Among those participants who set exercise goals, the relationship between BMI and the number of additional steps in the goal was analyzed by BMI tertiles. At baseline, there were no differences among BMI tertiles with regard to level of exercise. Those participants with BMI ≥ 31 set goals of significantly fewer additional steps compared to those with BMI < 29 ($p < 0.05$; ***Figure 3***).

The mean BMI was 30.5 kg/m^2 and the median was 29.8s kg/m^2. We divided two groups over and under 30 kg/m^2 BMI, in order to clarify relationships between BMI and the dietary problems and dietary goals. There were not significant differences of the percentage of dietary problems between the BMI levels over and under 30 kg/m^2 in women and men. (***Figure. 4***). Among the dietary goals, the percentage of the decreasing intake of snack was different between the BMI levels over and under 30 kg/m^2 in women ($p < 0.05$; ***Figure 5***).

Discussion

Most studies of traditional obesity treatment, including dietary restriction, nutritional education, and an increase in exercise, have demonstrated limited success. Other methods that have been used as an adjunct to dietary restriction in the treatment of obesity include lifestyle modification, drugs, therapeutic starvation, very low calorie diets, and surgical treatment. Long-term weight loss and maintenance requires management strategies including a combination of nutritional education and physical activity as well as behavioral interventions.[18)]

In the SCOP study, we constructed a strategy for obesity treatment that mainly included cognitive behavioral treatment for nutritional education and physical activity. The dietitians interviewed participants about their levels of social support, stress, motivation, and self-efficacy. More men expected support from others, such as their wives and family than women (***Table 1***). In addition, in men, the awareness of the need to keep healthy by oneself was significantly associated with the motivation to resolve the situation and the availability of support from others (***Table 2***). Studies have shown that social support is an important aid in weight maintenance,[19,20)] although the effect of family involvement on weight control is unclear. Wing et al. reported better weight maintenance when participants, especially women, were treated together with their spouses.[21)] In contrast, Black and Lantz reported weight maintenance to be better when participants were treated alone, particularly men.[22)] In the present study, however, men expected the support from others even though they were aware of the need to keep healthy by themselves in order to succeed in their weight loss.

The motivation to resolve the situation was significantly more prevalent in women than in men ($p < 0.05$; ***Table 1***). In women, the awareness of the need to keep healthy by oneself was also significantly associated with recognition of the benefits and probability of losing weight, the motivation to resolve the situation, and realizing the obstacles to success. Many studies have reported that a higher motivation for weight reduction was related to greater weight loss.[23)] However, the Weight Loss Readiness Test (WLRT), which was developed to access weight loss readiness[24)] and motivation, failed to predict weight loss.[23,25)]

In the SCOP study, the dietary goals were well matched with problems, as participants were first asked to list potential problems and then set goals based on these. More than 40% of men and women recognized eating too fast as a problem and about 15% saw eating too much as an issue (***Table 3***). Likewise, both men and women recognized as problems eating too few vegetables, too much fat or fatty foods, and high salt intake. More women listed eating sweet snacks as a problem, whereas more men saw alcohol intake as an issue (***Figure 1***).

Compared to men, significantly more women set the goal of decreasing the intake of snacks, whereas more men aimed to decrease the intake of specified foods, including drinking alcohol, revealing that the favorite foods and the problem eating behaviors were different between men and women (***Table 4 and Figure 2***). The dietary goal of "Decrease intake of fat or fatty food" was set mainly in the category of "Decrease intake of specified foods" in both men and women. In women, more participants over 30 kg/m^2 BMI focused about decreasing intake of snacks including 5 goals related snacks than that under 30 kg/m^2 BMI, even though the percentage of snacks in the problems was not different between BMI levels. The goals set by participants were in line with sound dietary advice, as studies have shown that weight loss and maintenance is associated with reduced frequency of snacks,[26)] less dietary fat,[26-30)] and increased intake of vegetables and fruits.[26)]

The dieticians usually proposed setting an exercise goal of an additional 1,000 steps per day to the actual steps last month. Although there was no difference among BMI tertiles with regard to the mean number of walking steps at the beginning of the intervention, women in the highest tertile (BMI = 31+) set significantly fewer additional steps as an exercise goal (***Figure 3***), suggesting that women in this tertile hesitate to walk. In women, there was a significant difference in the percentage of decreasing intake of snacks as a dietary goal between BMI levels over and under 30 kg/m^2 (***Figure 5***). This result may show that the participants in SCOP could set the successful dietary goal to lose weight by themselves with the guidance of the dieticians, as reported in previous study.[26)]

Self-monitoring of body weight and food intake were reported as important factors in weight loss as well as weight maintenance.[27,31,32)] In this study, the participants self-monitored and recorded items such as weight, daily food intake, and daily evaluations of their personal dietary and exercise goals and reported to dieticians the results of their efforts at the end of each month.

Obesity is recognized as a complex disorder involving appetite regulation and energy metabolism, and it is associated with a variety of comorbid conditions. Many studies have shown that traditional obesity treatment has been effective over the short term, but long-term outcomes do not mirror those satisfactory results. Lang and Froelicher concluded that the combination of a low-calorie diet, an increase of physical activity, and behavioral therapy should be incorporated in obesity treatments.[18)] They also found that interventions involving frequent behavioral therapy, such as weekly sessions, seemed to improve the participants' adherence to changes in eating and exercise patterns and produced better outcomes. Elfhag and Rossner reviewed a variety of potential factors and concluded that weight maintenance was associated with an internal motivation to lose weight, social support, better coping strategies, a better ability to handle life stress, self-efficacy, autonomy, assuming responsibility in life, and greater overall psychological strength and stability.[33)]

This survey baseline data revealed that the psychological characters were different in gender and the problems and dietary and exercise targets were also different in gender and BMI.

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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)

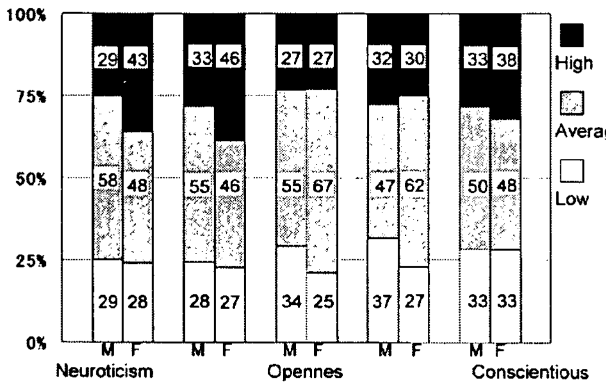

Fig. 1. The distribution of *T*-scores among the low class (T = 44 and lower), average class (T = 45–55), and high class (T = 56 and higher) in each personality domain of the NEO-FFI by sex. The values indicate the number of subjects (males, M, n = 116; females, F, n = 119)

· 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	Factor 2 Fast eating・Gluttony	Factor 3 Uncertainty of hunger	Factor 4 Promiscuous eating habits・Dining out	Factor 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 Comfort eating, Western food	Factor 2 Uncertainty of hunger	Factor 3 Fast eating	Factor 4 Dining out	Factor 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

