Original Article

Effects of 1-year weight loss intervention on abdominal skeletal muscle mass in Japanese overweight men and women

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Background and Objectives: Limited information is available on how weight loss intervention programs affect skeletal muscle mass especially in trunk. **Methods and Study Design:** A total of 235 overweight Japanese men and women aged 40-64 years with a body mass index of 28.0 to 44.8 kg/m^2 participated in this randomized controlled intervention study. They were randomly divided into a lifestyle intervention group and control group. Before and after the one-year lifestyle intervention for weight loss an abdominal transverse image was acquired by computed tomography. The cross-sectional areas (CSAs) of visceral fat, subcutaneous fat, and skeletal muscle of rectus abdominis, abdominal oblique, iliopsoas, and erector spinae muscle were calculated. **Results:** The body weight changed by approximately -5% in the intervention groups. The corresponding values for subcutaneous fat and visceral fat CSAs were -10.8 to -17.5% in both sexes. The reductions observed in skeletal muscle CSAs were significantly less (-6.0% and -7.2% in the men and women intervention groups respectively) than those in fat tissue CSAs. The CSA of each of the four skeletal muscle groups also significantly decreased; however, after adjustments for body weight at each time point, only reductions in the iliopsoas muscle in both sex and abdominal oblique muscles in men remained significant. **Conclusions:** The lifestyle weight loss intervention might reduce the relative amount of the abdominal skeletal muscles especially in iliopsoas muscle.

Key Words: muscle distribution, life style intervention, weight loss, visceral fat, middle-aged, Japanese

INTRODUCTION

Weight loss intervention programs are effective for reducing visceral fat mass. However, limited information is currently available on how these programs affect skeletal muscle mass, particularly in the trunk. Some longitudinal studies demonstrated the loss of skeletal muscle mass after the end of weight loss interventions, and in follow-up surveys, the limb's the skeletal muscle mass increased, whereas trunk skeletal muscles mass did not recover, particularly in men.[1-3] As for the cross-sectional studies, Zhang et al reported a negative correlation between the visceral adipose tissue area and psoas muscle density.[4] Tanaka et al also suggested the negative association between visceral fat and iliopsoas muscle group cross-sectional area (CSA) in overweight men.[5] These reports imply the visceral fat reduction following to weight reduction promotes the skeletal muscle loss.[4,5] In addition, individuals with visceral obesity need to train the abdominal skeletal muscles particularly the psoas muscle during the weight loss intervention. The trunk has a higher skeletal muscle mass than the limbs, therefore, reductions in trunk skeletal muscle mass with weight loss interventions may negatively and markedly affect whole-body skeletal muscle mass, similar to sarcopenia.[6] Sarcopenia is the age-related loss of skeletal muscle mass and physical function and leads to reduced mobilization and/or an inability to perform the simple activities of daily living (e.g., Cruz-Jentoft et al).[7] Sarcopenic obesity, in which skeletal muscle mass is lost while fat mass is preserved or even increases, has also been reported to have a negative impact on human health such as metabolic syndrome or physical disability.[8-11]

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Reactions to weight loss interventions may differ among each abdominal skeletal muscle group. Ryan and Harduarsingh-Permaul reported that, after a 6-month weight loss intervention, slight decreases in the erector spinae muscle CSA but not in the psoas muscle CSA.[12] Since their study only targeted elderly obese women, no data were obtained for other age groups and/or men. If skeletal muscle distribution changes in other ages or men following weight loss, it may cause low back pain or a balance ability. Furthermore, equations to estimate whole-body and/or trunk skeletal muscle mass from a single abdominal image cannot be applied after weight loss interventions.[13,14] Therefore, we investigated the relationship between weight loss and changes in the CSAs of abdominal skeletal muscles. We postulated that the CSA of a certain abdominal skeletal muscle group will decrease after the intervention.

METHODS

Subjects

This study was a secondary analysis of a randomized controlled trial, the Saku Control Obesity Program (SCOP, UMIN000016892), examining the effects of behavioral treatments and exercise at the Saku Central Hospital Human Dock Center.15 Recruitment was conducted by the Saku Health Dock Center in Nagano prefecture in 2006. This study is parallel randomized trial, namely that a total of 235 overweight Japanese men and women subjects aged 40-64 years (53.5±6.5 years) and with a body mass index (BMI) of 28.0-44.8 kg/m^2 (30.6±3.0 kg/m^2) were randomly divided into two groups: a lifestyle intervention group (individual-based counseling on diet and physical activity and control group. The control group received allocated intervention in second year (data was not shown in this study). The research plan was approved by the Ethical Committee of the National Institute of Health and Nutrition and Saku Hospital. Informed consent was obtained from all individual participants included in the study.

