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Original Article

Association of Personality (NEO-Five Factor Inventory) with Eating Behaviors and Physical Activity Levels in Obese Subjects in the Saku Control Obesity Program (SCOP)

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Abstract

BACKGROUND: Obesity is one of the most common risks for lifestyle-related diseases, but the personality of individuals in relation to obesity has not been well studied. We investigated the association of personality traits with physical activity levels and eating behaviors in obese subjects.

METHOD: The subjects were 116 males and 119 females in the Saku Control Obesity Program SCOP study. The influence of personality on obesity was analyzed using a questionnaire from the NEO-FFI. We analyzed the association of physical activity level (measured with an accelerometer) and eating behavior (assessed by a questionnaire) among the three classes (low, average, high) of scores within five personality domains.

RESULTS: Scores in the Neuroticism and Agreeableness domains of females were significantly higher than those of males. There were significant differences among the three classes of Neuroticism and Agreeableness with regard to physical activity levels. Eating behavior was associated with the Neuroticism and Openness domains. The scales of bad eating behavior related to obesity were positively correlated with scores in the Neuroticism domain in both males and females. In males the scale of all categories of eating behavior increased as scores in the Openness domain rose; in females the scale of "perception of constitution and weight" decreased as Openness scores rose.

CONCLUSION: Personality determined by NEO-FFI was related to physical activity level and eating behavior. In particular, the Neuroticism domain had great effects on these parameters.

KEY WORDS: obesity, personality, NEO-FFI, eating behavior, physical activities

Introduction

Obesity appears to be closely correlated with personality, and recent studies have shown that obese people are at increased risk of depression and Neuroticism.[1,2] A study using the NEO-Five Factor Inventory (NEO-FFI) reported that obese females had more neurotic tendencies compared with females who were not obese.[3] In addition, Yoshida et al reported that the effectiveness of treatment for obesity was influenced by differences in personality.[4]

To further investigate the effects of personality traits on obesity, we performed a psychological behavior analysis (NEO-FFI) of obese participants in a weight-loss intervention program. The present NEO-FFI [5] is a shortened version of the Revised NEO Personality Inventory (NEO PI-R). Yoshimura et al translated this version into Japanese, and its reliability and validity have been confirmed.[6] NEO-FFI is a questionnaire that measures personality traits within five domains, and it has been most widely used in the United States. The NEO-FFI has proven useful for the study of health consciousness and behavior in both young and elderly subjects.[7,8]

Although a wide array of research has shown a positive effect of weight loss in the prevention of lifestyle-related diseases, methods to achieve changes in physical activity and eating behaviors in obese individuals have not been well developed. In addition, no studies have examined how personality traits are related to the process of losing weight in obesity education programs. Therefore, we conducted a multifactorial study of the physical activity levels and eating behaviors among obese subjects using the NEO-FFI questionnaire. We also tried to clarify whether individual personality assessment can serve as a valuable tool in such individualized education programs.

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Method

The subjects and methods of this study were described in detail elsewhere in this supplement.[9] Subjects were 235 obese people (116 males and 119 females; 40–64 years) with BMI > 28.3 kg/m^2 at their last medical check-up at the Saku Central Hospital. The participants gave written informed consent prior to being enrolled in the SCOP study.

The NEO-FFI consists of 60 questions, 12 for each of five personality domains. For each question, subjects express agreement or disagreement on a five-point Likert scale: (1) strongly disagree, (2) disagree, (3) neutral, (4) agree, (5) strongly agree. The NEO-FFI is used to measure the five major domains of individual personalities (Neuroticism, Extroversion, Openness, Agreeableness, and Conscientiousness), which allow for a comprehensive assessment of normal adult personality. Raw scores of Neuroticism, Extroversion, Openness, Agreeableness, and Conscientiousness were converted into *T*-scores, and each domain was grouped into three classes: high (T = 56 and higher), average (T = 45-55), and low (T = 44 and lower).[10] *T*-scores have a mean of 50 and a standard deviation of 10 and allow for comparison of individuals across the population.

Physical activity levels were measured using an accelerometer (Suzuken, Nagoya, Japan); the details of how these levels were assessed is described elsewhere.[11] The device can monitor the number of steps as well as exercise intensity with the acceleration sensor, allowing calculation of the caloric expenditure through physical activity. Each subject received the device 2 weeks before the baseline health check-up. Participants were unable to view the data so that they would not consequently alter their normal routines of physical activity.

Participants'eating behavior was analyzed by a questionnaire in the Manual of Obesity 2006 written by the Japan Society for the Study of Obesity (see Appendix 1).[12,13] The questionnaire's 55 statements are based on the statements given by obese people in a clinical survey, and subjects were asked to agree or disagree on a four-point Likert scale: (1) disagree, (2) sometimes, (3) having a trend, (4) agree. The questionnaire is assessed by categorizing 51 items into the following eight categories: (1) perception of constitution and weight, (2) motivation for eating, (3) unhealthful eating, (4) feeling of fullness and hunger, (5) bad eating habits, (6) contents of diet, (7) unsteady eating pattern, and (8) total of all of them. One is a dummy question. The higher score in this questionnaire indicated worse in eating behavior. Based on each participant's answers; his or her eating behaviors were plotted along these eight axes and used for further analysis. Because we slightly modified the eating behavior questionnaire, the validity of the eight categories was analyzed using principal component analysis.

The associations between personality, physical activity levels, and eating behaviors were analyzed using SPSS® version 14.0 (SPSS Inc., Tokyo). Associations among the mean physical activity levels, eating behavior categories, and NEO-FFI classes were analyzed by ANOVA, Bonferroni test, and Games-Howell multiple comparison. Analysis was administrated according to each subject's sex because selecting the different question from 55 question to assess each category by sex. The database was processed using Excel®2003 (Microsoft, Redmond, WA, USA) and converted to SPSS.

Results

The mean and standard deviation of NEO-FFI raw scores of the subjects and the distribution of *T*-scores among the low, average, and high classes for each personality domain are shown in ***Table 1*** and ***Figure 1***. The raw scores for both males and females coincided well, except for significantly higher scores in females in the domains of Neuroticism and Agreeableness. Within each sex, there was no significant difference in the distribution of *T*-scores across all domains. Correlation coefficients among the raw scores of the NEO-FFI are shown in ***Table 2***. Significant negative associations were found between Neuroticism and Extroversion and between Neuroticism and Agreeableness in males. In females, however, significantly negative associations existed between Neuroticism and Extroversion, Neuroticism and Agreeableness, and Neuroticism and Conscientiousness, but significantly positive associations were found between Extroversion and Agreeableness, Extroversion and Conscientiousness, and Agreeableness and Conscientiousness.

Table 1 ***The raw score of NEO-Five Factor Inventory***

	male (n = 116)	female (n = 119)	total (n = 235)
Neuroticism	22.8 ± 5.6	25.5 ± 6.8 *	24.2 ± 6.4
Extraversion	25.3 ± 5.6	26.7 ± 6.1	26.0 ± 5.9
Openness	28.2 ± 5.1	28.6 ± 4.5	28.4 ± 4.8
Agreeableness	29.7 ± 4.4	32.2 ± 4.3 *	31.0 ± 4.5
Conscientiousness	28.1 ± 5.2	28.5 ± 5.9	28.3 ± 5.5

Value present the mean ±SD
* Significantly diffelent between sex (P<0.05)

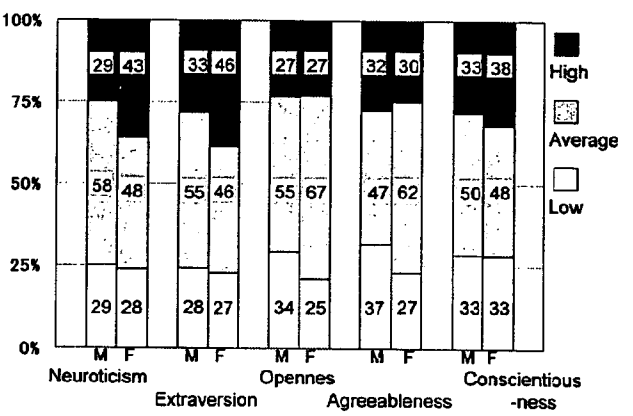

Fig. 1. The distribution of *T*-scores among the low class (T = 44 and lower), average class (T = 45–55), and high class (T = 56 and higher) in each personality domain of the NEO-FFI by sex. The values indicate the number of subjects (males, M, n = 116; females, F, n = 119)

· Relationship between NEO-FFI Scores and Physical Activity

Although the absolute number of daily step counts was greater in females (8015 ± 3126) than in males (7601 ± 3300), there was no significant difference between these values. METs h (exercise intensity × time) was similar in males and females: 3.0 ± 1.4 and 3.1 ± 1.3, respectively.

Tables 3 and 4 lists the number of steps and physical activity levels according to *T*-score class among the NEO-FFI domains. In females, daily step counts and METs·h were low in those with low Neuroticism scores, and physical activity was significantly higher in the average class than in the low class of Neuroticism.

