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Circ J 2006; **70:** 110–114

Cutoff and Target Values for Intra-Abdominal Fat Area for Prevention of Metabolic Disorders in Pre- and Post-Menopausal Obese Women Before and After Weight Reduction

Ryosuke Shigematsu, PhD; Tomohiro Okura, PhD*; Syuzo Kumagai, PhD**; Yuko Kai, PhD**,‡‡; Teruo Hiyama, MD†; Haruka Sasaki, MD††; Hitoshi Amagai, MSc‡; Kiyoji Tanaka, PhD*,§

Background The Japan Society for the Study of Obesity originally proposed a cutoff value of >100 cm^2 for the intra-abdominal fat area (IFA) as a definition for "visceral fat obesity" in Japanese adults. There are no studies on the cutoff or target values after weight reduction in pre- and post-menopausal women.
Methods and Results In the present study 149 pre-menopausal obese women (PreM, 43.3 years, 27.3 kg/m^2) and 58 post-menopausal women (PostM, 53.9 years, 27.7 kg/m^2) participated in a 14-week weight reduction program. The IFA was measured by computed tomography. The program induced significant reductions in body weight (8.6 kg in PreM and 7.8 kg in PostM). The IFA decreased significantly from 80.4±41.3 to 50.7±23.8 (PreM) and from 115.4±38.0 to 75.7±30.5 (PostM).
Conclusions The receiver-operating characteristic curve analyses revealed that the appropriate cutoff values were 80 cm^2 (PreM) and 110 cm^2 (PostM) before the program, and after the program the appropriate target values were determined as 60 and 70 cm^2, respectively. (*Circ J* 2006; **70:** 110–114)

Key Words: Diet; Exercise; Fat body; Menopause; Metabolic syndrome

The "visceral fat obesity" refers to the condition of excess intra-abdominal fat (IF), which places people having this type of excess fat at high risk for obesity-related metabolic disorders, such as hyperglycemia and dyslipidemia. The Japan Society for the Study of Obesity (JASSO)[1] originally defined visceral fat obesity in Japanese as having an IF area (IFA) >100 cm^2 and indicated that such people tend to have 1 or more metabolic disorders.[1] Nakamura et al reported that approximately 62% of patients with coronary artery disease have an IFA =100 cm^2 or more,[2] and Banno et al found that sleep-disordered breathing was closely associated with obesity.[3]

JASSO used a cross-sectional study design to validate the cutoff value for IFA of 100 cm^2 for the diagnosis of visceral fat obesity,[1] but intervention studies for assessing an appropriate target value that can be used for people who reduce their IF significantly have been lacking, and it is unclear whether, or at what point, decreasing IF improves metabolic disorders.

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There are several studies of the effects of menopause on the relationship of IF with metabolic diseases. Excess IF deposition is more prevalent in post-menopausal women than in pre-menopausal women[4] although it occurs more frequently in males of all ages.[5] Hunter et al[6] and Gower et al[7] showed that the IFA and the risk of coronary heart disease (CHD) were positively correlated and that each average in post-menopausal women was higher than that in pre-menopausal women. The results of the study by Rebuffe-Scrive et al[8] suggest that one of the reasons for this phenomenon is the more pronounced activation of lipoprotein lipase in the omental adipose tissue of post-menopausal women than in that of pre-menopausal women. The cutoff value for the IFA derived by JASSO[1] was defined using a combination of pre- and post-menopausal women; the standards were, therefore, not established while considering the presence of menopause.

Based on these results, the current study assesses JASSO's visceral fat obesity IFA cutoff value of 100 cm^2 in pre- and post-menopausal women and also assesses the IFA target value after a weight reduction program. We tested 2 related hypotheses: (1) the cutoff value would be valid when applied to a group consisting of only pre- or post-menopausal women and (2) it would remain valid in each group after reducing the IFA.