Intervention

This program was a one-year lifestyle intervention for weight loss based on a behavioral approach. Its contents were described in detail elsewhere.[15,16] Participants in the intervention group received individual counseling for diet and exercise as well as group sessions on effective exercise provided by registered dietitians and exercise instructors at the baseline and after 1, 3, 6, and 9 months. In the group session for exercise, an exercise instructor taught participants effective exercises for weight loss, such as how to stretch and walk, by providing examples, and participants mimicked these motions. In individual counseling sessions, participants discussed lifestyle habits (diet, dietary habits, and physical activities) that needed improvement and set monthly plans to modify them with the support of qualified fifteen dietitians, who usually worked as registered dietitians in their own places of employment and health fitness programmer. Participants in the control group did not receive any support in first 12 months and received intervention in following 12 months (data in second 12 months was not shown in the present study, then this study is a straight forward 12-month weight loss program for obese Japanese subjects). Due to the research style, participants and those assessing the outcomes were not blinded to group assignment.

Computed tomography (CT) measurement

Before and 1 year after the initiation of the intervention, a transverse image was acquired by CT at the level of the umbilicus while the subject was in a supine position. The CSAs of visceral fat tissue were assessed based on a CT scan (Fat scan; N2 system Corp., Japan) which was previously reported to strongly correlate with the directly ascertained total visceral fat volume by CT or magnetic resonance imaging.[17,18] The CSAs of subcutaneous fat and abdominal skeletal muscles, i.e., the rectus abdominis, abdominal oblique, erector spinae, and iliopsoas muscles, were semi-automatically calculated by a well-trained measurer using ImageJ (National Institute of Health, U.S.A.). A typical cross-sectional image, the definition of each skeletal muscle group and fat, the intra-class correlation coefficient, and coefficient of variation of each skeletal muscle group were reported elsewhere.[5]

Statistical analysis

Descriptive data were presented as the means and standard deviations (SDs) for each subject group. The Student's t-test was used to test the significance of differences between the means of men and women before interventions. Relationships between variables were analyzed using Pearson's correlation coefficient. Absolute and weight-adjusted differences in the CSA of each skeletal muscle were evaluated by two-way repeated measurements of ANOVA with post hoc. Statistical analyses were performed using SPSS 20.0 J (SPSS Japan, Inc., Tokyo, Japan). Statistical significance was set at $p<0.05$.

RESULTS

As a result of randomization, 59 men and 60 women were allocated to intervention group, and 57 men and 59 women to control group. There were no any important changes to the intervention delivered from what was planned, however, because of drop out, unclear image at either before or after the intervention, and obviously different locations before and after the intervention, some data were excluded from analysis. Finally, data for 207 participants (54 men and 51 women for intervention group, 50 men and 52 women for control group) was used to analyze (Figure 1). We calculated the sample size with the anticipated effect size: 0.25, desired statistical power level: 0.8, probability level: 0.05 by g*power software. The minimum sample size required was 34. The number of subjects in each group was larger than this number.

Physical characteristics before and after the intervention were shown in Table 1. Significant sex differences were observed in the mean values obtained for height, weight, and the CSAs of visceral fat, subcutaneous fat, and every skeletal muscle group before and after the intervention.

In the intervention group, the absolute values of all variables, except for the rectus abdominis in women, significantly decreased after the intervention (Table 1). Although body weight decreased by approximately 5% in the intervention groups, the corresponding decreases for