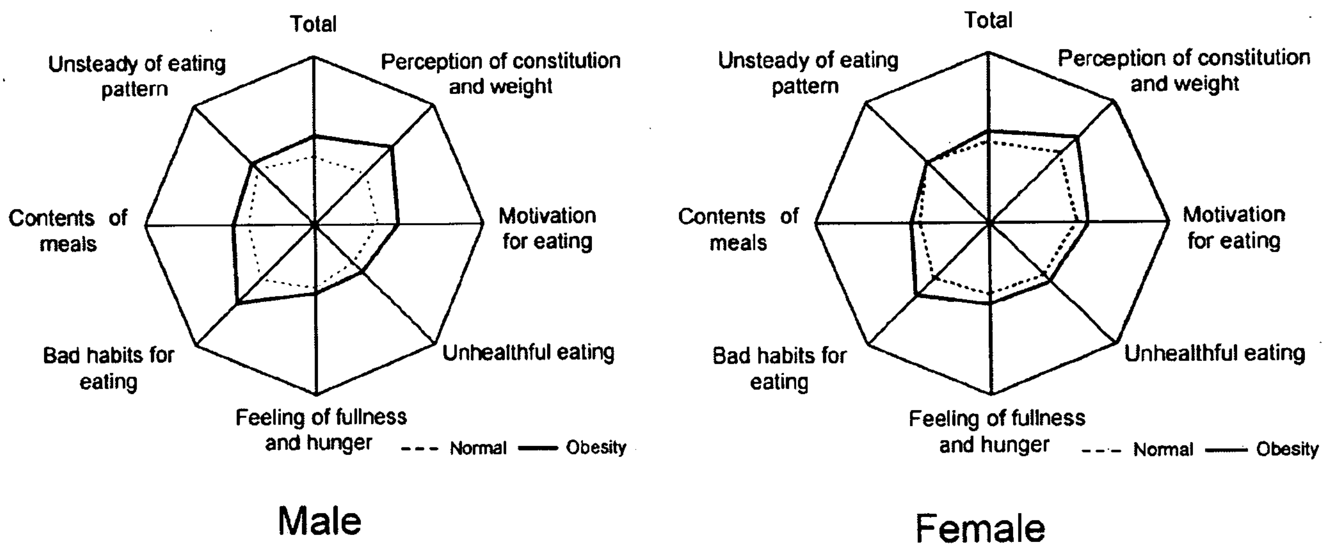

Fig. 2. Comparison between the eating behaviors of obese subjects in this study and normal-weight subjects in a previous study.[12] Displayed are the scores of obese subjects (solid line) and normal-weight subjects (dash line) by sex.

*Fig. 3*a

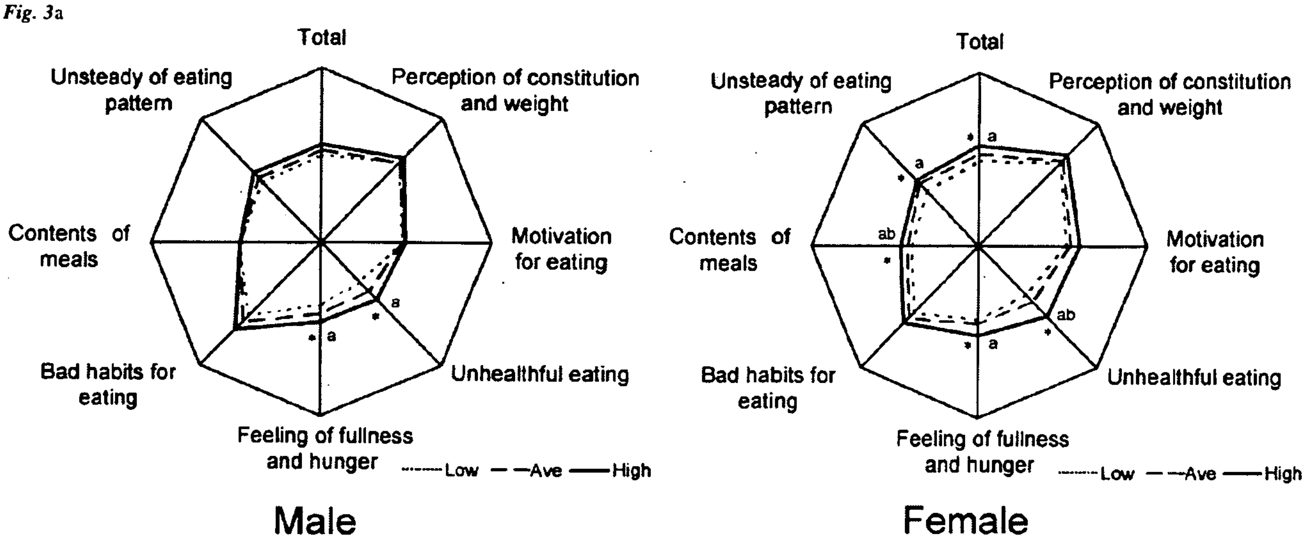

*Fig. 3*b

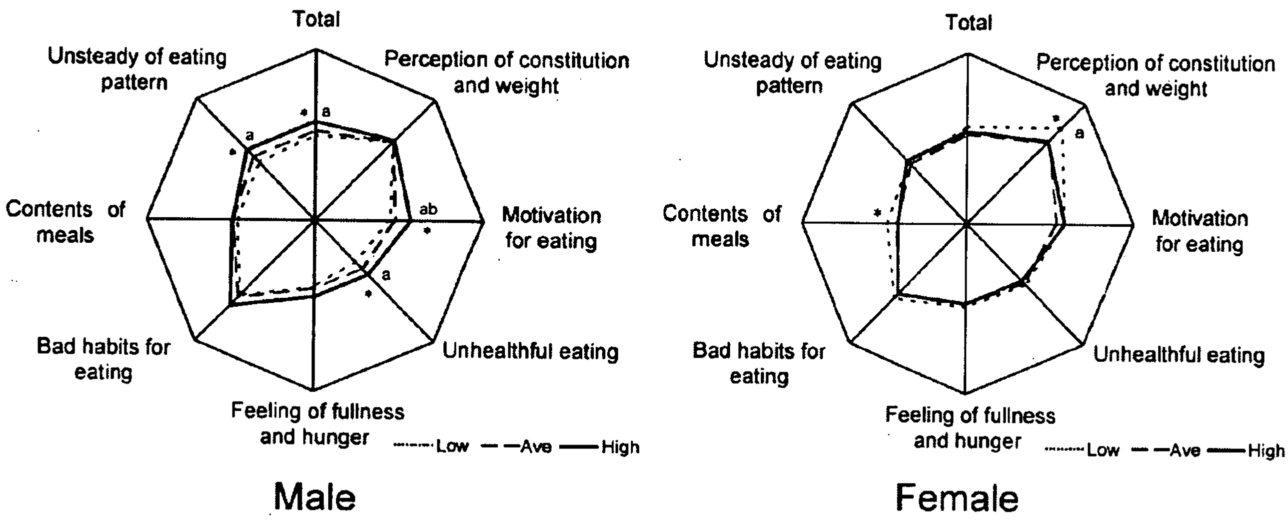

Fig. 3. Comparison of the eating behaviors among subjects in the low, average, and high classes of Neuroticism (a) and Openness (b), separated by sex (males, left; females, right). Asterisks indicate significant difference among the three classes (ANOVA, $*p < 0.05$). Each superscript indicates significant 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 month.	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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Original Article

The Use of a Uniaxial Accelerometer to Assess Physical-activity-related Energy Expenditure in Obese Men and Women: Saku Control Obesity Program (SCOP)

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Abstract

INTRODUCTION: Energy expenditure (EE) associated with physical activity is negatively correlated with prevalence of obesity and related diseases, and exercise plays a major role in prevention and treatment of these diseases. We determined baseline daily step-count and physical activity-related energy expenditure (PAEE) in 230 obese subjects (40–64 years old) participating in the Saku Control Obesity Program. The secondary purpose of this study was to determine the association between abdominal fat and amount of physical activity.