Methods

Participants

Advertisements were placed in local newspapers and on bulletin boards in Toride City in Ibaraki Prefecture and Abiko City in Chiba Prefecture in Japan to locate potential participants with a desire to lose weight. Those who responded to the advertisements were interviewed by telephone. The participants supplied information on demographics, menstrual status, and medical history. They were excluded from the study if their weight had been unstable for the past 6 months, if they had attended any weight reduction programs in the past year, or if they were breast feeding or pregnant. A study physician confirmed if participants were possibly pregnant. Further, the study staff and radiologic technologist explained to all participants that computed tomography (CT) can have deleterious effects. After applying the exclusion criteria to potential participants, the selected participants (n=220) received the details of the study's purpose and protocol. Oral informed consent, following the Helsinki Declaration principles and approved by the Higashi Toride Hospital Review Board, was obtained from each person. We defined "menopause" as the status of no menses for 1 year prior to the study. "Pre-menopause" was used define individuals who were not experiencing menopause. Therefore, the pre-menopausal group consisted of women who declared having menses in the year prior to the study (PreM). The post-menopausal group included those women who had not had menses for more than 1 year prior to the beginning of the study (PostM).

IFA

We measured the IFA and subcutaneous fat area (SFA) at the level of the umbilicus using cross-sectional CT (SCT-6800TX; Shimadzu, Japan). Scans were performed with the participants in the supine position. Details of the scanning have been reported by Tokunaga et al[9] and Yoshizumi et al.[10] Measurements taken before and after the program were conducted at the same time of day by the same technician to minimize technical error. The IFA and SFA were calculated using a computer-software program (FatScan; N2system, Japan).[10] The intra-class correlation for repeated IFA determinations in the laboratory (Institute of Health and Sport Sciences, University of Tsukuba) is 0.99 (n=30).

Obesity-Related Metabolic Disorders

The obesity-related metabolic disorders were defined as follows: accumulation of IF (waist circumference ≥90 cm in female) plus 2 or more co-morbidities consisting of (i) triacylglycerol (TG) ≥150 mg/dl and/or high-density lipoprotein cholesterol (HDLC) <40 mg/dl, (ii) systolic blood pressure (SBP) ≥130 mmHg or diastolic blood pressure (DBP) ≥85 mmHg, or (iii) fasting plasma glucose ≥110 mg/dl.[11,12] These biochemical assays were performed on approximately 10 ml of blood drawn from each participant after an overnight fast. The blood assays were analyzed by technicians at the Koto Biken Research Institute in Tsukuba, Japan. Total body composition was assessed by bioelectrical impedance methods.[13] We used the Tanaka formula[13] to estimate the total body density (Db) and the Brozek formula[14] to determine the percentage of body fat. The Tanaka formula accurately predicts the total Db in obese Japanese women (R=0.903, SEE=0.0061 g/cm^3, with the hydrodensitometrically determined Db). SBP and DBP were taken from the right arm using a mercury manometer after at least a 20-min rest while seated. Cuff sizes were selected based on upper arm girth and length.

Weight Reduction Program

A 14-week weight reduction program was monitored by a physician, dietician, exercise instructors, and graduate school students majoring in exercise intervention. After the baseline assessment, participants received instruction on the diet program, which comprised weekly 90-min diet consultations, at which a diet-recording notebook and several handouts were given to participants to help them adhere to the principles of the daily diet. They were asked to take a well-balanced supplemental food product (MicroDiet; Sunny Health Co, Ltd, Japan) daily as 1 of their meals, preferably as lunch or dinner. The MicroDiet, which includes various amino acids, vitamins, and minerals, was developed for very low-energy diets. To prevent boredom, the MicroDiet was served in 7 flavors: coffee, milk tea, cocoa, yogurt, banana, strawberry, and apple. Participants received packages consisting of 7 meals (each flavor) once a week. The nutritional values for each flavor were slightly different (ie, there was a range for protein (20.6–21.5 g), carbohydrate (15.0–18.1 g), fat (1.6–3.0 g), and energy (169–173 kcal) for each meal). The diet records were obtained from 86 participants (60 in the PreM group, 26 in the PostM group), who were randomly selected. One week before the study, the participants were asked to record everything they had eaten for the 3 days prior to the study. Furthermore, they were asked to record their diets for 3 days during week 7, the midpoint of the intervention.

