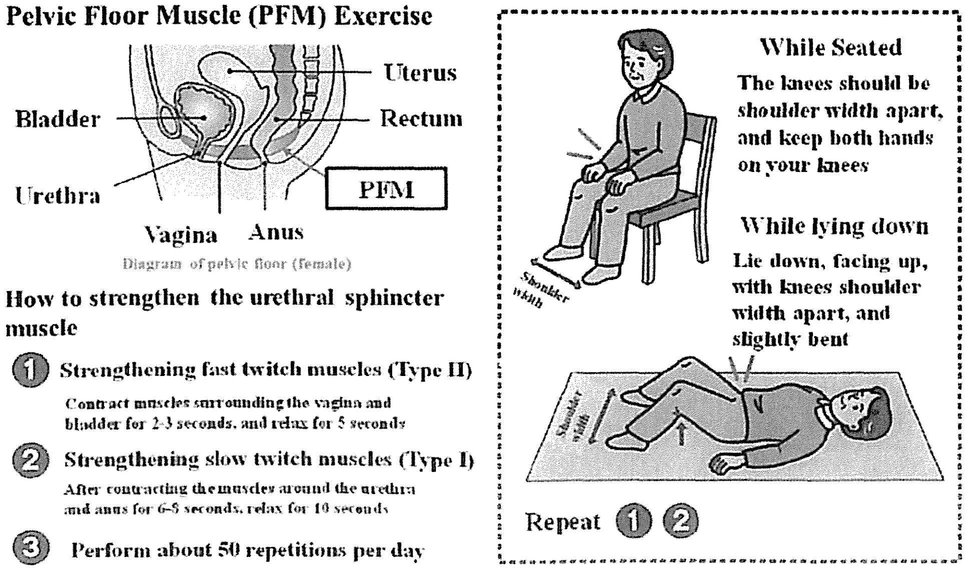

Figure 1. Pelvic floor muscle exercise for the treatment of urinary incontinence.

Elderly people participating in PFM training programs should be educated in the structure of the pelvic floor muscles (Figure 1) in order to gain awareness, and ultimately for proper execution of the exercises (Kim, 2012). Particularly, participants should be informed that straining the abdomen and increasing abdominal pressure would exert an added load on the PFMs. Training should focus on isolated force exertion of the PFMs without excessively straining the abdomen. Commonly, exercise programs include strengthening of both the fast and slow-twitch muscle fibers located at the pelvic floor. PFM exercise programs often incorporate alternations of: fast contractions, usually held for about three seconds followed by five second relaxation periods; sustained contractions, where the participants would hold the contraction for about six to eight seconds; and ten-second relaxation periods between the contractions. The PFM exercises can be performed in the seated, lying, and standing positions with the legs shoulder-width apart, and the emphasis placed on isolated training of the PFMs

(Figure 1). Regardless of the positions the exercises are performed (seated, lying, standing), the beneficial effects are equal (Borello-France et al., 2006).

Kegel (1948) also introduced a device known as the Perineometer to monitor PFM strength progress by measuring the strength of perineal muscular contraction, and is now widely used as a biofeedback instrument (described in further detail below). The Perineometer consists of a pneumatic vaginal chamber (8 cm in length, and 2 cm in diameter), which is inserted into the vaginal cavity, connected to an external pressure gauge. Women can watch the dial on the gauge as they contract their PFMs as instructed and monitor their progress. In the study conducted by Kegel (1948), the initial measurements (the first five days of starting PFM training) showed weak muscular contractions of about 20 mm of mercury resistance. Over the course of 25 days of progressive PFM training (20 minutes, three times a day), stronger muscular contractions were detected, at 80 mm of mercury resistance.