Table 2 Correlation coefficients in the scales of the five domain of NEO-Five Factor Inventory

	male : n = 116				female : n = 119			
	Extraversion	Openness	Agreeableness	Conscientiousness	Extraversion	Openness	Agreeableness	Conscientiousness
Neuroticism	-0.30 *	0.08	-0.23 *	-0.12	-0.43 *	0.01	-0.24 *	-0.32 *
Extraversion		0.06	0.11	0.18		-0.02	0.32 *	0.47 *
Openness			0.18	0.16			0.15	0.01
Agreeableness				-0.15				0.25 *

* $p<0.05$

Table 3 The association between the daily step counts and NEO-Five Factor Inventory.class in each domain

	Low class			Average class			High class		
		mean ± SD	(n)		mean ± SD	(n)		mean ± SD	(n)
Neuroticism	male	7178 ± 3284	(26)	male	7479 ± 3424	(57)	male	8242 ± 3069	(28)
	female	6741 ± 2422	(28)	female	8692 ± 3467	(48)	female	8090 ± 2937	(43) * a
Extraversion	male	7945 ± 2118	(27)	male	7512 ± 3848	(52)	male	7455 ± 3222	(32)
	female	7435 ± 3036	(27)	female	7918 ± 2980	(46)	female	8454 ± 3319	(46)
Openness	male	7926 ± 3301	(34)	male	7254 ± 2967	(51)	male	7856 ± 3932	(26)
	female	8303 ± 3371	(25)	female	7789 ± 2632	(67)	female	8310 ± 3999	(27)
Agreeableness	male	8659 ± 3950	(34)	male	6703 ± 2542	(46)	male	7773 ± 3244	(31) * a
	female	8825 ± 3366	(27)	female	7898 ± 2830	(62)	female	7529 ± 3448	(30)
Conscientiousness	male	7428 ± 3180	(32)	male	7364 ± 2624	(50)	male	8200 ± 4361	(29)
	female	7102 ± 2696	(33)	female	8055 ± 3080	(48)	female	8696 ± 3425	(38)

* Significant between groups by ANOVA (P<0.05)
a : Significantly different between Low class and Average class (P<0.05)
Low class : *T*-scores = 44 and lower
Average class : *T*-scores = 45 - 53
High class : *T*-scores = 56 and higher

Table 4 The association between METs · h and NEO-Five Factor Inventory class in each domain

	Low class			Average class			High class		
		mean ± SD	(n)		mean ± SD	(n)		mean ± SD	(n)
Neuroticism	male	2.8 ± 1.3	(26)	male	3.0 ± 1.5	(57)	male	3.3 ± 1.3	(28)
	female	2.6 ± 1.0	(28)	female	3.4 ± 1.5	(48)	female	3.2 ± 1.2	(43) * a
Extraversion	male	3.2 ± 0.9	(27)	male	3.0 ± 1.7	(52)	male	3.0 ± 1.3	(32)
	female	2.9 ± 1.3	(27)	female	3.1 ± 1.3	(46)	female	3.3 ± 1.4	(46)
Openness	male	3.1 ± 1.4	(34)	male	2.9 ± 1.3	(51)	male	3.1 ± 1.7	(26)
	female	3.2 ± 1.5	(25)	female	3.0 ± 1.1	(67)	female	3.3 ± 1.7	(27)
Agreeableness	male	3.5 ± 1.8	(34)	male	2.6 ± 1.1	(46)	male	3.1 ± 1.3	(31) * a
	female	3.5 ± 1.5	(27)	female	3.1 ± 1.2	(62)	female	2.9 ± 1.5	(30)
Conscientiousness	male	3.0 ± 1.4	(32)	male	2.9 ± 1.2	(50)	male	3.3 ± 1.9	(29)
	female	2.8 ± 1.1	(34)	female	3.2 ± 1.4	(47)	female	3.4 ± 1.5	(38)

* Significant between groups by ANOVA (P<0.05)
a : Significantly different between Low class and Average class (P<0.05)
Low class : *T*-scores = 44 and lower
Average class : *T*-scores = 45 - 53
High class : *T*-scores = 56 and higher

In males, there were no significant differences in daily step counts and METs·h among the Neuroticism classes. With regard to Agreeableness scores, in males both physical activity measures were lower in the average class than in the low and high classes. In females there was an increase in daily step counts and METs·h as Conscientiousness scores rose, but no significant difference existed among the classes according to ANOVA.

· Association between Eating Behavior and NEO-FFI Scores

The results of the principal component analysis with a varimax rotation for eating behavior are shown by sex in *Table 5*. According to the principal component analysis, 16 factors had eigenvalues > 1.0. For each sex, we chose the five highest factors, where the cumulative percentage for attribution was no less than 40%. In males, these factors were: (1) eat between meals; (2) fast eating·gluttony; (3) uncertainty of hunger; (4) promiscuous eating habits·dining out; and (5) supper conscious. In females the top factors were: (1) comfort eating·Western food; (2) uncertainty of hunger; (3) fast eating; (4) dining out; and (5) promiscuous eating habits. We examined the relationship between principal component scores of these factors and the raw scores in the five personality domains; although some associations were significant, the coefficients were all less than 0.265 (data not shown).

Stronger correlations were found between the eight eating behavior categories within the Manual of Obesity 2006

Table 5-1 Rotated factor loading based on rank correlations of eating behaiver

Male	Factor				
	1 Eat between meals	2 Fast eating· Gluttony	3 Uncertainty of hunger	4 Promiscuous eating habits· Dining out	5 Supper-conscious
I often eat between meals.	0.817	0.073	0.019	0.142	0.025
I often eat snacks.	0.778	0.061	-0.013	-0.016	0.073
I tend to eat anything when I have nothing to do.	0.671	0.115	0.181	0.089	-0.044
I often eat sweet rolls.	0.585	-0.082	0.048	0.064	0.089
I always keep food around.	0.550	0.124	0.158	0.311	0.030
I often have a midnight snack.	0.543	0.043	-0.021	0.247	0.064
I don't have a sense of hunger and fullness.	0.403	0.214	0.323	0.195	0.106
I eat a meal fast.	0.094	0.825	-0.069	0.107	-0.059
I don't chew well.	0.051	0.811	0.119	0.105	0.074
I eat as putting food into my mouse one after another.	0.043	0.759	0.236	0.010	0.042
I stuff food into my month.	-0.019	0.632	0.140	0.125	0.058
I'm told I eat a lot.	0.390	0.515	0.241	0.024	0.129
I don't satisfied unless I eat my fill.	0.340	0.440	0.033	0.156	0.159
I tend to order more than I can eat at eating out.	0.085	0.414	0.112	0.063	0.191
Just a meal, I can eat my favorite foods a meal	0.336	0.390	0.206	0.001	0.134
I cannot help cooking more than enough.	-0.008	0.198	0.757	0.074	-0.022
I eat a lot at dinner compared with other meals.	0.062	0.283	0.724	0.076	0.212
I'm uncomfortable unless I keep enough food let in a refrigerator.	0.191	0.017	0.625	0.165	0.071
When I find something good at the grocery store, I buy it even if it is not planed.	0.192	0.053	0.483	0.006	0.424
I eat well even if I have a cold.	0.029	0.267	0.399	0.046	-0.093
I have dinner late.	0.012	0.103	0.039	0.768	0.158
I don't have a regular meal rhythm.	0.233	0.183	0.103	0.649	-0.048
I don't have enough time to eat meal.	0.324	0.324	0.176	0.643	-0.012
I am a night person	0.098	-0.039	-0.199	0.554	0.157
I often eat out and have food delivered.	0.007	-0.061	0.274	0.545	0.308
I often buy at the convenience stores.	0.288	0.070	0.071	0.379	0.262
I have much occasions to attend dinner at drinking parties.	0.068	0.016	-0.060	0.145	0.781
I have many social occasions to eat.	0.101	0.219	0.066	0.203	0.681
I drink beer often.	-0.152	-0.009	0.155	0.010	0.572
I am not satisfied when a very few-food items are served at dinner.	0.174	-0.025	0.398	-0.057	0.535
I can't sleep when I feel hungry.	0.045	0.137	0.183	0.107	0.417

Principal components analysis with varimax rotation
Figure in front of each question is the number of each items of questionnaire (see Appendix)

Table 5-2 Rotated factor loading based on rank correlations of eating behaiver

Female	Factor				
	1 Cumfort eating, Western food	2 Uncertainty of hunger	3 Fast eating	4 Dining out	5 Promiscuous eating habits
I tend to eat fruits and sweets when I see them.	0.772	0.275	0.080	0.134	0.064
Just a meal, I can eat my favorite foods a meal	0.711	-0.014	0.253	-0.116	0.383
I tend to eat anything when I have nothing to do.	0.637	0.180	-0.020	0.257	-0.079
I tend to eat when I see others eating.	0.633	0.336	0.030	0.156	-0.150
I love sweets.	0.611	0.132	0.123	0.073	0.227
I always gain weight whenever I take long holidays.	0.603	-0.016	0.006	0.210	-0.133
I regret after I eat a lot.	0.575	0.282	0.218	0.087	-0.003
I often eat between meals.	0.574	0.124	0.068	0.003	0.237
I don't satisfied unless I eat my fill.	0.565	0.200	0.324	-0.076	0.153
I tend to eat when I am irritated or stressed.	0.554	0.138	-0.044	0.077	0.276
I believe that I gain weight because I like sweets	0.504	0.108	-0.054	0.081	0.048
I'm told I eat a lot.	0.502	0.203	0.250	0.094	-0.086
I eat more western food than Japanese food.	0.468	-0.275	0.118	0.445	0.050
I like greasy food.	0.420	-0.009	0.208	0.233	-0.022
I eat a lot at dinner compared with other meals.	0.136	0.785	0.022	-0.108	0.113
I cannot help cooking more than enough.	0.154	0.750	0.157	-0.215	0.052
I'm uncomfortable unless I keep enough food let in a refrigerator.	0.220	0.687	0.062	0.025	-0.165
I tend to order more than I can eat at eating out.	0.104	0.568	0.063	0.289	0.222
When I find something good at the grocery store, I buy it even if it is not planed.	0.340	0.471	0.166	0.120	0.172
I always keep food around.	0.326	0.403	0.153	0.274	0.152
I eat a meal fast.	0.047	0.053	0.818	0.162	-0.045
I don't chew well.	0.133	0.123	0.776	0.081	0.109
I eat as putting food into my mouse one after another.	0.238	0.159	0.632	0.121	0.126
I often buy at the convenience stores.	0.171	-0.078	0.148	0.755	0.194
I often eat fast food like hamburgers.	0.187	-0.010	0.025	0.718	-0.134
I eat meal a lot.	0.263	-0.145	0.207	0.525	0.090
I often eat out and have food delivered.	-0.059	0.194	0.196	0.507	0.314
I don't have a regular meal rhythm.	0.069	0.124	-0.039	0.040	0.765
I have dinner late.	0.154	-0.004	0.147	0.124	0.717
I often have a midnight snack.	0.250	0.230	0.197	0.010	0.485

Principal components analysis with varimax rotation
Figure in front of each question is the number of each items of questionnaire (see Appendix)

questionnaire and the raw scores in each of the personality domains *(Table 6)*. In females, scores in the eight categories had negative associations with the domains of Extroversion, Openness, Agreeableness, and conscientiousness. In both males and females, however, the associations with Neuroticism were positive. Extroversion scores had significant positive associations with eating behavior scores only in males, whereas Agreeableness and Extroversion scores had significant negative associations with these scores only in females.