METHODS: Daily step-count and PAEE were measured using a uniaxial accelerometer. The subjects wore the uniaxial accelerometer on their belt from the time they woke up until going to bed for 2 weeks. Adjusted PAEE (METs·h/day) was calculated based on daily PAEE and body weight.

RESULTS AND CONCLUSIONS: Daily step-count, PAEE, and adjusted PAEE were 7,815±3,211 (mean±SD) steps/day, 258±115 kcal/day, and 3.09±1.38 METs·h/day, respectively. There were no significant differences in daily step-count or adjusted PAEE between men and women. Daily step-count and adjusted PAEE were somewhat lower than the reference values for the quantity of physical activity for health promotion (8,000-10,000 steps/day and 3.3 METs·h/day) established by the Ministry of Health, Labour, and Welfare of Japan. BMI, visceral fat area, and abdominal circumference were negatively and weakly correlated with daily step-count and adjusted PAEE ($r=-0.13$ to -0.19, $P<0.05$ to 0.01). These results suggest that the amount of physical activity assessed by uniaxial accelerometry is partially associated with not only systemic obesity but also abdominal obesity.

KEY WORDS: accelerometer, energy expenditure, daily step-count, obesity, physical activity

Introduction

The energy expenditure (EE) associated with physical activity is negatively correlated with the prevalence of obesity and related diseases, such as diabetes, hypertension, and cardiovascular disease, and exercise has been shown to play a major role in the prevention and treatment of these diseases.[1-3] When developing treatment strategies for these diseases, including nutritional education, quantitative information related to physical activity is required to provide more effective goals. Thus, to prevent and treat these diseases more effectively, information regarding physical activity is useful, not only for researchers and healthcare workers but also for the general public.

Activity monitoring based on an accelerometry sensor is a useful method for obtaining objective information on physical activity patterns and for estimating the related EE,[4,5] because this type of sensor (Lifecorder; Suzuken Co. Ltd., Nagoya, Japan) can continuously measure the intensity, duration, and frequency of activity. The device has a unique algorithm for assessment of PAEE, especially unstructured activities. In addition, several studies indicated that the EE during running and walking estimated using this device correspond to the EE measured by indirect calorimetry, and the device was also more effective for measuring EE in free-living conditions as compared with a metabolic chamber.[6,7]

Increasing physical activity and decreasing caloric intake are indispensable for the improvement of excess weight and obesity. The Saku Control Obesity Program (SCOP) is a randomized control crossover study that aims to reduce visceral fat in overweight and obese subjects by interventions of physical activity and diet. Our systematic review suggested that an increase in adjusted PAEE at 10 METs·h/week (1.38 METs·h/day) is necessary to reduce visceral fat area in overweight and obese subjects.[8] The increase in adjusted PAEE corresponds to an increase of nearly 3,000 steps/day. Thus, all SCOP subjects receive physical activity modification education so that their daily step-count increase gradually by 3,000 steps/day. As each subject's target for modification of physical activity depends on the baseline level, accurate baseline measurements of physical activity are needed. The first purpose of the present study was to accurately determine the baseline status of physical activity using a uniaxial accelerometer. Furthermore, there have been few studies of the relationship between abdominal obesity and physical activity. Therefore, the second purpose of this study was to determine the association between visceral fat area measured by CT scan and amount of physical activity estimated by accelerometry.

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Methods

Each year about 7,000 examinees came to in Saku Health Doc Center for health checkups. Including all visits, the Saku Health Doc Center database contains approximately 197,000 records. We used the database to select initial examination records, and about 45,000 examinees were identified. For this study, the inclusion criteria were age 40–64 years and a body mass index (BMI:kg/m^2) within the upper quintile (28.3). Exclusion criteria were psychiatric conditions or physical conditions (i.e., significant hepatic or renal dysfunction and significant cardiovascular disease such as heart failure, stroke, and transient ischemic attacks) that would preclude full participation in the study; current treatment for obesity; current treatments known to affect eating or weight (e.g., medications). A total of 917 people whose BMI was more than 28.3 (upper quintile) were identified in the health checkup database, and 235 participants were enrolled in the Saku Control Obesity Program (SCOP). [9]

Five subjects who did not wear the accelerometer for 7 days or more were excluded from the study. Of the remaining 230 subjects, 111 were male and 119 were female. All research procedures of SCOP were performed according to the Helsinki Declaration. All subjects gave their written informed consent to participation in the study, and all procedures were reviewed and approved by the Ethical Review Board of the National Institute of Health and Nutrition.

To determine the baseline values of physical activity, each subject wore a uniaxial accelerometer on his or her belt from the time of waking to going to bed for 2 weeks. Measurements were as follows: daily step-count; PAEE; adjusted PAEE for body weight; and time spent in light, moderate, and vigorous physical activity. As the daily physical activities varied across the measurement period, daily mean values were calculated.

The activity monitor measures acceleration in the vertical direction. According to technical details provided by the manufacturer (Suzuken Co.,Ltd.), it samples the acceleration at 32 Hz and assesses values ranging from 0.06 to 1.94 g (where 1.00 g is equal to the acceleration of free fall). The acceleration signal is filtered by an analog band-pass filter and digitized. The frequency of acceleration signals is used to determine the step frequencies. Studies have shown that during walking the step frequencies measured by the accelerometer are within ±3% of the actual number of steps.[10] A maximum pulse over 4 s is taken as the acceleration value, and the activities are categorized into 11 activity levels based on the pattern of the accelerometer signal. The activity levels are subsequently converted by an algorithm to calculate EE (kcal) based on the following principle: when the sensor detects or more three acceleration pulses for 4 consecutive seconds, the activities are recognized as physical activity and are categorized into one of 9 activity levels (levels 1.0–9.0). The activity levels are calculated and counted every 4 s. The activity levels for ranges from 1.0 to 9.0 in steps of one unit corresponded to 1.465, 2.075, 2.808, 3.601, 4.537, 5.737, 7.324, 9.460, and 10.661 cal/kg/4 s, respectively.[7] There was a strong correlation between the activity levels and the measured EE while walking (r^2=0.93; P<0.001).[7] The daily PAEE (kcal) was calculated by summing the EE corresponding with activity levels every 4 s (cal/kg/4 s) and the product of the body weight (kg) of each subject.