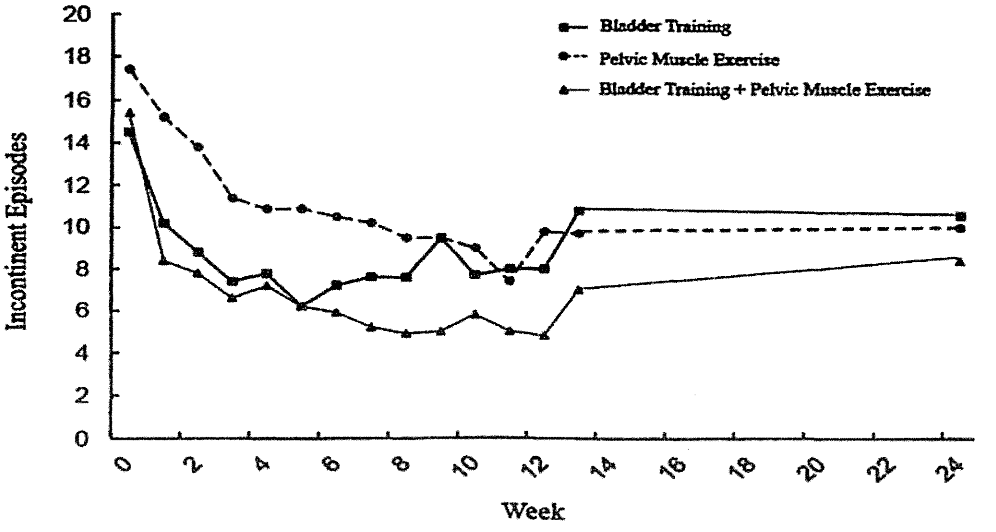

Figure 2. Change in mean weekly number of incontinent episodes over time by treatment group. (Wyman, J.F.; Fantl, J.A.; McClish, D.K. & Bump, R.C. (1998). Comparative efficacy of behavioral interventions in the management of female urinary incontinence. Continence Program for Women Research Group. *American Journal of Obstetrics and Gynecology,179*, 999-1007, with permission from Elsevier).

Exercise training periods vary between 3 weeks and 6 months. The greatest effect is seen at 6 weeks for bladder training; between 11 to 12 weeks for PFM exercise; and combined bladder training and PFM exercise seems to be most effective between 8 to 12 weeks of training (Wyman et al., 1998) (Figure 2).

2.2. Fitness Exercise

Previous studies have reported that urinary incontinence is associated with obesity and high body mass index (BMI). These studies suggest that increases in body weight causes increases in abdominal-wall weight, which in turn increases intra-abdominal pressure and intra-vesicular pressure (Bo, 2004). Therefore, abdominal fat reduction from exercise may decrease intra-abdominal pressure, perhaps causing improvements in urethral sphincter contraction; hence, decreasing urinary incontinence risk (Figure 3). Bump et al. (1992) found that surgically induced weight loss in obese women significantly reduces weekly incontinence episodes. Weight reduction is desirable for obese women with urinary incontinence (Subak et al., 2009).

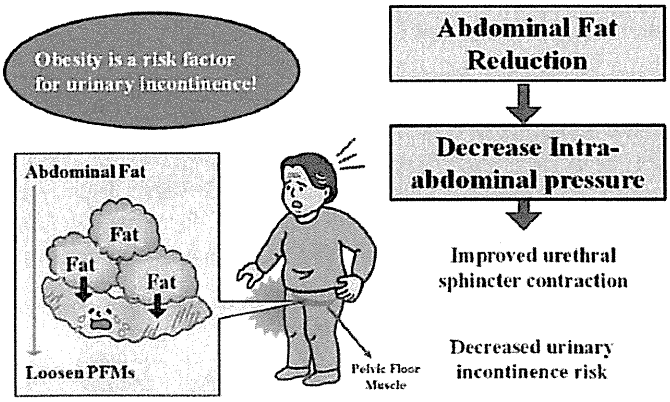

Figure 3. Relationship between abdominal fat and loosened pelvic floor muscles.

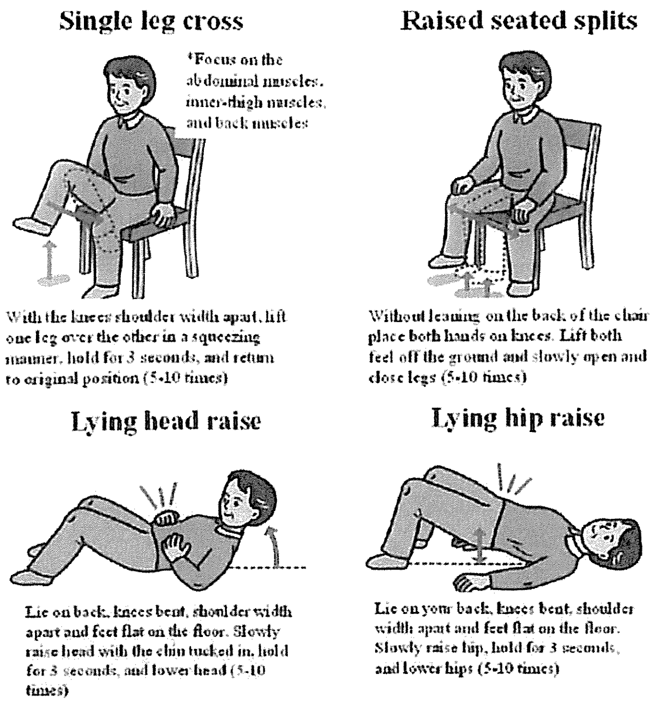

Figure 4. Examples of exercises aimed to reduce abdominal fat and increase mobility.