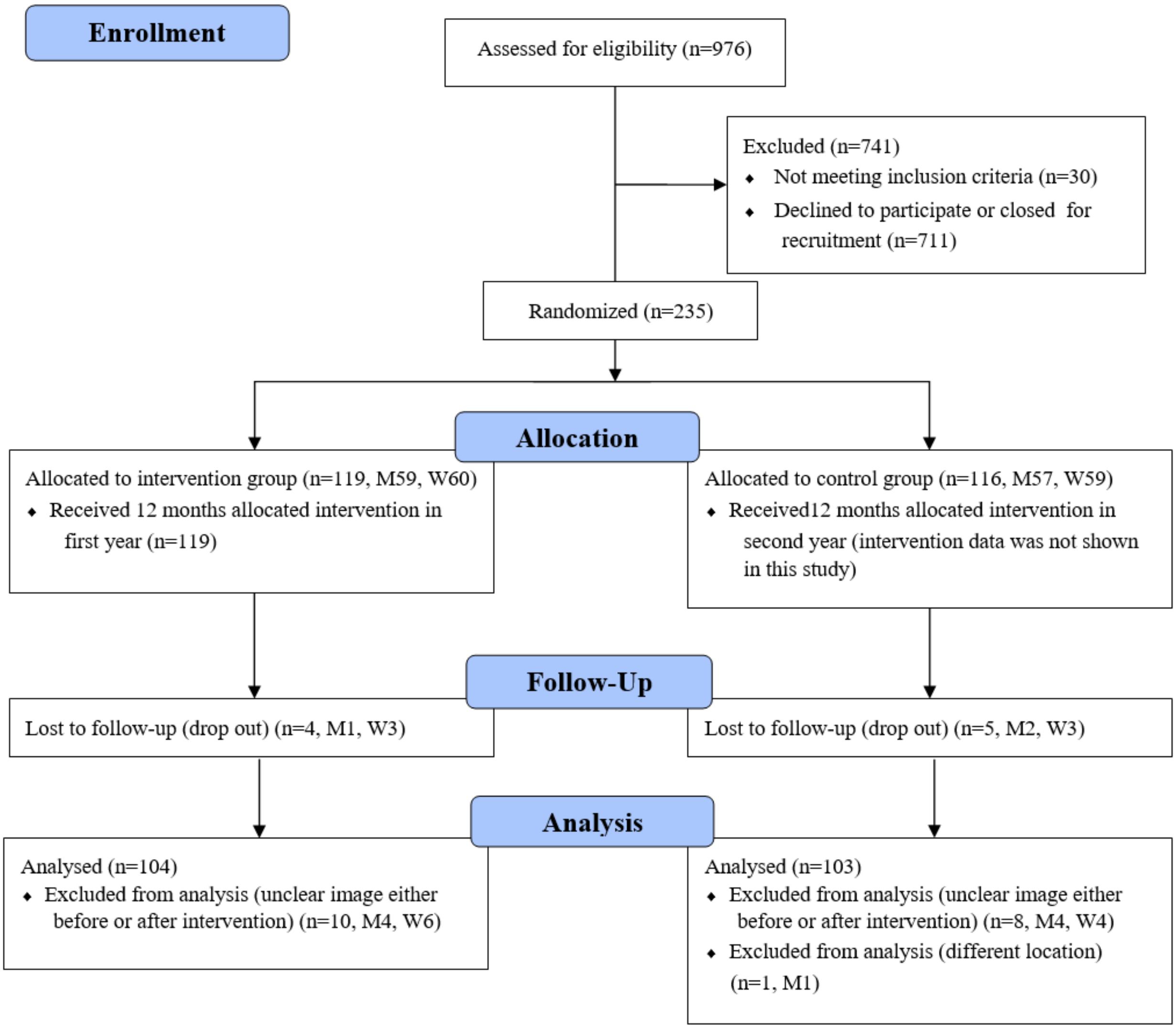

Figure 1. Participant flow of this study. M; men, W; women.

subcutaneous fat and visceral fat tissue (-10.8 to -17.5%) were more in both sexes. In contrast, no significant changes were observed in the control group.

The relationship between changes in body weight and the CSAs of visceral fat, subcutaneous fat, and skeletal muscles in the intervention group were shown in Figure 2. Significant relationships were observed in both sexes (r=0.380~0.860, $p<0.05$, respectively). The slopes of the regression lines were steeper for visceral fat and subcutaneous fat than for skeletal muscle.

The weight-adjusted CSAs (CSAs divided by body weight$^{2/3}$) of each skeletal muscle group in the intervention groups were shown in Table 2. In the men intervention group, the weight-adjusted CSAs in sum of all skeletal muscle groups, the abdominal oblique muscle, and the iliopsoas muscle significantly decreased ($p<0.05$). The corresponding value for the erector spinae muscle slightly decreased ($p<0.10$). In the women intervention group, weight-adjusted iliopsoas muscle CSA significantly decreased ($p<0.05$). The corresponding value for the abdominal oblique muscle slightly decreased ($p<0.10$). The CSA of the erector spinae muscle and the sum of the 4 skeletal muscle groups did not significantly change. In both sexes, the weight-adjusted CSA of the rectus abdominis muscle did not significantly change.