We compared the mean score of the eight eating behavior categories by sex with those from a previous study on normal-weight subjects *(Fig. 2)*.[12] In both males and females, the scales of "perception of physical constitution and weight" and "bad habits for eating" in our subjects were much higher than those of the normal-weight subjects.

Diagrams of the eight eating behavior categories by three classes (low, average, high) of Neuroticism and Openness are shown in *Figure 3* (no other domains showed significant associations). Significant differences among the three classes of Neuroticism scores were seen in the categories "unhealthful eating" and "feeling of fullness and hunger" in males. In all categories, the higher the Neuroticism class, the higher the eating behavior score. Females showed a similar trend, except "total points," "unsteady eating pattern," and "contents of meals" also showed significant difference between Neuroticism classes. Among the three classes of Openness scores, there were significant differences in the eating behavior categories of "total points," "motivation for eating," "unhealthful eating," and "unsteady eating pattern" in males. In females, "contents of meals," and "perception of constitution and weight" showed a significant difference among Openness classes.

Table 6 Correlation coefficients between NEO-Five Factor Inventory scale and principal component score by eating behavior questionnaire

		Neuroticism	Extraversion	Openness	Agreeableness	Conscientiousness
Male	Total point	0.221 *	0.204 *	0.272 *	0.007	-0.015
	Conception of body constitution and weight	0.090	0.120	0.084	-0.142	0.123
	Motivation for eating	0.112	0.204 *	0.273	0.079	0.030
	Unhealthful eating	0.338 *	0.022	0.278 *	-0.082	0.099
	Feeling of fullnes and hunger	0.313 *	0.141	0.155	-0.023	0.070
	Bad habits for eating	0.212 *	0.197 *	0.174	0.058	-0.056
	Contents of meals	0.015	0.192 *	0.111	0.009	-0.136
	Unsteady of eating pattern	0.224 *	0.114	0.316 *	0.051	-0.111
Female	Total point	0.277 *	-0.055	-0.085	-0.133	-0.211 *
	Conception of body constitution and weight	0.143	-0.046	-0.271 *	-0.176	-0.225 *
	Motivation for eating	0.161	0.087	0.012	0.052	-0.106
	Unhealthful eating	0.353 *	-0.136	-0.024	-0.112	-0.090
	Feeling of fullnes and hunger	0.238 *	-0.114	-0.042	-0.168	-0.140
	Bad habits for eating	0.148	-0.003	-0.082	-0.103	-0.114
	Contents of meals	0.240 *	-0.098	-0.208 *	-0.207 *	-0.240 *
	Unsteady of eating pattern	0.203 *	-0.070	0.095	-0.081	-0.192 *

* $p<0.05$

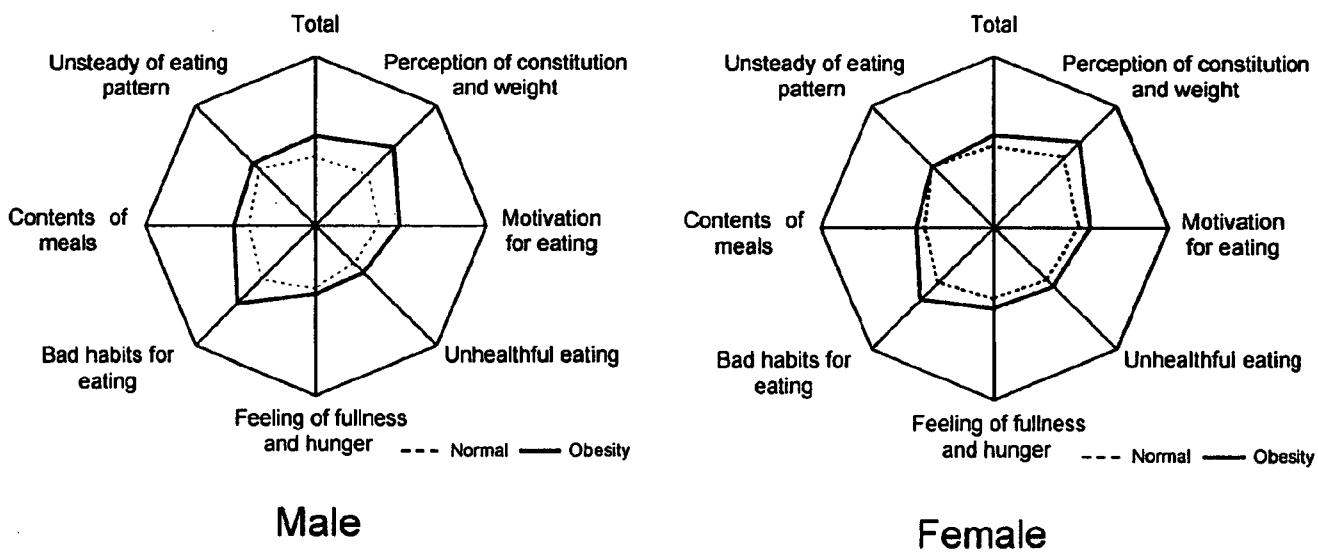

Fig. 2. Comparison between the eating behaviors of obese subjects in this study and normal-weight subjects in a previous study.[12] Displayed are the scores of obese subjects (solid line) and normal-weight subjects (dash line) by sex.