If an acceleration pulse due to physical activity (*i.e.*, corresponding to activity levels 1.0–9.0) is not followed immediately by another acceleration pulse, it is not counted as 0.0 but level 0.5 is arbitrarily assigned for 3 min. It is assumed that the subject is standing up (or sitting down) and remaining in that state. These postures involve a higher EE than the resting supine position. Briefly, isolated spurts of acceleration are assumed to be due to acute changes in posture (lying down, sitting, and standing), because walking and moving around are typically rhythmic activities. EE due to very small trunk movements and posture effects (*e.g.*, changing from sitting to standing position, light deskwork) were not included in the PAEE. Thus, the PAEE measured by the accelerometer was systematically underestimated during a 24-h period, and the accelerometer assessed energy expenditure well during both the exercise period and the non-structured activities.[7]

As the PAEE is associated with body weight, PAEE adjusted for body weight (adjusted PAEE) was calculated as follows: adjusted PAEE (METs·h)=PAEE (kcal)/[W (kg) × 1.05].[11] The various activity levels are categorized as light (<3.0 METs), moderate (3.0–6.0 METs), and vigorous (>6.0 METs), and the time spent in each activity category per total time of physical activity (%) was calculated. In addition, the time spent in sedentary activity (sitting at a desk, visiting friends, reading, or watching television) was obtained from subjects' answers to the International Physical Activity Questionnaire (IPAQ).[12]

Anthropometric measurements (height, weight, and abdominal circumference) were determined in the standing position after the subjects removed their clothes, shoes, and socks. Abdominal circumference as a surrogate measurement of abdominal obesity was measured at the level of the umbilicus during expiration. Abdominal fat distribution was determined with subjects in the supine position using CT according to the procedure described previously.[13] Visceral fat areas were measured on one cross-sectional scan obtained at the umbilicus.

All statistical analyses were performed using SPSS® software (version 14.0; SPSS Inc., Chicago, IL, USA). All data are shown as means ± standard deviation. The differences between groups were analyzed by unpaired t-test. Linear regressions and Pearson's correlation coefficients were calculated. In addition, stepwise regression analysis was performed. Statistical significance was set at $P<0.05$.

Results

The subjects' characteristics are listed in ***Table 1***. Although there were no significant differences in age or BMI between men and women, height, body weight, and abdominal circumference in men were significantly greater than those in women. Using the Japanese diagnostic criteria, the prevalence of metabolic syndrome was 62.9% in men and 51.3% in women. These values

Table 1 Subject characteristics at baseline

Variables	Total (n = 235)	Men (n = 116)	Women (n = 119)
Age (years)	53.9 ± 6.6	53.4 ± 6.6	54.5 ± 6.4
Height (cm)	161.8 ± 8.6	168.4 ± 5.8	155.4 ± 5.5*
Weight (kg)	80.7 ± 12.1	86.4 ± 11.8	75.2 ± 9.5*
BMI (kg/m^2)	30.8 ± 3.4	30.4 ± 3.5	31.1 ± 3.1
Abdominal circumference (cm)	106 ± 9	105 ± 9	107 ± 8
SBP (mmHg)	138 ± 19	136 ± 17	140 ± 20
DBP (mmHg)	85 ± 14	84 ± 14	86 ± 13
FPG (mg/dL)	112 ± 26	112 ± 25	112 ± 27
TG (mg/dL)	158 ± 84	167 ± 89	148 ± 78
HDL cholesterol (mg/dL)	53 ± 11	50 ± 10	56 ± 12*
Visceral fat area (cm^2)	144 ± 53	159 ± 54	130 ± 47*

BMI, body mass index; SBP, systolic blood pressure; DBP, diastolic blood pressure; FPG, fasting plasma glucose; TG, triglyceride; HDL, high density lipoprotein
*: p < 0.05 vs. men

Table 2 ***Daily physical activity at baseline***

Variables	Total (n = 230)	Men (n = 111)	Women (n = 119)
No. steps (steps/day)	7815 ± 3211	7601 ± 3300	8015 ± 3127
PAEE (kcal/day)	258 ± 115	271 ± 127	246 ± 102*
Adjusted PAEE (METs·h/wk)	3.09 ± 1.38	3.02 ± 1.43	3.15 ± 1.35
Time spent in light PA (%)	77.2 ± 12.2	76.1 ± 12.2	78.2 ± 12.2
Time spent in moderate PA (%)	21.5 ± 11.0	23.0 ± 11.9	20.0 ± 9.9*
Time spent in vigorous PA (%)	1.1 ± 1.4	0.9 ± 1.1	1.2 ± 1.5
Time spent in sedentary activity (min/day)	381 ± 230	436 ± 247	324 ± 188*

PAEE, physical-activity-related energy expenditure; METs, metabolic equivalents; PA, physical activity
*: p < 0.05 vs. men

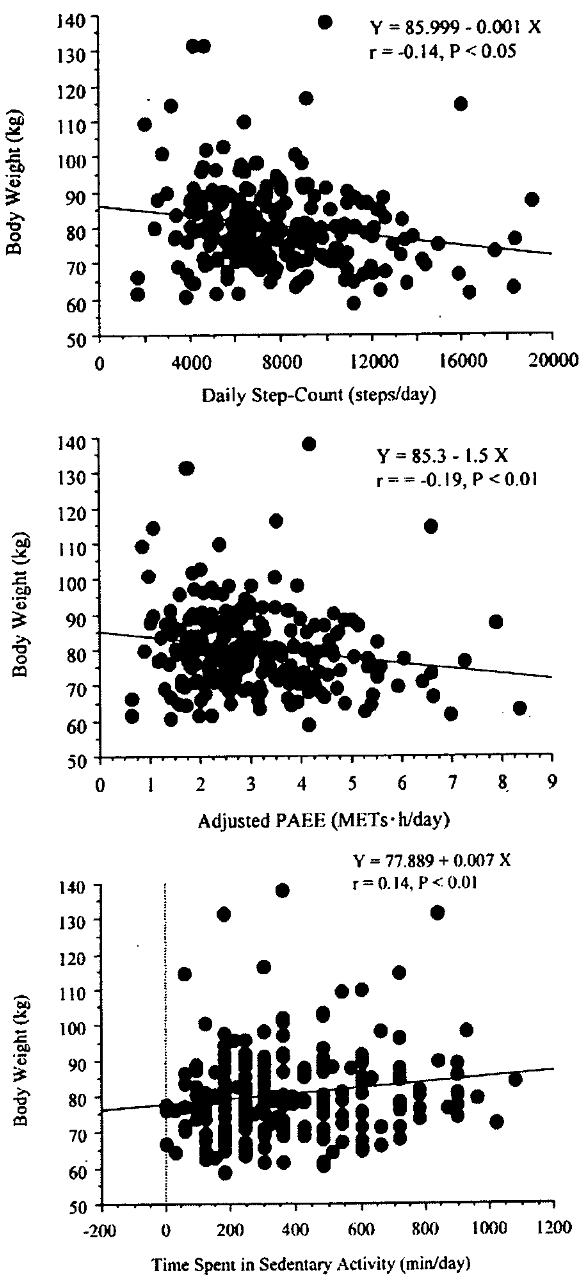

Fig. 1. Relationships between body weight and daily step-count (upper), adjusted physical activity-related energy expenditure (middle), and time spent in sedentary activity (bottom).

are notably lower in both men and women compared to the prevalence calculated using the International Diabetes Federation definition[14] based on waist circumference for Japanese (men: 77.6%, women: 72.3%), whereas only the values for women are lower using the American Heart Association/National Heart, Lung, and Blood Institute definition (men: 51.7%, women: 72.3%).[15]

The physical activity properties at baseline (*i.e.*, daily step-count, PAEE, adjusted PAEE, and time spent in light, moderate, and vigorous physical activity) are shown in ***Table 2***. The daily PAEE was significantly larger in men as compared with women. The time spent in moderate physical activity was longer in men than in women. In contrast, the time spent in sedentary activity in women was significantly shorter than that in men. There were no significant differences in other physical activity parameters between men and women. Although the association between occupation and PAEE was examined, there were no significant differences among the occupational categories (data not shown).