DISCUSSION

The main results of the present study were 1) a one-year lifestyle intervention for weight loss reduced subcutaneous and visceral fat CSAs more than skeletal muscle CSAs and 2) after the weight loss intervention, the distribution of abdominal skeletal muscle CSAs changed, namely, iliopsoas muscle CSA in both sex and abdominal oblique muscle CSA in the men significantly decreased, even after adjustments for differences in body weight before and after the intervention.

Previous studies reported that decreases in the skeletal muscle mass of the limbs were restored two years after weight loss interventions, whereas those in the trunk muscles were not.[1-3] Therefore, although skeletal muscle loss after weight loss interventions was less than that of fat tissues, skeletal muscle mass ideally needs to be maintained because the quantity of skeletal muscle is one of the factors influencing physical fitness such as maximum oxygen consumption (e.g., Proctor and Joyner) or joint torque.[19,20] Previous studies mostly reported the whole volume of trunk skeletal muscles only and information on which skeletal muscle group shows mass decreases following weight loss is limited. To the best of our knowledge, only Ryan and Harduarsingh-Permaul analyzed changes in abdominal skeletal muscle distribution

Table 1. Changes in physical characteristics of subjects.

	Intervention					Control				
	Pre		Post		Change	Pre		Post		Change
Variables	Mean	SD	Mean	SD	(%)	Mean	SD	Mean	SD	(%)
Men (n)			54					50		
Body weight (kg)	84.0	7.6	79.8*	8.0	-5.0	86.2	9.0	86.4	9.4	0.2
BMI (kg/m^2)	30.1	2.0	28.6*	2.1	-5.0	30.1	2.3	30.0	2.5	-0.2
Waist circumference (cm)	101	5.6	97.5*	5.9	-3.0	102	6.2	103	6.3	0.9
Subcutaneous fat (cm^2)	256	44.6	224*	47.0	-11.8	250	62.5	240	57.9	-2.9
Visceral fat (cm^2)	148	52.9	126*	48.9	-12.8	156	46.5	151	49.4	-1.2
Skeletal muscle (cm^2)										
Total	182	25.3	169*	20.9	-6.0	180	19.3	180	23.0	0.3
Rectus abdominis	16.2	3.8	15.0*	3.1	-4.5	17.0	4.6	17.1	5.1	0.2
Abdominal oblique	60.2	10.2	55.5*	9.7	-7.3	59.9	8.3	59.8	9.4	-0.2
Erector spinae	72.3	11.8	66.8*	11.8	-6.6	70.9	14.6	70.7	16.8	-0.4
Iliopsoas	34.7	6.9	31.9*	6.7	-7.7	32.2	7.2	32.7	7.2	2.3
Women (n)			51					52		
Body weight (kg)	73.2	7.2	69.3*	7.7	-5.3	73.8	7.1	73.6	7.9	-0.2
BMI (kg/m^2)	30.5	2.4	28.8*	2.8	-5.3	30.5	2.3	30.4	2.4	-0.2
Waist circumference (cm)	102	7.2	98.0*	8.0	-4.3	102	6.9	103	7.8	0.8
Subcutaneous fat (cm^2)	331	69.8	294*	69.3	-10.8	318	71.2	309	61.3	-1.7
Visceral fat (cm^2)	123	42.2	98.8*	35.4	-17.5	128	44.6	124	45.9	-3.0
Skeletal muscle (cm^2)										
Total	142	27.7	130*	16.8	-7.2	135	12.9	133	14.4	-1.1
Rectus abdominis	13.0	3.0	12.6	2.7	-0.4	13.0	2.6	13.1	3.0	1.3
Abdominal oblique	41.5	6.5	39.0*	6.3	-5.5	41.8	6.6	40.8	6.9	-2.3
Erector spinae	61.5	14.3	58.4*	13.4	-3.2	58.3	10.7	57.7	12.1	-0.1
Iliopsoas	21.5	4.2	19.9*	3.7	-6.5	21.9	3.7	21.6	3.4	-0.6

BMI: body mass index.
*Significantly different than Pre ($p<0.05$).