Fig. 3a

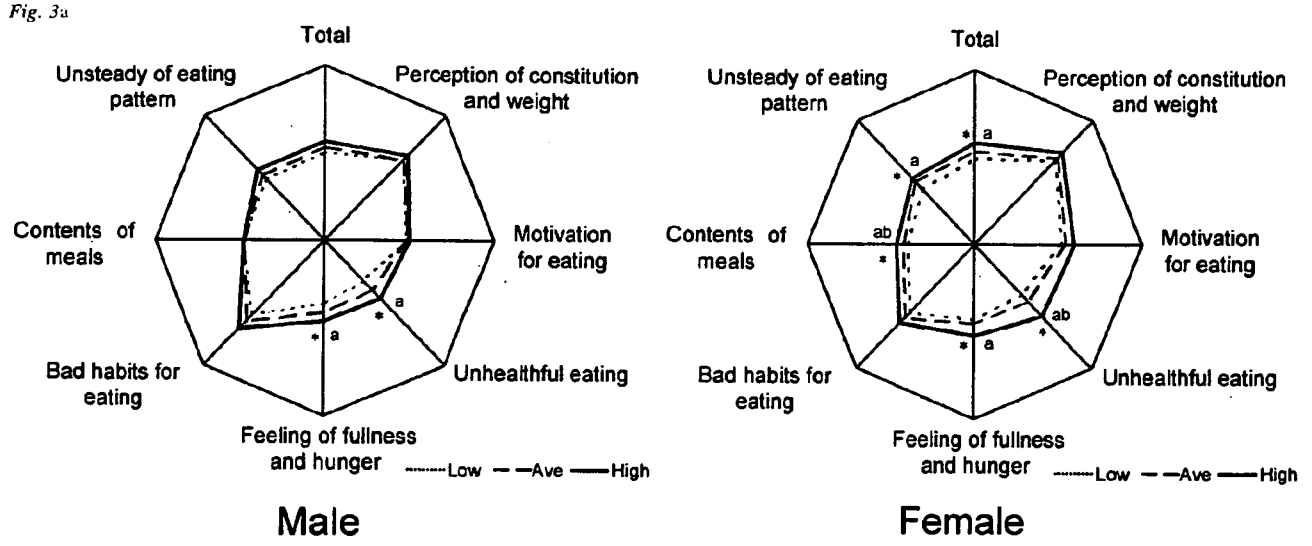

Fig. 3b

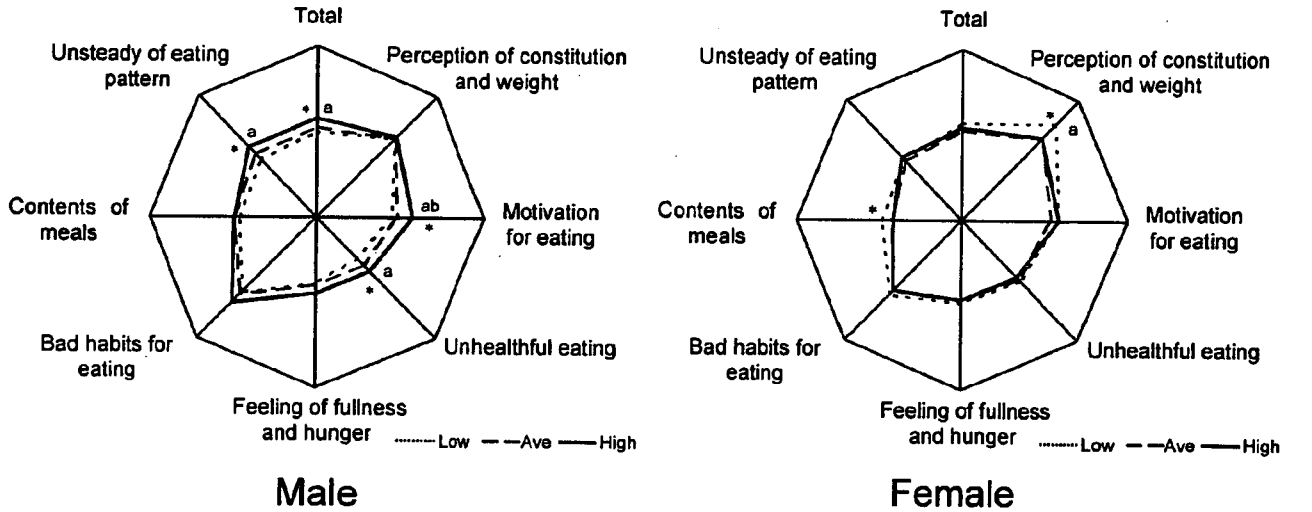

Fig. 3. Comparison of the eating behaviors among subjects in the low, average, and high classes of Neuroticism (a) and Openness (b), separated by sex (males, left; females, right). Asterisks indicate significant difference among the three classes (ANOVA, *p < 0.05). Each superscript indicates significant difference between High vs Low (a: P<0.05), significant between High vs Ave in (b:P<0.05), significant between Ave vs Low (c: P<0.05) by multiple comparison.

Discussion

Basic personality is considered to be static throughout a person's life unless a significant incident occurs.[14] Therefore, personality is an important element that affects an individual's lifestyle, including eating behavior and physical activities. However, the relationship between lifestyle and the personality traits of obese people has not been studied in detail.

According to Costa and McCrae, the five-factor model of personality should not be used to judge the value (i.e., good vs. bad) of particular personality traits;[14] rather it allows for a comprehensive assessment of normal adult personality. Consistency was reported between the five personality domains of the NEO-FFI as rated by the subjects themselves and by close family and friends. This consistency suggests that the questionnaire in the NEO-FFI can be successfully translated into different languages without losing efficacy.

Considering the distribution of NEO-FFI personality domains among the subjects in this study, in females there was a tendency to *T*-score higher in Neuroticism and Extroversion, although there were no significant differences among the low, average, and high classes in these domains. The mean *T*-score and the standard deviation of the subjects in this study were 56 and 28, whereas those in the normative population were 50 and 10 for each domain. Thus, compared with the subjects who are representative samples of other area examined in previous studies [6,15] our subjects tended to be somewhat more neurotic and extroverted. It is expected that these differences were influenced from obesity. However, they might are influenced from regional difference. An American national survey[16] showed that the distribution of NEO-FFI was not effected by the differences of age, race and sex. Thus, it is necessary to compare the subjects in same region for more reliable results.

Costa and Mcrae said that an individual with high scores of Neuroticism tends to be nervous, uneasy, and very sensitive to stress, whereas a person with low scores of Neuroticism tends to be relaxed and stable.[14] A study by Gidi showed a positive

correlation between BMI and Neuroticism scores in both obese and the non-obese females.[3] In addition, previous studies showed that Neuroticism is positively correlated with levels of Eating Disorder and bad eating behavior.[17,18] In this study, females in the high class for Neuroticism showed high scores for eating behaviors. Thus, it is suggested that a person with high scores of Neuroticism may have some problems related to eating behavior. Also, females in the high class for Neuroticism had high daily step counts and high METs·h. Considering the result, people with a low Neuroticism score, who tend to be relaxed, secure, and confident, may not overeat but may also engage in little physical activity.

In males, the scores of all categories of eating behavior increased as Openness scores rose. People with a high degree of Openness tend to be very curious and quick to take positive actions,[10] and their curiosity and activities might cause somewhat of a rise in appetite. In contrast, we found no positive association between Openness scores and eating behaviors among females. Thus, it appears that the effects of Openness on eating behavior differ between males and females.

With regard to Agreeableness, the average class of males showed low values for daily step counts and METs·h, whereas those in the low and high classes had higher physical activity. Meta analysis studying the correlates of personality and physical activities did not show the association between Agreeableness and physical activities until 2006.[19] Subjects of the studies which use NEO-FFI including this meta-analysis were selected from students, cancer survivors, elderly people; were not middle-aged people such as our study. It isn't still clear that there was the association between Agreeableness and physical activities. It is necessary to clearly the association of NEO-FFI and physical activities in greater number of samples with and without obesity in general population including middle-aged people.

According to our analysis based on the NEO-FFI, different personality trait distributions were found between obese people and the general population, so further study regarding personality traits is necessary for the obese population. For instance, among the five personality domains, there was a significant difference in eating behaviors among the three classes of Neuroticism in both males and females, with the scores of nearly all categories of eating behavior increasing as Neuroticism scores rose. The associations between eating behaviors, physical activity levels, and personality traits defined by the NEO-FFI showed that personality analysis can serve as a useful tool in health education. As seen in ***Figure 2***, obese people showed a broader range of scores for the eight categories of eating behavior compared to the general adult population.[12] Using this eating behavior questionnaire, we were able to identify which categories caused more problems for each subject, which can then be used to improve an individual's eating behavior through nutritional education.

Although personality has long been considered to be unchangeable throughout an individual's life, Adil et al. recently reported that the personality scales have changed in a short period of time.[20] Another study reported that the NEO-FFI scales differ between elderly people and college students.[21] Thus, if personality can change over the course of a person's life, these baseline data should help us to elucidate which pre-intervention traits allow for more successful behavior modification with regard to eating behavior and physical activity.

Questionaire of eating behavior

	Question	Question number from Mannual of Obesity
1	I often have a midnight snack.	4
2	I am a night person	18
3	I don't have a regular meal rhythm.	27
4	I often eat between meals.	21
5	I don't have enough time to eat meal.	47
6	I have dinner late.	37
7	I don't eat breakfast.	48
8	I'm often told I eat a lot.	8
9	Just a meal, I can eat my favorite foods a meal	13
10	I don't satisfied unless I eat my fill.	15
11	I regret after I eat a lot.	32
12	I can't sleep when I feel hungry.	39
13	I think about next meal just after a meal.	45
14	I often eat snacks.	11
15	I like strong seasoning.	14
16	I often eat fast food like hamburgers.	30
17	I like greasy food.	43
18	I like noodles.	19
19	I often eat sweet rolls.	40
20	I love sweets.	52
21	I tend to eat left-over food because I don't want to waste.	12
22	I tend to eat when I am irritated or stressed.	16
23	I always keep food around.	23
24	I tend to eat when I see others eating.	24
25	I tend to eat fruits and sweets when I see them.	34
26	I always gain weight whenever I take long holidays.	20
27	I tend to eat anything when I have nothing to do.	31
28	I believe myself to gain weight more easily than others.	42
29	I believe myself to gain weight even by drinking water.	22
30	I eat a meal fast.	1
31	I eat as putting food into my mouse one after another.	55
32	I don't chew well.	25
33	I stuff food into my mouth.	41
34	I tend to order more than I can eat at eating out.	28
35	I cannot help buying more food than necessary.	33
36	I cannot help cooking more than enough.	38
37	I believe that I gain weight because I like sweets	2
38	I often buy at the convenience stores.	3
39	I eat a lot at dinner compared with other meals.	35
40	I gain weight because I have not sufficient physical activity.	36
41	I'm uncomfortable unless I keep enough food let in a refrigerator.	5
42	When I find something good at the grocery store, I buy it even if it is not planed.	44
43	I drink beer often.	46
44	I am not satisfied when a very few-food items are served at dinner.	17
45	I don't have a sense of hunger and fullness.	49
46	I have many social occasions to eat.	50
47	I don't loose weight although I don't so much.	51
48	I tend not to be hungry before meals.	53
49	I eat meal a lot.	54
50	I gain weight because I lie down soon after I finish meal.	6
51	I have much occasions to attend dinner at drinking parties.	7
52	I get irritated when I'm hungry.	9
53	I eat well even if I have a cold.	10
54	I eat more western food than Japanese food.	29
55	I often eat out and have food delivered.	26

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メタボリックシンドロームと生活習慣との関連

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調査・研究

メタボリックシンドロームと生活習慣との関連

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はじめに

メタボリックシンドロームは内臓脂肪の蓄積を基盤に，高血圧，耐糖能障害，脂質代謝異常などが集積し，動脈硬化をもたらすとして注目されている[1)]．日本では2005年4月，メタボリックシンドローム診断基準検討委員会により診断基準が公表された[2)]．

メタボリックシンドロームの予防，改善では薬物療法にも増して，日々の運動や食事の生活習慣が重要であることは容易に予想される．今回われわれは，今後のメタボリックシンドロームの予防，改善のための適切な生活習慣介入法の資料とするために，わが国のメタボリックシンドロームの診断基準を用いて，メタボリックシンドロームと生活習慣との関連を検討した．

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1. 対象と方法

対象は，岡山県南部健康づくりセンターで，形態計測，安静時血圧測定，空腹時採血，自記式アンケートによる生活習慣調査を行なった男性1,252名，女性1,934名，合計3,186名であった（表1）．