The exercise program included 3 weekly 45-min sessions. During the first and second weeks of the 14-week program, exercise sessions consisted mainly of walking and stretching, with the gradual addition of a bench-stepping exercise[15] as the main element. Thereafter, the exercise session consisted of a 10-min warm-up, 25-min bench stepping, and a 10-min cool-down. The bench stepping targeted an exercise intensity in which the participant's heart rate reached a level 10–15% higher than the level corresponding to her lactate threshold (LT). The LT was defined as the point at which blood lactate concentration maintained a non-linear increase above the level at rest.[16] To determine LT, a series of venous blood samples (1 ml each) was drawn from the antecubital vein every minute during a maximal cycling exercise test, which was done with an accompanying electrocardiogram as a baseline assessment. All blood samples were analyzed by the electrochemical enzymatic method using a lactate analyzer (model 23L, YSI Inc, OH, USA). For establishing LT, the log (oxygen uptake)–log (lactate) transformation method was used.[16]

Exercise was consistently performed for 45 min throughout the 14 weeks, but the intensity was progressively increased. In the first 2 weeks, the bench-stepping instructor targeted the intensity as described. After the 3rd week, the instructor progressively increased the intensity by increasing the cadence of the step and adding more dynamic movements. Ratings of the perceived exertion (RPE)[17] by all participants were also monitored during the bench stepping. Based on their RPE, the instructor moderated the intensity as "somewhat hard" to "hard," which corresponded to LT or a little above LT.[18]

Statistical Analysis

Differences in variables between the beginning and end of the program were tested in each group by using Student's paired t-tests. Data were analyzed with the SPSS 11.01J statistical software package (SPSS, Chicago, IL, USA), and P-values less than 0.05 were considered statistically significant.

To assess the cutoff value (before weight reduction) and

Table 1 Baseline Characteristics of Participants

	PreM + PostM (n=207)	PreM (n=149)	PostM (n=58)
Age (years)	46.2±8.1	43.3±6.7 (24–57)	53.9±6.0 (45–62)
Height (cm)	157.0±5.2	157.9±5.1 (146.1–171.8)	154.6±4.9 (145.6–165.4)
Weight (kg)	67.6±8.2	68.1±7.6 (53.6–87.6)	66.3±9.7 (50.0–111.3)
Body mass index (kg/m²)	27.4±3.0	27.3±2.9 (21.8–37.3)	27.7±3.3 (20.9–40.7)
Percent body fat (%)	34.6±4.9	34.1±4.2 (24.9–46.7)	35.9±6.2 (24.1–51.9)
Intra-abdominal fat area (cm²)	90.2±43.3	80.4±41.3 (12.2–222.9)	115.4±38.0 (32.3–191.2)
Subcutaneous fat area (cm²)	252.2±82.1	250.9±75.4 (103.5–548.0)	255.5±97.9 (90.5–684.0)
Abdominal circumstance (cm)	95.7±8.6	95.1±8.4 (73.8–118.0)	97±8.9 (80.5–131.5)

Values are means±standard deviations (minimum–maximum).
PreM, pre-menopausal obese group; PostM, post-menopausal obese group.

Table 2 Effects of a 14-Week Weight Reduction Program on Anthropometric Variables, Abdominal Fat Area, Metabolic Variables, and Blood Pressures