In all subjects, the daily step-count was closely related to the daily PAEE (r=0.92, P<0.001) and adjusted PAEE (r=0.99, P<0.001). The daily step-count was positively associated with the time spent in moderate physical activity (r=0.35, P<0.001), but negatively associated with time spent in light physical activity (r=−0.30, P<0.001). BMI was negatively correlated with the daily step-count (r=−0.13, P<0.05) and adjusted PAEE (r=−0.14, P<0.05). Moreover, body weight was negatively correlated to the daily step-count (r=−0.19, P<0.01, ***Figure 1, top***) and adjusted PAEE (r=−0.18, P<0.01, ***Figure 1, middle***). Visceral fat area was negatively and significantly correlated to the daily step-count (r=−0.14, P<0.05, ***Figure 2, top***) and adjusted PAEE (r=−0.15, P<0.05, ***Figure 2, bottom***). Abdominal

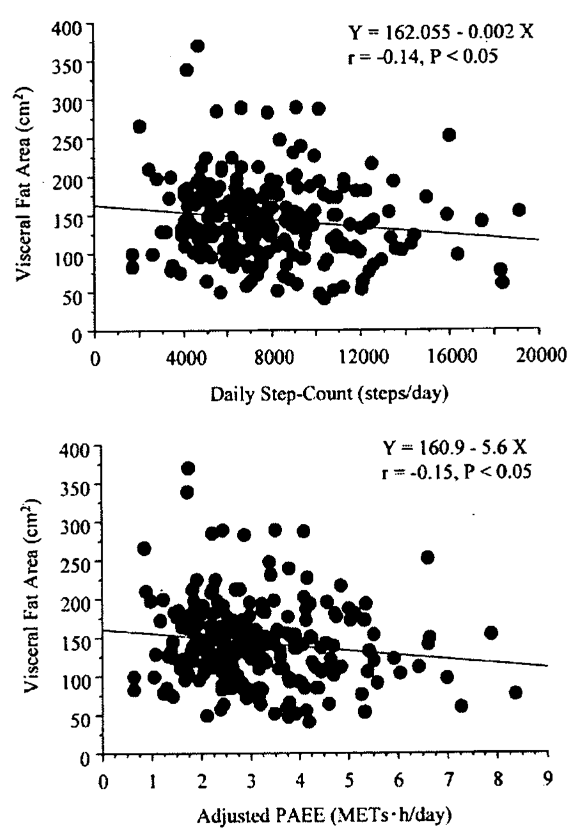

Fig. 2. Relationships between visceral fat area and daily step-count (upper), adjusted physical activity-related energy expenditure (middle), and time spent in sedentary activity (bottom).

circumference as a surrogate measurement of abdominal obesity was negatively and significantly related to the daily step-count ($r=-0.14$, $P<0.05$) and adjusted PAEE ($r=-0.16$, $P<0.05$). However, body weight had positive and significant correlations with daily PAEE ($r=0.15$, $P<0.05$) and the time spent in sedentary activity ($r=0.14$, $P<0.05$, ***Figure 1, bottom***). If all activities were weight-bearing, the PAEE would only be expected to be directly related to body weight.

Stepwise regression analysis showed that the daily step-count could be adopted as an independent variable for BMI and body weight, and adjusted PAEE could be adopted as an independent variable for visceral fat area and abdominal circumference.

Discussion

The main findings of this descriptive study were as follows. First, the mean daily step-count was 7,815 steps in all SCOP subjects, with no difference between men (7,601 steps) and women (8,015 steps). Second, the adjusted PAEE for body weight was 3.09 METs·h/day in all subjects, and there was no sex-related difference. The adjusted PAEE was somewhat smaller than the reference values for the quantity of physical activity for primary prevention of lifestyle-related diseases (3.3 METs·h/day) established by the Ministry of Health, Labour, and Welfare of Japan.[16] Third, the amount of physical activity (daily step-count and adjusted PAEE) was significantly and negatively related to body size (body weight and BMI) and abdominal fat (visceral fat area and abdominal circumference) in the pooled subjects, although the correlation coefficients were weak ($r=-0.1$ to -0.2).

Average daily step-count in Japanese men is generally greater than that in Japanese women as assessed by a national health and nutrition survey.[17] In the present study, the daily step-count in female subjects was about 1,400 steps/day greater than that in male participants. The unexpectedly higher daily step-count in the female subjects may be related to their slower walking speed and shorter stride than the male subjects. In fact, the time spent in moderate physical activity (brisk walking) by women was significantly shorter than that by men, and the time spent in light physical activity (slow walking) tended to be longer in women as compared with men.

In 2006 the Ministry of Health, Labour, and Welfare reexamined the recommended quantity of exercise for primary prevention of lifestyle-related diseases (originally proposed in 1989) and set reference values for the quantity of physical activity and exercise for Japanese people between the ages of 20 and 69 years. Specifically, for individuals who intend to promote health mainly through physical activity, walking 8,000 to 10,000 steps/day (23 METs·h/week) was set as the target daily amount of physical activity.[16] In the present study, the daily step-count and adjusted PAEE for body weight were 7,815 steps/day and 3.09 METs·h/day, respectively, which were somewhat lower than the reference values described above.

Several previous studies from the USA and UK indicated that daily step-counts in overweight and obese adults are lower than those in normal-weight peers.[18,19] The present study showed that adjusted PAEE and daily step-count were significantly and negatively correlated with visceral fat and abdominal circumference in the pooled overweight and obesity subjects. This is the first evidence that the amount of physical activity is partly associated with not only systemic obesity but also abdominal obesity. Furthermore, in accordance with the results of stepwise regression analysis, although daily step-count was an independent predictor of weight and BMI, adjusted PAEE was an independent predictor of abdominal obesity, *i.e.*, visceral fat area and abdominal circumference. As adjusted PAEE is determined by the duration and intensity of physical activity, accumulation of abdominal fat may be associated with not only the duration but also the intensity of physical activity. We should emphasize that the relationships between amount of physical activity and obesity variables were weak ($r=-0.1$ to -0.2). This implies that factors other than physical inactivity (*e.g.*, overeating) may strongly contribute to obesity in the SCOP subjects. To clarify the cause of obesity in SCOP subjects, the results from the uniaxial accelerometer should be compared with the responses to dietary history questionnaires.

Increasing physical activity and reducing caloric intake are indispensable for the improvement of excess weight and obesity. SCOP is a randomized control crossover study aiming to reduce visceral fat of overweight and obese subjects by interventions of physical activity and diet. Our systematic review suggested that an increase in adjusted PAEE at 10 METs·h/week (1.38 METs·h/day) is necessary to reduce visceral fat of overweight and obese subjects. The increase in daily step-count corresponds to an increase of almost 3,000 steps/day as compared with the baseline. Therefore, all SCOP subjects receive physical activity modification education so that their daily step-count increases gradually by 3,000 steps/day, and it is necessary to set the mean value of action targets for 11,000 steps/day and 4.5 METs·h/day.

The validity and reliability of the uniaxial accelerometer have been established.[6,7,10] One methodological limitation, however, is that a uniaxial accelerometer cannot measure very light physical activity (<1.8 METs).[7] Daily life includes a great deal of very light physical activity, and very light PAEE occupies more than the half of total PAEE. Therefore, we should emphasize that the PAEE obtained in the present study was not total PAEE but PAEE at 2METs intensity or more. Moreover, the cross-sectional study design is another limitation of the present study. The results of the present cross-sectional study must be confirmed prospectively with exercise intervention studies in future.