形態計測では，身長，体重，ウエスト囲，ヒップ囲を，空腹時採血では，中性脂肪，HDLコレステロール，血糖を測定した．また，食事，運動，タバコ，アルコールに関する13項目の自記式アンケートを行なった（表2）．

メタボリックシンドロームの診断は，わが国の診断基準[2)]にしたがって，ウエスト囲男性85cm以上，女性90cm以上を必須として，①空腹時血糖110mg/dL以上，②最高血圧130mmHg以上

表1　対象

	男性	女性
症例数	1,252	1,934
年齢	46.7 ± 12.3	48.5 ± 12.6
身長（cm）	168.7 ± 6.0	155.8 ± 5.7
体重（kg）	71.1 ± 11.7	56.1 ± 9.0
ウエスト（cm）	85.3 ± 9.8	73.7 ± 9.6
ヒップ（cm）	94.5 ± 6.2	91.2 ± 6.1
安静時最高血圧(mmHg)	130.0 ± 15.8	124.2 ± 17.5
安静時最低血圧(mmHg)	81.3 ± 11.2	76.3 ± 10.3
中性脂肪（mg/dL）	147.1 ± 117.4	97.4 ± 69.7
HDLコレステロール（mg/dL）	54.9 ± 14.8	66.8 ± 16.6
空腹時血糖（mg/dL）	105.9 ± 28.4	96.3 ± 20.2

平均値± SD

表2　生活習慣に関するアンケート

1) タバコを吸いますか.	はい	いいえ	やめた
2) 酒（アルコール）を飲みますか.	はい	いいえ	やめた
3) 家庭の料理の味と比べて，外食の料理の味はどうですか.	薄く感じる	ほとんど同じ	濃く感じる
4) めん類を食べる時，汁を残していますか.	ほとんど残す	半分残す	ほとんど飲む
5) 食事の時間は規則正しいですか.	不規則	時々不規則	規則的
6) よくかんで食べていますか.	早食い	時々不規則	規則的
7) 1回の食事の量はどのくらいですか.	常に腹一杯	時々不規則	常に腹八分目
8) 食事をしないことがありますか.	1日1回はある	週2〜3回	ほとんどない
9) 外食，店屋物，市販の弁当をどのくらい食べていますか.	1日1〜2回	週2〜3回	ほとんど食べない
10) 間食や夜食をとることがありますか.	ほとんど毎日	週2〜3回	ほとんどとらない
11) 食事は自分で作りますか.	ほとんどつくる	時々つくる	ほとんどつくらない
12) 減量のため食事制限をしたことがありますか.	はい	いいえ	
13) 現在，定期的（1日合計30分以上を週2回以上行ない，3カ月以上継続）に運動していますか.	はい	いいえ	

または最低血圧85mmHg以上，③中性脂肪150mg/dL以上またはHDLコレステロール40mg/dL未満の3項目のうち2項目以上を満たす場合とした．それぞれの疾患で薬物療法中の場合は，それぞれの項目に含めることとした．

結果は，平均値±標準偏差で表し，有意差検定はχ^2検定，ロジスティック回帰分析を用い，5%未満を有意とした．

2. 結　果

3,186名でのメタボリックシンドロームの頻度を検討した結果を表3に示す．ウエスト囲85cm以上を満たした男性は1,252名中618名（49.4%）であった．一方，女性90cm以上を満たしたのは1,934名中126名（6.5%）であった．メタボリックシンドロームの頻度は，男性は70歳未満では加齢とともに増加し，全体では335名（26.8%）がメタボリックシンドロームと診断された．女性は，閉経期以後加齢とともに増加したが，全体では69名（3.6%）のみがメタボリックシンドロームと診断され，著明な男女差が認められた．

メタボリックシンドロームと生活習慣との関連をχ^2検定により検討すると（表4），男性では「タバコを吸いますか」，「よくかんで食べていますか」，「1回の食事の量はどのくらいですか」，「減量のため食事制限をしたことがありますか」，「現在，定期的（1日合計30分以上を週2回以上行ない，3カ月継続）に運動していますか」の項目で有意な関連が認められた．女性では，「よくかんで食べていますか」，「減量のため食事制限をしたことがありますか」の項目で有意な関連を認めた．

年齢の影響を考慮し，ロジスティック回帰分析により検討すると（表4）男女とも「よくかんで食べていますか」，「1回の食事の量はどのくらいですか」，「減量のため食事制限をしたことがありますか」，「現在，定期的（1日合計30分以上を週2回以上行ない，3カ月継続）に運動していますか」で有意な関連を認め，男性では「タバコを吸いますか」の項目でも有意な関連を認めた．つまり，男女ともメタボリックシンドローム群では，早食いで，常に腹一杯食べ，運動不足で，減量経験があるという生活習慣が明らかとなった．また，男性ではタバコとの関連も明らかとなった．

なお，メタボリックシンドロームとの関連が認められた早食い，常に腹一杯食べ，運動不足という3つの生活習慣のうち，3つとも満たす場合のメタボリックシンドロームの頻度は，男性24名中4名（16.7%），女性38名中2名（5.3%），2つ満たす場合は男性263名中86名（32.7%），女

表3　性別，年代別メタボリックシンドロームの頻度

年齢	症例数	ウエスト ウエスト≧85cm(男性) ウエスト≧90cm(女性)	血圧 最高血圧≧130mmHg かつ/または 最低血圧≧85mmHg	耐糖能障害 空腹時血糖≧110mg/dL	脂質代謝障害 中性脂肪≧150mg/dL かつ/または HDLコレステロール<40mg/dL	メタボリック シンドローム
男性						
20～29	114	32 (28.1)	40 (35.1)	10 (8.8)	29 (25.4)	13 (11.4)
30～39	270	116 (43.0)	123 (45.6)	32 (11.9)	125 (46.3)	45 (16.7)
40～49	354	200 (56.5)	211 (59.6)	73 (20.6)	189 (53.4)	114 (32.2)
50～59	305	166 (54.4)	199 (65.2)	108 (35.4)	142 (46.6)	93 (30.5)
60～69	170	90 (52.9)	125 (73.5)	64 (37.6)	99 (58.2)	61 (35.9)
70～79	39	14 (35.9)	31 (79.5)	11 (28.2)	15 (38.5)	9 (23.1)
合計	1,252	618 (49.4)	729 (58.2)	298 (23.8)	599 (47.8)	335 (26.8)
女性						
20～29	197	4 (2.0)	18 (9.1)	2 (1.0)	32 (16.2)	1 (0.5)
30～39	265	12 (4.5)	44 (16.6)	11 (4.2)	62 (23.4)	5 (1.9)
40～49	500	28 (5.6)	155 (31.0)	29 (5.8)	115 (23.0)	10 (2.0)
50～59	571	39 (6.8)	293 (51.3)	67 (11.7)	217 (38.0)	25 (4.4)
60～69	333	29 (8.7)	220 (66.1)	57 (17.1)	169 (50.8)	17 (5.1)
70～79	68	14 (20.6)	60 (88.2)	22 (32.4)	47 (69.1)	11 (16.2)
合計	1,934	126 (6.5)	790 (40.8)	189 (9.7)	642 (33.2)	69 (3.6)

( ) は%

性272名中13名（4.8%），1つ満たす場合は男性569名中153名（26.9%），女性891名中36名（4.0%），まったく満たさない場合は男性396名中92名（23.2%），女性733名中18名（2.5%）であった．

3. 考　察

今回の3,186名の検討から，メタボリックシンドロームの頻度は，男性26.8%，女性3.6%で著明な男女差が認められた．わが国の疫学研究である端野，壮瞥町研究では40歳以上の男性808名のうち21%がメタボリックシンドロームと診断された[2]．われわれも以前，当センター利用者男性908名，女性1,320名，合計2,228名でメタボリックシンドロームの頻度を検討した結果，男性30.7%，女性3.6%がメタボリックシンドロームと診断された[3]．今回，3,186名での検討結果も以前のわれわれの報告とほぼ同様であった．男女差は，健診受診者であること，高齢者では一般地域住民に比べると比較的健康な人が多いことも考えられるが，女性でウエスト囲90cm以上を満たすのが6.5%と少ないことが大きな原因と思われた．今後は，女性のウエスト基準をもう少し低めに設定した方がよいのではないか[4]などのメタボリックシンドロームの診断基準に関する検討，継続的に脳血管障害，心疾患などの発症との関連を調査することが必要であろう．

今回の検討のもうひとつの特筆すべき点は，わが国の診断基準を用いたメタボリックシンドロームと生活習慣との関連を明らかにしたことである．男女ともメタボリックシンドローム群では，早食いで，常に腹一杯食べ，運動不足で，減量経験があるという生活習慣が明らかとなった．また，男性ではタバコとの関連も明らかとなった．横山ら[5]は，492名の2型糖尿病患者で，生活習慣がメタボリックシンドローム各因子へおよぼす影響をアンケートにより調査し，「朝食をとらない」，「満腹まで食べる」，「肉や魚またご飯やめん類をたっぷり食べる」，「イライラすると食べる」がBMIとの強い関連を認め，「食べる速度が速い」，「日常でよく歩かない」がBMIに加え，血圧，