	PreM + PostM (n=207)		PreM (n=149)		PostM (n=58)	
	Before	After	Before	After	Before	After
Weight (kg)	67.6±8.2	59.3±7.4* (−12%)	68.1±7.6	59.6±6.9* (−12%)	66.3±9.7	58.5±8.5* (−12%)
Body mass index (kg/m²)	27.4±3.0	24.0±2.7* (−12%)	27.3±2.9	23.9±2.6* (−12%)	27.7±3.3	24.4±2.9* (−12%)
Percent body fat (%)	34.6±4.9	29.4±4.6* (−15%)	34.1±4.2	28.8±4.0* (−15%)	35.9±6.2	31.1±5.5* (−13%)
Intra-abdominal fat area (cm²)	90.2±43.3	57.7±28.1* (−32%)	80.4±41.3	50.7±23.8* (−31%)	115.4±38.0	75.7±30.5* (−34%)
Subcutaneous fat area (cm²)	252.2±82.1	181.6±76.9* (−29%)	250.9±75.4	176.2±73.2* (−31%)	255.5±97.9	195.5±84.6* (−24%)
Abdominal circumference (cm)	95.7±8.6	85.2±8.6* (−6%)	95.1±8.4	84.9±8.0* (−5%)	97.3±8.7	86.2±10.0* (−7%)
Fasting plasma glucose (mmol/L)	5.41±1.13	4.94±0.68* (−7%)	5.25±0.86	4.88±0.68* (−6%)	5.84±1.57	5.10±0.67* (−10%)
Total cholesterol (mmol/L)	5.71±0.95	5.17±0.89* (−9%)	5.59±0.95	5.02±0.83* (−9%)	6.00±0.89	5.57±0.92* (−7%)
Triacylglycerol (mmol/L)	1.18±0.59	0.80±0.41* (−23%)	1.13±0.59	0.76±0.38* (−24%)	1.30±0.58	0.91±0.48* (−21%)
HDLC (mmol/L)	1.70±0.38	1.65±0.33* (−1%)	1.72±0.36	1.65±0.32* (−2%)	1.66±0.44	1.65±0.35 (+2%)
SBP (mmHg)	132.4±18.8	120.6±16.5* (−8%)	129.9±17.9	118.6±15.5* (−8%)	138.7±19.7	125.8±17.7* (−9%)
DBP (mmHg)	82.1±11.7	74.4±11.0* (−9%)	81.0±11.5	74.2±10.5* (−8%)	84.9±11.9	74.8±12.4* (−12%)

Values are means±standard deviations (relative change, %).
PreM, pre-menopausal obese group; PostM, post-menopausal obese group; HDLC, high-density lipoprotein cholesterol; SBP, systolic blood pressure; DBP, diastolic blood pressure.
**Significant intra-group difference (P<0.05).*

Table 3 Number and Percentage of Participants That Exceeded Each Criterion of the Metabolic Disorders Before and After Weight Reduction Program

	PreM (n=149)		PostM (n=58)	
	Before	After	Before	After
High abdominal circumference	112 (75%)	37 (25%)	50 (86%)	18 (31%)
High triacylglycerol and/or low HDLC	27 (18%)	6 (4%)	11 (19%)	6 (10%)
High triacylglycerol	26 (17%)	5 (3%)	9 (16%)	5 (9%)
Low HDLC	3 (2%)	3 (2%)	4 (7%)	2 (3%)
High systolic and/or diastolic blood pressure	80 (54%)	36 (24%)	41 (71%)	23 (40%)
High systolic blood pressure	74 (50%)	33 (22%)	39 (67%)	23 (40%)
High diastolic blood pressure	52 (35%)	22 (15%)	28 (48%)	8 (14%)
High fasting plasma glucose	11 (7%)	6 (4%)	14 (24%)	6 (10%)

Abbreviations see in Table 2.

the target value (after weight reduction) for IFA, receiver-operating characteristic (ROC) curve analysis was applied to the data derived from the IFA and the number of metabolic disorders. By provisionally varying the cutoff/target values of IFA, we calculated the sensitivities and specificities for each value. Sensitivity was defined as the proportion of participants having a given disorder who also had an IFA equal to or greater than the provisional value to all participants having a given disorder. Specificity was defined as the proportion of participants having no disorders who had an IFA that fell below the provisional value to all participants having no disorders. The sensitivities and specificities were calculated for every 10 cm² of IFA from 30 to 140 cm². At each 10 cm² provisional value, the sensitivity was multiplied by the specificity, and the point having the maximum product of sensitivity × specificity was considered to be the most valid cutoff/target value.