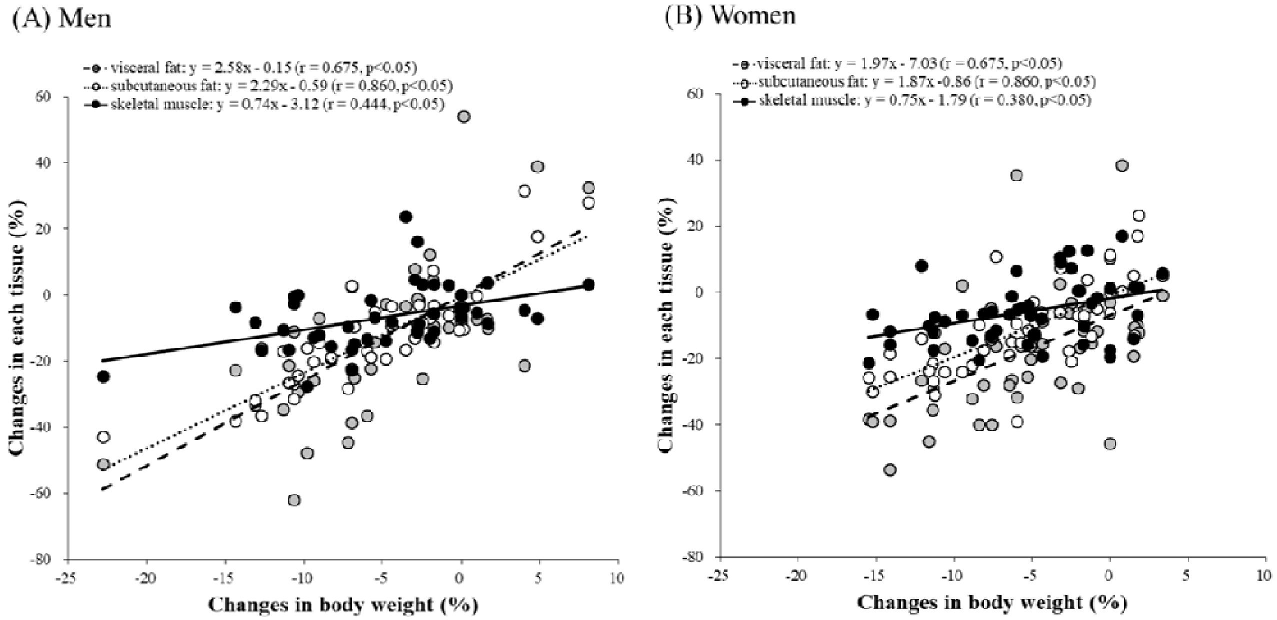

Figure 2. Relationship between changes in body weight and those in the CSAs of visceral and subcutaneous fat and skeletal muscle in intervention group. The left panel (A) was for men, and right panel (B) was for women.

Table 2. Changes in weight-adjusted skeletal muscle CSAs of intervention groups.

Skeletal muscles ($cm^2/kg^{2/3}$)	Men Intervention (n = 51)					Women Intervention (n = 52)				
	Pre		Post		Change (%)	Pre		Post		Change (%)
	Mean	SD	Mean	SD		Mean	SD	Mean	SD	
Total	9.49	1.15	9.14**	0.92	-2.8	7.88	0.81	7.71	0.77	-1.7
Rectus abdominis	0.84	0.19	0.81	0.15	-1.5	0.74	0.16	0.75	0.13	3.3
Abdominal oblique	3.14	0.48	3.00**	0.47	-4.1	2.38	0.37	2.53*	0.38	-2.1
Erector Spinae	3.78	0.61	3.61*	0.62	-3.4	3.53	0.80	3.46	0.70	0.4
Iliopsoas	1.81	0.33	1.72**	0.34	-4.5	1.23	0.22	1.18**	0.21	-3.0

Weight-adjusted skeletal muscle CSA: absolute CSAs were divided by weight$^{2/3}$.
*$p<0.10$; **$p<0.05$.

and their compositions after a weight loss intervention and reported a significant decrease in erector spinae muscle CSA in postmenopausal obese women.[12] Their finding are inconsistent with the present results, namely, significant reductions in iliopsoas muscle CSA in women. This discrepancy is mainly due to weight adjustments. Differences in the contents of exercise, durations of interventions, and subjects' age, and race also affect the controversial result. In any case, this study is the first to report a change in skeletal muscle distribution with adjustments for differences in body weight before and after a one-year weight loss intervention in middle-aged overweight Japanese men and women.