表4 メタボリックシンドロームと生活習慣との関連

質問	男性			女性		
	MS(−)	MS(+)	年齢補正後	MS(−)	MS(+)	年齢補正後
タバコを吸いますか.						
はい	309	138	$p < 0.01$ $p < 0.01$	139	5	
いいえ	383	105		1,694	62	
やめた	225	92		32	2	
酒（アルコール）を飲みますか.						
はい	666	251		615	16	
いいえ	226	73		1,231	52	
やめた	25	11		19	1	
家庭の料理の味と比べて，外食の料理の味はどうですか.						
薄く感じる	34	12		68	5	
ほとんど同じ	313	137		589	20	
濃く感じる	570	186		1,211	44	
めん類を食べる時，汁を残していますか.						
ほとんど残す	181	56		830	24	
半分残す	436	160		828	33	
ほとんど飲む	300	119		207	12	
食事の時間は規則正しいですか.						
不規則	158	48		180	6	
時々不規則	379	138		839	30	
規則的	380	149		846	33	
よくかんで食べていますか.						
早食い	346	165	$p < 0.01$ $p < 0.01$	553	32	$p < 0.01$ $p < 0.01$
時々不規則	494	153		1,154	31	
規則的	77	17		158	6	
1回の食事の量はどのくらいですか.						
常に腹一杯	115	59	$p < 0.05$ $p < 0.01$	266	16	$p < 0.05$
時々腹一杯	616	223		1,293	43	
常に腹八分目	186	53		306	10	
食事をしないことがありますか.						
1日1回はある	92	26		137	4	
週2〜3回	115	37		181	5	
ほとんどない	710	272		1,547	60	
外食，店屋物，市販の弁当をどのくらい食べていますか.						
1日1〜2回	319	131		189	5	
週2〜3回	319	103		637	28	
ほとんど食べない	279	101		1,039	36	
間食や夜食をとることがありますか.						
ほとんど毎日	89	47		517	19	
週2〜3回	308	107		621	20	
ほとんどとらない	520	181		727	30	
食事は自分でつくりますか.						
ほとんどつくる	56	15		1,454	55	
時々つくる	203	70		258	9	
ほとんどつくらない	658	250		53	5	
減量のため食事制限をしたことがありますか.						
はい	212	140	$p < 0.01$ $p < 0.01$	599	44	$p < 0.01$ $p < 0.01$
いいえ	705	195		1,266	25	
現在，定期的（1日合計30分以上を週2回以上行ない，3カ月以上継続）に運動していますか.						
はい	369	113	$p < 0.05$ $p < 0.01$	662	20	$p < 0.05$
いいえ	548	222		1,203	49	

MS：メタボリックシンドローム

HbA1c，中性脂肪，HDLコレステロールとも有意に関連したと報告している．厚生労働省研究班の調査では，内臓脂肪蓄積者では，「満足するまで食べる」，「甘いものが好き」，「野菜がきらい」，「間食をよくとる」，「運動量が少ない」という特徴が明らかにされている[1]．われわれも以前，肥満者(BMI 26.4以上)の生活習慣を性と年齢を一致させた正常体重者（BMI 19.8以上24.2未満），過体重者（BMI 24.2以上26.2未満）と比較し，男性肥満者は，不規則な生活をし，常に腹一杯まで食べる，女性肥満者は，不規則な生活をし，早食いで，減量のため食事制限をしたことがあることを報告した[6]．また，8,000人あまりの検討からも肥満度と生活習慣との有意な関連を認めた[7]．今回，わが国の診断基準を用いたメタボリックシンドロームと生活習慣との間にも有意な関連が認められ，メタボリックシンドロームの予防，改善における生活習慣の大切さが改めて確認できた．特にメタボリックシンドロームでは，男女とも「早食い」，「常に腹一杯まで食べる」，「運動不足」を改善し，減量を上手に成功させるように導くことが重要で，男性では「タバコ」を含む生活習慣の乱れがメタボリックシンドロームの罹患に関連していることをよく理解させることも必要である．

しかしながら，本検討ではいくつかの問題点も残る．今回，われわれは生活習慣の指標として，13項目の質問を用いたが，この13項目が生活習慣を全般的に表すという明確な根拠はない．したがって，今後はより根拠のある指標を用いた検討が必要であろう．また，本検討は横断調査である．足達ら[8-10]は行動科学の臨床応用である行動療法を減量に適用し，生活習慣の改善をとおしてその有用性を明らかにするとともに，高コレステロール血症，糖尿病などにも応用できることを報告している．したがって，今後今回の結果をもとにした介入調査によって，生活習慣改善によるメタボリックシンドロームの予防，改善効果を検討することも必要である．

4. まとめ

わが国のメタボリックシンドロームの診断基準を用いて生活習慣との関連を検討した結果，メタボリックシンドロームでは，早食いで，常に腹一杯食べ，運動不足で，減量経験があるという生活習慣が明らかとなった．また，男性では「タバコ」を含む生活習慣の乱れもメタボリックシンドロームの罹患に関連しているものと思われた．

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ORIGINAL ARTICLE

A dose–response relation between aerobic exercise and visceral fat reduction: systematic review of clinical trials

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Objective: It has been suggested that exercise has preferential effects on visceral fat reduction. However, the dose–response effect remains unclear because of limited evidence from individual studies. The purpose of this study was to systematically review the current literature to establish whether reduction of visceral fat by aerobic exercise has a dose–response relationship.
Methods: A database search was performed (PubMed, 1966–2006) with appropriate keywords to identify studies exploring the effects of aerobic exercise as a weight loss intervention on visceral fat reduction. Visceral fat reduction was expressed as the percentage of visceral fat change per week (%ΔVF/w). The energy expenditure by aerobic exercise was expressed as ∑(metabolic equivalents × h per week (METs · h/w)).
Results: Nine randomized control trials and seven non-randomized control trials were selected. In most of the studies, the subjects performed aerobic exercise generating 10 METs · h/w or more. Among all the selected groups (582 subjects), visceral fat decreased significantly ($P<0.05$) in 17 groups during the intervention, but not in the other 4 groups. There was no significant relationship between METs · h/w from aerobic exercise and %ΔVF/w in all the selected groups. However, when subjects with metabolic-related disorders were not included (425 subjects), METs · h/w from aerobic exercise had a significant relationship with %ΔVF/w ($r=-0.75$). Moreover, visceral fat reduction was significantly related to weight reduction during aerobic exercise intervention, although a significant visceral fat reduction may occur without significant weight loss.
Conclusion: These results suggest that at least 10 METs · h/w in aerobic exercise, such as brisk walking, light jogging or stationary ergometer usage, is required for visceral fat reduction, and that there is a dose–response relationship between aerobic exercise and visceral fat reduction in obese subjects without metabolic-related disorders.
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Keywords: central obesity; metabolic-related disorder; clinical trial; METs · h/w; aerobic exercise

Introduction

Obesity is a widespread and growing problem around the world, with a population of more than 1 billion overweight adults, of which at least 300 million are clinically obese.[1] Excess adipose tissue, especially visceral adipose tissue, releases inflammatory cytokines that increase insulin resistance in skeletal muscles.[2] Furthermore, central obesity, which is defined as a state of excessive visceral fat accumulation, is associated with a decreased production of adiponectin, an adipose-specific molecule with anti-diabetic, anti-atherosclerotic and anti-inflammatory functions.[3] In recent years, central obesity has been defined as a predominant risk factor for metabolic syndrome,[4,5] a condition for which a collection of cardiovascular biomarkers are correlated with an increased probability of heart disease, stroke and diabetes. These biomarkers include high plasma triacylglycerol, low high-density lipoprotein cholesterol, high plasma blood glucose, and high blood pressure.

Numerous studies have investigated the effects of diet, drugs and exercise on reduction in weight, total fat mass and/or visceral fat mass.[6,7] Generally, diet therapy is the most effective method for decreasing weight and total fat mass rapidly, because it easily results in a negative energy balance, as compared with exercise or drug therapies.[8] However, it has been suggested that aerobic exercise has specific effects on decreasing visceral fat mass as it may lead to increased sympathetic tonus, thereby increasing lipolysis

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especially in abdominal fat.[9] For that reason, exercise therapy is expected to be one of the most effective methods for improving central obesity.

Several investigators have reviewed the effects of physical activity (or aerobic exercise) on the reduction in body weight, total fat mass and/or visceral fat mass.[10–14] Ross and Janssen[13] suggested that physical activity was associated with a reduction of total fat, in a dose-dependent manner, within 16 weeks. However, the effects of physical activity on visceral fat reduction were unclear. Kay and Fiatarone Singh[10] also reviewed the influence of physical activity on abdominal fat. Although they concluded that physical activity had a beneficial influence on visceral fat reduction, a dose–response relationship was not examined. After Ross and Janssen[13] reviewed the dose–response relationship between physical activity and visceral fat reduction, several papers were published.[15–25] In the present study, we systematically reviewed the literature to clarify whether aerobic exercise for weight loss is positively associated with visceral fat reduction, and to determine the minimal amount of aerobic exercise required to achieve visceral fat reduction.

Materials and methods

Data collection

A PubMed (1966–May 2006) database search was performed to identify studies examining the effects of aerobic exercise as a weight loss intervention on visceral fat reduction using the following keywords: (physical activity, exercise, (physical and training), sports, physical education, or physical fitness) and (((abdominal, abdomen, or visceral) and (fat or adipose)) or ((waist, abdominal, or abdomen) and (girth or circumference))). The searches were limited to humans and clinical trials. Several studies were selected from reference lists cited in the selected studies.