Acknowledgments

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Original Article

Accuracy of Predictive Equations for Basal Metabolic Rate and Contribution of Abdominal Fat Distribution to Basal Metabolic Rate in Obese Japanese People

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Abstract

BACKGROUND: Large errors may occur when predicting basal metabolic rate (BMR) based on physical characteristics in obese people. In addition, the contribution of abdominal visceral fat to BMR remains controversial. This study examined the accuracy of several predictive equations for BMR and the contribution of abdominal fat distribution to BMR in obese Japanese participants in the Saku Control Obesity Program (SCOP).
METHODS: BMR was determined using a mask and Douglas bag in adult males (n = 12) and females (n = 11). We measured abdominal subcutaneous and visceral fat areas using computerized tomography.
RESULTS: All the equations, with the exception of Bernstein's, overestimated BMR in obese males. Some equations, including the Japan-Dietary Reference Intakes and the Food and Agriculture Organization of the United Nations/World Health Organization/United Nations University (FAO/WHO/UNU) equations, overestimated BMR in obese females, while the Harris-Benedict and Henry equations provided relatively accurate predictions of BMR in obese females. We found no correlation between abdominal visceral fat area and BMR when adjusted for sex, fat-free mass, and abdominal subcutaneous fat area (partial r =−0.022). Abdominal subcutaneous fat area correlated significantly with BMR when adjusted for sex, fat-free mass, and abdominal visceral fat area (partial r = 0.732), although this correlation was no longer significant after adjustment for total fat mass (partial r = 0.266).
CONCLUSIONS: In obese Japanese subjects, most the predictive equations overestimated BMR in males, whereas some equations were relatively accurate for females. Our findings indicate abdominal fat distribution may not be independently related with BMR.

KEY WORDS: Basal metabolic rate, obese, predictive equation, abdominal visceral fat

Introduction

Basal metabolic rate (BMR) constitutes the largest component of total energy expenditure in the majority of people. Because BMR can be predicted from simple anthropometric measurements, it is often used to estimate total energy expenditure.

Many equations have been developed for estimating basal or sleeping metabolic rates based on anthropometric measurements, age, and sex.[1,2)] These equations can be helpful when actual metabolic measurements are not available. It has been shown in Caucasians, however, that BMR is considerably more difficult to predict in obese than in normal-weight subjects.[2-5)] Studies have found that predictive equations overestimate BMR and/or that large prediction errors may occur in obese subjects.[2-5)] In addition, most of the equations currently available apply only to Caucasians. The validity of the predictive equations has not been examined in obese Japanese subjects, despite several studies showing that some of the predictive equations are not applicable to nonwhite populations.[6-9)]

In addition, the contribution of abdominal fat distribution to BMR remains controversial. Some studies have shown a relationship between abdominal visceral fat (AVF) area and BMR or resting metabolic rate,[10-14)] whereas others have not.[15-17)] To our knowledge, no study has examined these relationships in Japanese subjects using computerized tomography (CT), with the exception of Okura et al, who investigated the relationship in healthy elderly subjects.[14)] They reported that adjusted resting energy expenditure correlated inversely with AVF but not with abdominal subcutaneous fat (ASF). While significant, this relationship with AVF was relatively weak (r = −0.131).

In the present study, we examined the validity of predictive equations for BMR in obese Japanese men and women. The contribution of abdominal fat distribution, as measured by CT, to BMR was also examined.

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Methods

Subjects

The subjects in the study were 50- to 54-year-old obese subjects (12 males and 12 females) residing in Saku city. They were randomly selected from among the participants in the Saku Control Obesity Program (SCOP), the details of which are described elsewhere in this supplement.[18,19] The measurements of BMR for one of the female subjects failed; therefore, data for 12 males and 11 females were used in the present study.

The study protocol was approved by the Ethics Committees of the National Institute of Health and Nutrition and Saku Central Hospital. The study protocol was explained to the subjects prior to enrollment, and all subjects provided their informed consent.

Basal Metabolic Rate

The subjects reported to the hospital for the series of measurements at approximately 8 am on the study day. BMR was measured in the supine position and in the post-absorptive state (12 hours or longer after the last meal). The temperature in the room was controlled at 24–26°C. The measurement was performed using a mask and Douglas bag for 20 minutes with 1 minute of intermission. The volume of expired air was measured with a certified dry gas meter (Shinagawa DC-5, Tokyo, Japan). The expired air was sampled and the O_2 and CO_2 concentrations were measured using a gas analyzer (Arco System, AR-1, Kashiwa, Japan) with a galvanic O_2 sensor and an infrared CO_2 sensor. For each of the consecutive measurements, the gas analyzer was calibrated initially using atmospheric air. The values of O_2 consumption and CO_2 production were expressed under standard temperature, pressure, and dry air conditions. BMR was estimated from O_2 consumption and CO_2 production using Weir's equation.[20]

Anthropometric Measurements

Body weight was measured to the nearest 0.1 kg and height to the nearest 0.1 cm using a stadiometer. The measurements were performed in light clothing and underwear. Body mass index (BMI) was calculated as weight (kg) divided by square of height (m^2). Percentage body fat was evaluated by the bioelectric impedance method (Tanita, BF-220, Tokyo, Japan).

To assess ASF and AVF levels, a CT scan was performed at the level of the umbilicus, with the subject in the supine position. ASF and AVF areas were determined using commercially available software (Fat Scan; N2 System Corp., Osaka, Japan).[21] The attenuation range of CT numbers for ASF was set as the mean ± 3 standard deviation (SD).

Predictive Equations of Basal Metabolic Rate

The predictive equations of Japan-Dietary Reference Intakes (DRI),[22] Harris and Benedict,[23] the Food and Agriculture Organization of the United Nations/World Health Organization /United Nations University (FAO/WHO/UNU),[24] Henry,[25] Owen,[26,27] Mifflin,[28] and Bernstein[29] were evaluated (***Table 1***). For the Japan-DRI equations, the Ministry of Health and Welfare proposed adjusting for body weight.[30] Therefore, the equations including this adjustment were also examined. For the FAO/WHO/UNU equations, those using body weight only are often used. However, in the present study, equations using body weight and height were also examined.

Statistical Analyses

The results are presented as the mean ± SD. The % difference of the prediction error was calculated as the residual divided by the measured value for each subject. The relationship between measured and predicted values of BMR and anthropometric measurements was examined using Pearson's correlation. Sex was treated as a binomial variable (0 for males, 1 for females) and was adjusted for in the partial correlation analysis. Adjustment for age was not performed because the range was small (50–54 years). Statistical significance was set at $p < 0.05$ for all predictors. The statistical analyses were performed using SPSS® for Windows (version 14.0; SPSS Inc., Chicago, IL, USA).