Results

Of the 220 women originally enrolled in this study, 13 dropped out because they moved out of the area, needed to care for a family member, or felt fatigued. Consequently, 207 women completed the study (Table 1), and attendance averaged 92% (range 83–100%).

There were significant decreases in the anthropometric variables, IFA, SFA, metabolic variables, and blood pressures in each group (Table 2). Total body composition analysis revealed that the reduction in body weight was mostly from loss of body fat. The reduction in fat-free mass

Table 4 Sensitivities and Specificities From Each Provisional Cutoff/Target Value of Intra-Abdominal Fat Area (IFA)

Cutoff/target value (IFA, cm²)	*PreM*				*PostM*			
	Before		*After*		*Before*		*After*	
	Sensitivity	*Specificity*	*Sensitivity*	*Specificity*	*Sensitivity*	*Specificity*	*Sensitivity*	*Specificity*
30	0.96	0.04	0.93	0.22	1.00	0.00	1.00	0.06
40	0.91	0.23	0.87	0.42	1.00	0.06	1.00	0.11
50	0.89	0.37	0.73	0.57	0.98	0.12	1.00	0.3
60	0.80	0.47	0.67	0.71	0.95	0.18	0.91	0.40
70	0.72	0.55	0.33	0.82	0.93	0.29	0.91	0.63
80	0.63	0.74	0.27	0.89	0.90	0.41	0.82	0.66
90	0.53	0.81	0.07	0.96	0.88	0.59	0.64	0.72
100	0.45	0.89	0.07	0.98	0.85	0.59	0.64	0.79
110	0.40	0.95	0.07	0.99	0.73	0.71	0.45	0.96
120	0.27	0.96	0.07	0.99	0.56	0.82	0.36	0.98
130	0.21	0.97	0.07	1.00	0.41	0.94	0.18	1.00
140	0.16	0.97	0.00	1.00	0.29	0.94	0.09	1.00

Abbreviations see in Table 1.
Underlined values indicate the most valid cutoff/target values.

was significant, but the absolute change was less than the change in fat mass.

The daily average energy intake in the PreM group was 2,100±354 kcal at 1 week before the study and it decreased significantly to 1,163±242 kcal. The PostM group significantly reduced their energy intake from 1,870±394 kcal to 1,029±152 kcal. The daily protein intake in the PreM group was 78.1±15.1 g, and it decreased significantly to 70.3±14.2 g. In the PostM group, it decreased significantly from 86.1±33.5 g to 65.1±9.0 g. The daily fat intake decreased significantly from 66.3±14.9 g to 33.1±9.9 g in the PreM group and from 56.6±20.4 g to 27.4±6.2 g in the PostM group. The daily carbohydrate intake also decreased significantly from 285.5±61.2 g to 147.5±31.3 g in the PreM group and from 272.3±94.1 g to 136.1±23.8 g in the PostM group.

The percentage of participants that exceeded each criterion of the metabolic disorders is shown in Table 3. More than 50% of the participants had a high abdominal circumference before the program (PreM, 75%; PostM, 86%). The most frequent disorder in both groups was hypertension, with hyper-SBP (PreM, 50%; PostM, 67%) and hyper DBP (PreM, 35%; PostM, 48%). After the program, the percentages of all disorders, except for hypo-HDLC in the PreM group, decreased.

The characteristics of the 12 provisional cutoff/target values for IFA from 30 cm² to 140 cm² are presented in Table 4. Sensitivities before the program ranged from 0.16 to 0.96 in the PreM group and from 0.29 to 1.00 in the PostM group. Specificities ranged from 0.04 to 0.97 for the PreM group and from 0.00 to 0.94 for the PostM group. The products obtained by multiplying the sensitivity by the specificity at each provisional value ranged from 0.04 to 0.47 in the PreM group and from 0.00 to 0.52 in the PostM group. The largest products of sensitivity and specificity were found at 80 cm² (0.47) for the PreM group and 110 cm² (0.52) for the PostM group. Therefore, the cutoff values with the best equilibrium between sensitivity and specificity approached 80 cm² in the PreM group and 110 cm² in the PostM group before weight reduction. Using the same method of analysis, the most valid target values after the weight reduction program were determined to be 60 cm² for the PreM group and 70 cm² for the PostM group.