Study selection

Studies were selected if they met the following criteria: (1) they involved clinical trials (that is, randomized controlled or non-randomized); (2) they must have included at least one group of aerobic exercise alone; (3) the age of subjects was between 18 and 65; (4) subjects had a mean body mass index (BMI) of $<25\,kg/m^2$, or a mean BMI of $\geqslant 25\,kg/m^2$, but with a small amount of visceral fat (if the mean plus s.d. of the visceral fat area (VFA) in a group was less than $100\,cm^2$ (in which case, only 16% of the subjects are estimated to have over $100\,cm^2$ of visceral fat), that group was considered not to need to reduce visceral fat) were excluded;[15,26–28] (5) the studies used computed tomography (CT) or magnetic resonance imaging (MRI) as a measurement of visceral fat; (6) the subjects were instructed to maintain energy intake before and during the intervention; and (7) the exercise amount and change in visceral fat could be calculated by the procedures described. Only groups that were instructed to practice aerobic exercise without weight loss by additional energy intake, which corresponded to the increased energy expenditure (EE) by prescribed aerobic exercise, were included.[22,29] We excluded data from studies using drug therapy, but included data from their control groups with aerobic exercise therapy alone.[17] Resistance training groups were also excluded, because calculation of their EE is difficult and the mechanism of decreasing visceral fat during resistance training may be different to that for aerobic exercise. Furthermore, if we identified two studies that used approximately the same research subjects, the study containing the least amount of information was excluded. Within these criteria-matched studies, groups that were not instructed to practice exercise during the intervention were employed as the control group for the degree of visceral fat reduction compared to the aerobic exercise groups.[15,19,21–23,29] Eligible studies were reviewed independently by two of the authors to assess inclusion suitability and data extraction accuracy.

Conversion to %ΔVF/w

In the selected studies, several units (for example, cm^2, cm^3, kg) were used for expressing the quantity of visceral fat. VFA was measured at either the 3rd-4th lumbar or 4th-5th lumbar vertebrae. Kvist *et al.*[30] and Shen *et al.*[31] have shown a strong correlation between the 4th-5th lumbar VFA, or the 3rd-4th lumbar VFA, and total visceral fat volume, respectively. However, they have also reported that the actual values do not accurately match between the 4th-5th and 3rd-4th lumbar VFA as well as VFA measured by CT vs MRI in the same region.[32] Therefore, we converted the visceral fat amount reported in each study to a percentage of visceral fat change per week (%ΔVF/w), which enabled us to directly compare the groups.

Conversion to METs · h/w

Aerobic exercise amounts during the intervention were converted to ∑(metabolic equivalents × h per week (METs · h/w)), which adjusted the EE for body size. Weekly EE by aerobic exercise during the intervention was acquired using the following criteria: (1) if an actual value was shown, that value was used;[22,29] (2) if an estimated or instructed value by authors was stated, that value was used;[16,19,24] (3) if values were not expressed,[9,15,17,18,20,21,23,25,27,33,34] EE was calculated using exercise intensity, exercise time, exercise frequency, body weight and VO2max/VO2peak as follows:[35]

$$EE\,(kcal/week) = (V \times I)/1000 \times 5 \times F \times T \times W \text{ or}$$
$$= (3.5 + (V - 3.5) \times I')/1000 \times 5 \times F \times T \times W,$$

where 3.5 ml/kg/min is resting metabolic rate, 5 kcal/l is EE for oxygen consumption per liter, V is VO2max or VO2peak (ml/kg/min), I is exercise intensity (for example, if exercise was done by 70%VO2max, the value is 0.7.), I′ is exercise intensity (if exercise was done by 70% heart rate reserve, the

value is 0.7.), F is exercise frequency (times/week), T is exercise time (min/session) and W is body weight (kg).

For the exercise intensity and time used in the EE calculation, the values decided by authors in each study were used. For studies that gradually increased exercise intensity and time, final target values were used. In cases where only the number of daily steps was shown,[20] 100 steps was calculated as one minute of exercise,[36] and intensity was assumed to be that for normal walking (3.5 METs).[37] If only the percentage of the heart rate maximum (%HRmax) for exercise intensity was shown, the exercise intensity by %HRmax was converted into exercise intensity by percentage of heart rate reserve. For the EE calculation, we did not include exercise volume during warm-up and cool-down (for example, stretching) periods, since several studies described this information, while others did not. Following these calculations, EE by aerobic exercise/week in each study was converted to METs · h/w using the following equation:[35]

$$\text{METs} \cdot \text{h/w} = \text{EE}/((\text{W} \times 3.5 \times 5/1000) \times 60),$$

where W is body weight (kg).

Data analysis

The amount of visceral fat decrease in each group was considered to be statistically significant if the *P*-value was less than 0.05. Correlations between METs · h/w and %ΔVF/w in selected groups, with or without the metabolic-related disorders, such as type 2 diabetes and dyslipidemia, were assessed by weighted Pearson's correlation coefficients (*r*) for the number of subjects. The Kruskal–Wallis test and the Mann–Whitney's *U*-test for *post hoc* comparisons were applied for comparing the mean %ΔVF/w values between the control and exercise groups that had been divided into tertiles by METs · h/w amount. We also analyzed these correlations in several categorized groups (for example, groups with only women or men, and groups with more or less than 16-week interventions). Furthermore, the relationship between METs · h/w and %ΔWeight/w, and between %ΔVF/w and %ΔWeight/w, were expressed by weighted *r* values for the number of subjects. Because %ΔVF/w and METs · h/w were calculated from mean values in each study, only these variables and the number of subjects were available for analyses. Therefore, specific analytic programs for meta-analysis could not be used, although the number of subjects was weighted for.

Results

Two hundred and fifty-five studies were selected from PubMed (1966–May 2006) with the appropriate keywords. From these papers, plus the added references collected from the cited literature, nine randomized control trials (RCT)[9,15,16,19,22–24,29,33] and seven non-randomized control trials (nRCT)[17,18,20,21,25,27,34] were selected according to our criteria (Table 1). The studies included 13 RCT groups and 8 nRCT groups examining solo aerobic exercise interventions (Table 2). The subjects of six groups in four of the studies were diagnosed as having metabolic-related disorders.[9,16,24,33] In all of the selected studies, the calculated METs · h/w ranged from 5.9 to 47.1, and the %ΔVF/w ranged from −6.062 to 0.078, including four groups that did not show any significant changes in VF during the intervention period.

Correlation coefficients between METs · h/w and %ΔVF/w are shown in Figure 1. METs · h/w had a significant correlation with %ΔVF/w in the groups that did not include subjects with metabolic-related disorders ($r = -0.75$), although there was no significant correlation when all groups were selected ($r = -0.28$). The selected groups without metabolic-related disorders were divided into tertiles by their METs · h/w amount. %ΔVF/w values in the 1st, 2nd and 3rd exercise groups were significantly higher than that of the control group, although these exercise groups were not significantly different from each other (Figure 2). Significant correlations were also observed in the women-only group, while there was no significant correlation in the men-only group (Table 3). Groups were also categorized by their duration of either shorter or longer than the 16-week intervention period (short-term or long-term intervention duration). Only in the short-term intervention groups, without metabolic-related disorder subjects, did METs · h/w exhibit a significant correlation with %ΔVF/w ($r = -0.81$).

For analysis of the relationship between %ΔWeight/w and METs · h/w or %ΔVF/w, the two groups[22,29] that did aerobic exercise without weight loss, were excluded. As a result, METs · h/w had a significant correlation with %ΔWeight/w in all of the selected groups ($r = -0.79$), as well as the groups without metabolic-related disorder subjects ($r = -0.87$) (Figure 3). Furthermore, %ΔVF/w had a strong relationship with %ΔWeight/w in the groups not including metabolic-related disorder subjects ($r = 0.93$), even though there was a significant correlation in all the selected groups ($r = 0.64$) (Figure 4).

Discussion

Dose–response relationship between aerobic exercise and visceral fat reduction

The present study indicates aerobic exercise volume has a dose–response relationship with visceral fat reduction in subjects without metabolic-related disorders. There are several excellent reviews for investigating the relationship between diet and exercise interventions and weight and/or visceral fat reduction.[6,7,10–14] Ross and Janssen[12] suggested that physical activity with or without weight loss was associated with a reduction in visceral adipose tissue, although insufficient evidence limited their reaching a definitive conclusion. Based on this research, Ross and Janssen[13] also reviewed dose–response relationships between

Table 1 Characteristics of selected studies in this paper

Reference	*RCT or nonRCT*	*Intervention*		*Subject*			
		Duration	*Type of group*	*Gender*	n	*Age (year)*	*Specific characteristics*
Despres *et al.*[34]	NonRCT	6 months	A	F	13	38.8±5.3	
Donnelly *et al.*[15]	RCT	16 months	A	F	25	24±5	
			C	F	18	21±4	
			A	M	16	22±4	
			C	M	15	24±4	
Green *et al.*[17]	nonRCT	20 weeks	Dr+A	F	30	56.4±5.4	Estrogen replacement therapy (ERP), postmenopausal
			A	F	18	52.3±6.3	Non ERP, postmenopausal
Halverstadt *et al.*[18]	nonRCT	24 weeks	A	M+F	83 (34+49)	57.9±0.6	Combined LIPG (endothelial lipase gene) genotype CC and CT/TT
Irwin *et al.*[19]	RCT	12 months	A	F	87	61.0 (59.6–62.5)	Menopausal
			C	F	86	60.6 (59.1–62.1)	Menopausal
Miyatake *et al.*[20]	nonRCT	1 year	A	M	31	(32–59)	
Park *et al.*[21]	nonRCT	24 weeks	C	F	10	43.1±1.67	
			A	F	10	42.2±1.91	
			A+R	F	10	43.4±1.04	
Ross *et al.*[22]	RCT	14 weeks	Di	F	15	43.9±4.9	
			A	F	17	43.2±5.1	
			A[a]	F	12	41.3±7.2	
			C	F	10	43.7±6.4	
Ross *et al.*[29]	RCT	12 weeks	Di	M	14	42.6±9.7	
			A	M	16	45.0±7.5	
			A[a]	M	14	44.7±7.6	
			C	M	8	46.0±10.9	
Schwartz *et al.*[27]	nonRCT	27 weeks	A	M	13	28.2±2.4	
			A	M	15	67.5±5.8	
Short *et al.*[23]	RCT	16 weeks	A	M+F	65	40.5±1.1	
			C	M+F	37	40.7±1.4	
Wilund *et al.*[25]	nonRCT	12 weeks	A	M+F	16 (6+10)	56±1	CETP (cholesteryl ester transfer protein) genotype (B1B1)
			A	M+F	14 (8+6)	56±1	CETP (cholesteryl ester transfer protein) genotype (B1B2)
Boudou *et al.*[33]	RCT	8 weeks	A	M	8	42.90±5.20	Type 2 diabetics
Giannopoulou *et al.*[16]	RCT	14 weeks	Di+A	F	11	57.4±1.7	Diabetics, menopausal
			Di	F	11	58.5±1.7	Diabetics, menopausal
			A	F	11	55.5±1.7	Diabetics, menopausal
Mourier *et al.*[9]	RCT	8 weeks	A	M+F	10	45±2	Diabetics
			C	M+F	11	46±3	Diabetics
Slentz *et al.*[24]	RCT	32 weeks	A[b]	M+F	40	54.0±5.5	Dyslipidemia, postmenopausal
			A[b]	M+F	46	53.0±7.0	Dyslipidemia, postmenopausal
			A[b]	M+F	42	51.5±5.3	Dyslipidemia, postmenopausal
			C	M+F	47	52.3±7.65	Dyslipidemia, postmenopausal