Table 1 Predictive equations for basal metabolic rate used in the present study

Predictive equations (kcal/day)	Males	Females
Japan-DRI [22]	weight × 21.5	weight × 20.7
Japan-DRI with adjustment for body weight [22,30]	[21.5 + (10.8 - 0.173 × weight)] × weight	[20.7 + (8.9 - 0.172 × weight)] × weight
Harris and Benedict [23]	66 + (13.7 × weight) + (5.0 × height) − (6.8 × age)	665 + (9.6 × weight) + (1.8 × height) − (4.7 × age)]
FAO/WHO/UNU (body weight) [24]	879 + (11.6 × weight)	829 + (8.7 × weight)
FAO/WHO/UNU (body weight and height) [24]	901 + (11.3 × weight) + (16.0 × height/100)	865 + (8.7 × weight) − (25.0 × height/100)
Henry [25]	[(59.2 × weight + 2480)]/4.184	[(40.7 × weight + 2900)]/4.184
Owen [26,27]	879 + (10.20 × weight)	795 + (7.18 × weight)
Mifflin [28]	5 + (9.99 × weight) + (6.25 × height) − (4.92 × age)	−161 + (9.99 × weight) + (6.25 × height) − (4.92 × age)
Bernstein [29]	−1032 + (11.0 × weight) + (10.2 × height) − (5.8 × age)	844 + (7.48 × weight) − (0.42 × height) − (3.0 × age)

weight: kg, height: cm, age: year.
Predictive equations for 50 to 54-yr-old obese subjects were used.

Results

The physical characteristics of the subjects are summarized in *Table 2*. There was a similar degree of correlation between the measured and predicted values of BMR for the various predictive equations (r = 0.839–0.859). The relationships between measured and predicted BMR based on the Japan-DRI, DRI-adjusted, Harris-Benedict, and Bernstein equations are shown in *Figures 1 and 2*. In obese males, the majority of equations overestimated BMR, particularly for those with lower BMR (*Figure 1*), whereas Bernstein's equation significantly underestimated BMR (*Table 3*). In particular, the Japan-DRI and FAO/WHO/UNU equations overestimated BMR to the greatest extent. The Mifflin equation provided a better prediction of BMR, while the equation overestimated BMR. In obese females, the Japan-DRI and FAO/WHO/UNU equations overestimated BMR, whereas the Harris-Benedict and Henry equations provided a relatively accurate prediction of BMR (*Figure 2*). In both sexes, adjustment for body weight in the Japan-DRI equations attenuated the overestimation of BMR, although the value still remained too high. In addition, the FAO/WHO/UNU equations with or without body height provided almost identical values. The SD of the % difference of the predicted BMR was comparable between the various equations.

Following adjustment for sex and fat-free mass, BMR correlated significantly with ASF (r = 0.806, $p < 0.001$) and AVF (r = 0.493, $p < 0.05$). When sex, fat-free mass, and ASF were adjusted for, BMR was not correlated with AVF (r = −0.022, n.s.). The relationships between AVF and residual of BMR adjusted for sex, fat-free mass, and ASF is shown in *Figure 3*. On the other hand, BMR correlated significantly with ASF when adjusted for sex, fat-free mass, and AVF (r = 0.732, $p < 0.001$); however, this correlation was no longer significant after additional adjustment for total fat mass (r = 0.266, n.s.).

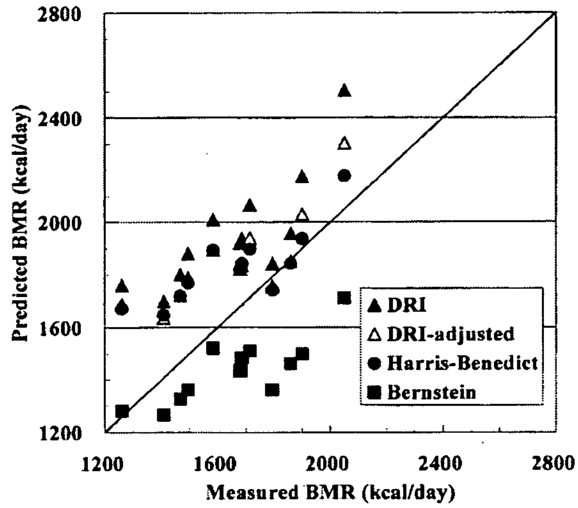

Fig. 1. Relationships between measured and predicted basal metabolic rate (BMR) in obese males. DRI: Japan-Dietary Reference Intakes.

Table 2 Physical characteristics of subjects

	Mean± SD	Range
Males		
Age (year)	52 ± 1	50.0 - 54.0
Body height (cm)	172.8 ± 3.9	168.8 - 179.2
Body weight (kg)	91.3 ± 10.0	79.1 - 116.5
Body mass index (kg/m²)	30.6 ± 3.3	27.7 - 39.2
Percentage of body fat (%)	28.3 ± 4.9	23.4 - 39.2
Abdominal subcutaneous fat area (cm²)	272 ± 80	163 - 436
Abdominal visceral fat area (cm²)	165 ± 51	98 - 289
Females		
Age (year)	53 ± 2	50.0 - 54.0
Body height (cm)	158.6 ± 5.8	152.0 - 169.3
Body weight (kg)	82.5 ± 12.2	69.3 - 109.7
Body mass index (kg/m²)	32.7 ± 3.8	28.4 - 40.0
Percentage of body fat (%)	44.3 ± 7.0	34.7 - 62.5
Abdominal subcutaneous fat area (cm²)	383 ± 96	250 - 619
Abdominal visceral fat area (cm²)	140 ± 57	84 - 266

SD: standard deviation

Table 3 Measured and predicted basal metabolic rate in obese people

	Values(kcal/day)		%difference(%)	
	Mean± SD	Range	Mean± SD	Range
Males				
Measured	1659 ± 226	1262 - 2051		
Predicted				
Japan-DRI [22]	1963 ± 216	1701 - 2505	19.2 ± 9.8	2.7 - 39.6
Japan-DRI with adjustment for body weight [22,30]	1856 ± 178	1639 - 2304	12.8 ± 9.7	-2.1 - 33.8
Harris and Benedict [23]	1831 ± 142	1648 - 2178	11.4 ± 10.0	-2.9 - 32.5
FAO/WHO/UNU (body weight) [24]	1938 ± 116	1797 - 2230	18.2 ± 12.0	4.2 - 45.0
FAO/WHO/UNU (body weight and height) [24]	1961 ± 113	1822 - 2245	19.6 ± 12.3	5.4 - 46.9
Henry [25]	1885 ± 142	1712 - 2241	14.8 ± 10.7	0.7 - 38.8
Owen [26,27]	1811 ± 102	1686 - 2067	10.5 ± 11.4	-2.7 - 35.9
Mifflin [28]	1744 ± 108	1601 - 1996	6.3 ± 10.3	-6.4 - 28.2
Bernstein [29]	1436 ± 125	1267 - 1713	-12.7 ± 7.4	-24.0 - 1.7
Females				
Measured	1477 ± 210	1192 - 1895		
Predicted				
Japan-DRI [22]	1709 ± 253	1435 - 2271	15.8 ± 7.2	-1.8 - 24.5
Japan-DRI with adjustment for body weight [22,30]	1599 ± 210	1372 - 2064	8.6 ± 6.6	-6.2 - 18.5
Harris and Benedict [23]	1496 ± 126	1367 - 1777	2.1 ± 8.0	-7.5 - 15.7
FAO/WHO/UNU (body weight) [24]	1547 ± 106	1432 - 1783	5.8 ± 9.2	-5.9 - 21.9
FAO/WHO/UNU (body weight and height) [24]	1543 ± 106	1430 - 1778	5.6 ± 9.2	-6.2 - 21.6
Henry [25]	1496 ± 119	1367 - 1760	2.2 ± 8.2	-7.1 - 16.7
Owen [26,27]	1388 ± 88	1293 - 1583	-5.0 ± 8.6	-16.5 - 9.9
Mifflin [28]	1396 ± 149	1240 - 1719	-4.9 ± 7.0	-15.0 - 5.9
Bernstein [29]	1370 ± 94	1273 - 1581	-6.3 ± 8.1	-16.6 - 7.7