In previous studies, trunk muscles were divided into several muscle systems; the rectus abdominis and erector spinae muscles are global mobilizers that initiate movements, whereas the abdominal oblique and iliopsoas muscles are global stabilizers that are permanently active at low levels and complement the function of the local system by controlling and limiting movements by means of eccentric activation characteristics.[21-23] Both of the muscles showing significantly decreased masses following the present intervention were global stabilizers. In general, skeletal muscle reductions generally occur because of, for example, subclinical inflammation caused by tumor necrosis factor-α (TNF-α), interleukin-6 (IL-6), etc., loss of α-motor neuron input to muscle, enhanced protein degradation due to a lower nutritional intake, and withdrawal of hormonal anabolic input or insulin action, and so on.[24] The skeletal muscle CSAs in the control group did not change; therefore, the aging effect was excluded. Regarding the iliopsoas muscle, which plays a role in flexion the hip joint, the load to the muscle in daily life may have decreased because the absolute amount of the lower extremities decreased following the weight loss intervention. On the other hands, as for the abdominal oblique muscle, there might be an effect of abdominal pressure. Tanaka et al. reported a higher CSA for the abdominal oblique muscle in middle-aged men than in young men and speculated that this was caused by abdominal pressure in the middle-aged men.[6] Namely, the greater CSA of intraperitoneal tissue including visceral fat itself becomes a load during breathing and it may induce a greater percentage of CSA in respiratory muscles such as abdominal oblique muscle group.[25,26] In the present study, visceral fat CSA significantly decreased after the intervention. Therefore, reduced abdominal pressure may contribute to the decrease observed in abdominal oblique skeletal muscle CSA.

Although body weight decreased by approximately 5% after the intervention, the weight-adjusted CSAs of the rectus abdominis and erector spinae muscles did not significantly change. Exercise instructions such as stretching and walking in the present study may have suppressed reductions in rectus abdominis and erector spinae muscle CSAs because these are global mobilizers and anti-gravity muscles.[21] A previous study examined the muscle activities of the erector spinae and rectus abdominal muscles and suggested that their activation levels during daily life are higher than those of other skeletal muscle groups located in the abdomen.[22] Therefore, the different responses observed among the abdominal skeletal muscle groups following the weight loss intervention may be attributed to changes in the patterns of loading on these muscles and/or activation levels during daily physical activities. In other words, stretching and walking may be insufficient to mobilize and stimulate the iliopsoas and abdominal oblique muscles.

The present results indicated that the iliopsoas and abdominal oblique muscles in middle-aged Japanese men and women were negatively affected by weight reductions. Shen et al. reported an equation to predict whole-body skeletal muscle mass from abdominal skeletal muscle CSAs.[13] Recent studies used the iliopsoas skeletal muscle CSA at the height of the 3rd lumbar vertebra to diagnose disease-related muscle atrophy.[27-29] However, the present result indicated that the caution is needed when interpreting body weight changes based on these equations. Furthermore, the present results indicate that we need to specifically strengthen the skeletal muscles during weight loss periods. Especially, iliopsoas and abdominal oblique muscles which play important roles in daily life, such as stabilizing the lumbar spine.[30] Iliopsoas muscle also has a role in flexion the hip joint and is important for the prevention of fall in the elderly people. Sanada et al reported sarcopenia is a stronger predictor of all-cause mortality more than obesity or sarcopenic obesity in elderly over 70 years.[31] Therefore, resistance training at the middle age is thought to be more important for the future prevention of elderly care.

There were some limitations in the present study. We examined only 1 image from the abdomen. Although our preliminary study using 27 adult men showed a strong correlation between skeletal muscle CSA at the umbilicus level and the whole trunk skeletal muscle volume ($r=0.805$, $p<0.05$), the height of the umbilicus may be a little vary between individuals. In addition, the present study did not exclude intramuscular fat from skeletal muscle CSAs. Previous studies reported fat accumulation, particularly in the rectus abdominal muscle.[12] Therefore, contractile element in the rectus abdominis muscle might significantly decreased in the present study in fact. Moreover, this is a combined intervention of physical activity and dietary intake. We should demonstrate the difference of change in abdominal skeletal muscle mass between diet program and physical activity program or both. It is also informative the pattern of change in abdominal tissue composition not only at before and after 1-year intervention but also at different time points. Further studies are warranted to clear these points.

Finally, we investigated the effects of a one-year weight loss intervention on abdominal skeletal muscle CSAs. The results obtained showed that the intervention significantly reduced body weight and the CSAs of visceral fat, subcutaneous fat, and skeletal muscles in middle-aged and overweight Japanese men and women. However, when skeletal muscle CSAs were adjusted for body weight at each time point, significant reductions were only observed in the iliopsoas muscle in both sex and abdominal oblique muscle in men. These results indicate that when a weight loss intervention is applied, relative volume in the rectus abdominis and erector spinae muscles is preserved; however, strength training for the iliopsoas and abdominal oblique muscles needs to be added to maintain their CSA per body weight.

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AUTHOR DISCLOSURES

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