Abbreviations: A, aerobic exercise therapy; A[a], aerobic exercise therapy without a weight loss; A[b], three different types of aerobic exercise therapy in the study; C, control; Di, diet therapy; Dr, drug therapy; F, female subjects; M, male subjects; *n*, number of subjects (number of males+number of females); R, resistance training therapy; RCT, randomized control trials. Age expressed by mean±s.d. (range).

Table 2 Summary of aerobic exercise groups in this paper

Reference	*Subjects*				*Aerobic exercise*	
	Gender	*Age (yr)*	*BMI (kg/m^2)*	*% fat (%)*	*Session time and intensity*	*Mode or used exercise instrument*
Despres *et al.*[34]	F	38.8	34.5	47.0	90 min, 55%HRmax	Walking
Donnelly *et al.*[15]	M	22	29.7	28.3	45 min, 70%VO2max	Treadmill
Green *et al.*[17]	F	56.4	29.3	40.8	75%VO2max	Ergometer
Halverstadt *et al.*[18]	M+F	57.9		36.0	70%VO2max	
Irwin *et al.*[19]	F	61	30.5	47.6	Mean 81%HRmax	Treadmill walking and stationary bicycling in Lab, and aerobic exercise (e.g. walking, aerobics, bicycling) at home
Miyatake *et al.*[20]	M	32–59	28.6	29.3	7012→8839 steps/day (plus 1827 steps/days)	Normal walking
Park *et al.*[21]	F	42.2	25.3	42.2	60–70%HRmax	Fast walking
Ross *et al.*[22]	F	43.2	32.8		Mean 80%HRmax	Brisk walking or light jogging on treadmill
	F	41.3	32.9		Mean 82%HRmax	Brisk walking or light jogging on treadmill
Ross *et al.*[29]	M	45	32.3		Mean 77%HRmax	Brisk walking or light jogging on treadmill
	M	44.7	31.3		Mean 77%HRmax	Brisk walking or light jogging on treadmill
Schwartz *et al.*[27]	M	67.5	26.2	24.7	45 min, 85%HRreserve	Walking/jogging
Short *et al.*[23]	M+F	40.5	26.6	31.4	80%HRmax	Stationary bicycling
Wilund *et al.*[25]	M+F	56		38.0	40 min, 70%VO2max	
	M+F	56		34.0	40 min, 70%VO2max	
Boudou *et al.*[33]	M	42.9	28.3		1) 2 times/week, 45 mi n, 75%VO2peak, 2) 1 time/week, 10 min, 85%VO2peak, and 12 min, 50%VO2peak	Ergometer
Giannopoulou *et al.*[16]	F	55.5	35.9		60 min, 65–70%VO2max, energy expenditure: 250.95–298.75 kcal/session	Walking
Mourier *et al.*[9]	M+F	45	30.4	24.4	1) 2 times/week, 45 min, 75%Vo2peak, 2) 1 time/week, 10 min, 75%VO2peak, and 12 min, 50%VO2peak	Ergometer
Slentz *et al.*[24]	M+F	54	29.8		40–55%VO2max, 14 kcal/kg/wk (12 miles/week)	Treadmill walking
	M+F	53	29.7		65–80%VO2max, 14 kcal/kg/wk (12 miles/week)	Treadmill jogging
	M+F	51.5	29.1		65–80%VO2max, 23 kcal/kg/wk (20 miles/week)	Treadmill jogging

Table 2 (Continued)

Aerobic exercise					*Weight*						*Visceral fat*							
VO2max (baseline)	*Frequency (times/ week)*	*Time (min/ session)*	*Energy expenditure (kcal/week)*	*METs·h/w*	*Before (kg)*	*After (kg)*	*Δ (kg)*	*%Δ (%)*	*%Δ (%/ week)*	*Sig[1]*	*Before*	*After*	*Δ*	*Unit*	*%Δ (%)*	*%Δ (%/ week)*	*Sig[2]*	*Method*
	4–5	90	1913	20.2	90.0	86.3	−3.7	−4.11	−0.069	*	124.7	121.3	−3.4	cm^2	−2.73	−0.045	NS	CT
	5	45	3300	33.4	94.0	85.2	−8.8	−9.36	−0.136	*	97.9	75.5	−22.4	cm^2	−22.88	−0.334	*	
21.3±4.0	3	50	920	11.4	76.8	76.9	0.1	0.13	0.007	NS	121.6	117.8	−3.8	cm^2	−3.13	−0.156	NS	CT
25.2±0.5	3	40	853	10.1	80.6	79.5	−1.1	−1.36	−0.057	*	127.8	113.4	−14.4	cm^2	−11.27	−0.469	*	CT
20.1 (19.3–20.9)	3.5	176/week	1051	12.3	81.6		−1.3	−1.59	−0.031	*	147.6		−8.5	cm^2	−5.76	−0.113	*	CT
	7	18.27	507	5.9	82.0	79.0	−3.0	−3.66	−0.091	*	108.7	87.0	−21.7	cm^2	−19.96	−0.499	*	CT
34.2±3.2	6	60	1908	28.5	63.7	59.0	−4.7	−7.38	−0.307	*	195.0	112.4	−82.6	cm^2	−42.36	−1.765	*	CT
	7	64	3668 (524±52/session)	40.2	86.9	80.9	−6.0	−6.90	−0.493	*	2.3	1.6	−0.7	kg	−30.43	−2.174	*	MRI
	7	63	3619 (517±58/session)	39.1	88.1	87.6	−0.5	−0.57	−0.041	NS	2.2	1.8	−0.4	kg	−18.18	−1.299	*	
	7	60.4	4886 (698/session)	45.8	101.5	94.0	−7.5	−7.39	−0.616	*	186.0	134.0	−52.0	cm^2	−27.96	−2.330	*	MRI
	7	63.3	4844 (692/session)	47.1	97.9	97.4	−0.5	−0.51	−0.043	NS	191.0	159.0	−32.0	cm^2	−16.75	−1.396	*	
29.1±4.4	4.44±0.43	45	2009	24.0	79.6	77.1	−2.5	−3.14	−0.131	*	144.5	109.0	−35.5	cm^2	−24.57	−1.024	*	
25.6 (40.5±1.1/ FFM)	4	40	1166	14.0	79.2	78.7	−0.5	−0.63	−0.039	*	133.0	124.0	−9.0	cm^2	−6.77	−0.423	*	CT
25±1	3	40	882	10.0	84.0	83.2	−0.8	−0.95	−0.079	NS	146.0	130.0	−16.0	cm^2	−10.96	−0.913	*	CT
26±1	3	40	863	10.4	79.0	77.8	−1.2	−1.52	−0.127	*	128.0	109.0	−19.0	cm^2	−14.84	−1.237	*	
23.45±3.60	3	1) 45, 2) 22	836	9.2	86.9	85.0	−1.9	−2.19	−0.273	NS	153.3	84.2	−69.1	cm^2	−45.06	−5.632	*	MRI
	3–4	60	962	9.9	92.9	91.2	−1.7	−1.83	−0.131	NS	5204.0	4675.0	−529.0	cm^3	−10.17	−0.726	*	MRI
23.0±1.2	3	1) 45, 2) 22	795	8.9	85.3	83.8	−1.5	−1.76	−0.220	NS	156.1	80.4	−75.7	cm^2	−48.49	−6.062	*	MRI
	3.5	178	1232	6.9	88.0			−0.70	−0.022	*	173				1.70	0.053	NS	CT
	3.1	120	1190	13.3	85.0			−0.80	−0.025	*	154				2.50	0.078	NS	
	3.6	173	1971	21.9	85.7			−2.60	−0.081	*	168				−6.90	−0.216	*	

Abbreviations: CT; computed tomography; F, female subjects; M, male subjects; METs·h/w, ∑(metabolic equivalents × hour) per week; MRI, magnetic resonance imaging; Sig[1], a significant weight change was observed during the intervention ($P<0.05$); Sig[2], a significant visceral fat change was observed during the intervention ($P<0.05$); Δ, change. Results expressed by mean (range) or mean±s.d.