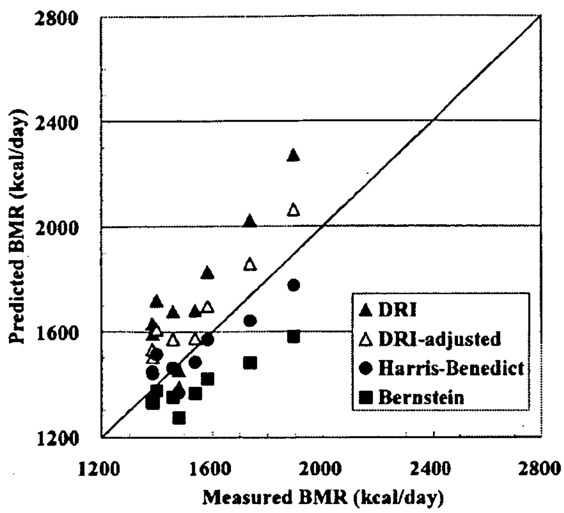

Fig. 2. Relationships between measured and predicted basal metabolic rate (BMR) in obese females. DRI: Japan-Dietary Reference Intakes.

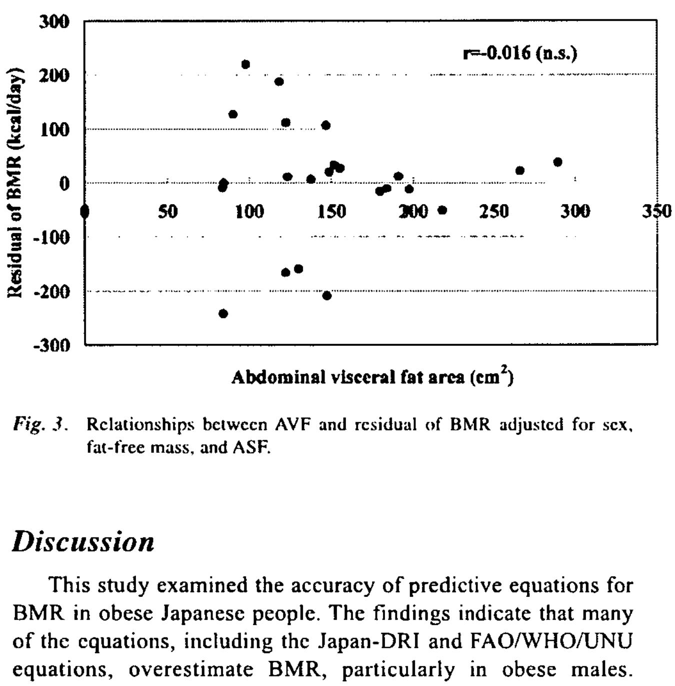

Fig. 3. Relationships between AVF and residual of BMR adjusted for sex, fat-free mass, and ASF.

Discussion

This study examined the accuracy of predictive equations for BMR in obese Japanese people. The findings indicate that many of the equations, including the Japan-DRI and FAO/WHO/UNU equations, overestimate BMR, particularly in obese males. Similar results have been reported in many studies on Caucasians. However, several of the equations provided accurate estimates of BMR, mainly in obese females. Among the equations, the Mifflin equation in males, and the Harris-Benedict and Henry equations in females, provided a better accurate prediction of BMR.

The Japan-DRI equations are simple multiples of body weight (21.5 × body weight for males, 20.7 × body weight for females). The other equations include an intercept in addition to a term for body weight and in some cases terms for body height and age as well. Considering these differences, it is understandable that the Japan-DRI equations overestimate BMR in obese subjects of both sexes. To improve this, a term for adjustment of body weight was provided for each sex.[30] While this term reduced the overestimation of BMR, a large overestimation of BMR (12.8 ± 9.7 % for males and 8.6 ± 6.6 % for females) still remained. The suggested values for adjustment of body weight were obtained in rather lean Japanese subjects, with fat-free mass contributing considerably more to BMR than fat mass. Therefore, a low fat-free mass relative to body weight (indicated as a high percentage of body fat) may explain the overestimation, even after additional adjustment for body weight.[1] In contrast, Bernstein's equation, which was developed for obese Caucasians, underestimated BMR, especially in obese males.

The other equations incorporate an intercept, and some of them have terms for body height and age. Thus, it is expected that the terms adjust BMR for body composition to some degree, similar to BMI. However, the FAO/WHO/UNU equations that include terms for body weight and height provided comparable values to those with a term for body weight only. Considering the mean values of % difference, inclusion of terms for body height and/or age is not likely to improve the prediction of BMR in obese people, whereas the existence of an intercept or a curvilinear term would be expected to improve the predictive ability of the equation.

With the exception of the Japan-DRI equation, the predictive equations did not overestimate BMR to a large extent in obese females. This sex difference was not observed in previous studies. Female subjects in the present study had slightly higher BMI than male subjects, and their percentage body fat was also greater. While these differences should have been associated with overestimation of BMR considering the result of the present study, this can not explain the sex difference. Thus, the reason for the observed sex difference in the present study remains unclear.

The SD values of the % difference ranged from 7.4% to 12.3% in obese males and 6.6% to 9.2% in obese females. Previous studies reported that the interindividual coefficient of variation was about 8-13% in healthy people,[31,32] although interindividual variability of sleeping metabolic rate was less, at least for Japanese subjects.[9] The values calculated in the present study were within this range, but different from those of a previous study of obese subjects.[3] A possible reason for this difference may have been the uniformity of body composition, although the range of percentage body fat in the present study was large in both sexes, suggesting that this was unlikely to be the reason.

It remains controversial whether AVF is related to BMR.[10-17] Because AVF is related to sex, fat mass, and ASF, it is necessary to adjust for these variables in order to examine the relationship between AVF and BMR. In the present study, we adjusted not only for sex and fat-free mass but also for ASF to clarify the independent contribution of abdominal fat distribution. As a result, ASF but not AVF correlated independently with BMR after adjustment for sex and fat-free mass. However, this significant correlation disappeared after additional adjustment for fat mass, indicating that the independent correlation between ASF and BMR may actually reflect the relationship between fat mass and BMR. Adipose tissue has a small but definite contribution to BMR, while ASF and fat mass are correlated with each other, particularly in obese people, who have a large fat mass. If the relationship between ASF and BMR reflects the relationship between fat mass and BMR, this implies that abdominal fat distribution is not associated with BMR in obese Japanese people.

One of the limitations of the present study was the relatively small sample size. However, to obtain values of % difference when using predictive equations of BMR, the sample size used should provide relatively stable results. In the present study, normal-weight subjects were not included. To clarify the characteristics of obese subjects, this may be another problem. In addition, the analysis evaluating the contribution of abdominal fat distribution was performed in all subjects with adjustment for the effect of sex. As a consequence, comparison with the results of earlier studies could not be undertaken. Some of these previous studies reported the results for separate age categories, sex, and menopausal status.

In conclusion, the majority of the predictive equations overestimated BMR in obese Japanese males, whereas some equations were relatively accurate for obese females. In obese people, overestimated BMR may lead to overestimation of total energy expenditure. Caution is therefore needed when selecting predictive equations of BMR for obese Japanese people. Our results indicate abdominal fat distribution was not independently related to BMR.

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