Discussion

In only a few studies, attempts have been made to determine the cutoff or target value for obesity-related metabolic disorders.[1,19,20] In the present study the cutoff values of IFA were 80 cm² for pre-menopausal women and 110 cm² for post-menopausal women before weight reduction, which are similar to the 100 cm² value considered appropriate by JASSO[1] in a study that did not differentiate between pre- and post-menopausal women. Williams et al, in a combined study of both pre- (n=133) and post-menopausal women (n=87), concluded that 110 cm² was the cutoff value for IFA above which the risk of metabolic disorders increases.[20] Despres and Lamarche indicated that 130 cm² of IFA was the point at which the metabolic risks increase significantly, derived from a sample of 115 males and 72 females.[19] Considering those findings, the cutoff values in the current study seem to be reasonable.

A difference of 30 cm² in the cutoff values was noted between the PreM women (80 cm²) and the PostM women (110 cm²) before weight reduction. Williams et al reported that menopause has little effect on the risks of metabolic disorders, such as HDLC, TG, SBP, DBP, and TC:HDLC ratio,[20] although in a review by Knopp,[21] post-menopausal women were found to have elevated risks because of decreased estrogen contributing to increased low-density lipoprotein cholesterol (LDLC) and decreased HDLC concentrations. Hunter et al[6] have also reported that post-menopausal women showed a greater IFA than pre-menopausal women and that menopausal status was significantly related to an increased risk for CHD risk factors (ie, LDLC, TC:HDLC ratio). Therefore, in the current study, the cutoff values were expected to differ according to the menopausal status of the participants. Because estrogen decreases the risk of CHD during the pre-menopausal period, perhaps counterbalancing some of the CHD risks brought on by excess IF,[21] further assumptions were made that the cutoff value for PreM women would be the same or even greater than that of PostM women. The ROC analyses revealed a difference of 30 cm² between the cutoff values in each group, but the value of the PreM group was lower than that of the PostM group. The study from the Women's Health Initiative also showed that estrogen would not confer benefits for preventing CHD among women with estrogen plus progestin therapy relative to women given a placebo.[22]

There seem to be other factors in addition to estrogen affecting the risk of metabolic disease; for example, aging, which correlates to an increase in IFA[2,6,23] and adiponectin[24] may be a factor.

In previous studies, a cross-sectional design was used to determine an IFA cutoff value[1,19,20] but because it is also important to determine a target IFA value for reducing the risk of metabolic disease, an intervention design was used in the current study. The IFA relates to the risk of obesity-related metabolic disorders; therefore, we assumed that the target values after weight reduction would remain the same as before the program, but they were lower. Although the reasons for this are unclear, we speculate that once a person is suffering from a metabolic disorder, a significant reduction in IFA may not be enough in itself to ameliorate the situation.

Study Limitations

The reasons for the relatively low sensitivities and specificities derived from IFA and metabolic disorders are unclear. Some unmeasured factors, such as diet and the genetic effect of metabolic disorders, may play a part. Furthermore, homeostasis was not maintained during and just after the weight loss. Another limitation is that the number of participants was small and that the mean body mass index or IFA was not very high, although most participants were obese. Future studies should include a larger number of extremely obese participants to verify the target values for risk of IFA after weight reduction. A significant decrease in HDLC in the PreM group was found after weight reduction, which may have been caused by the diet. Hagan et al[25] reported that HDLC decreased as middle-aged women lost body weight during a 12-week diet program. The significant decrease in TC could be attributed to the fact that TC includes HDLC.

In conclusion, this study presents the cutoff values for IFA in both pre- and post-menopausal obese women, as well as the target values after weight reduction, which are useful for the diagnosis of obesity-related metabolic disorders. Before weight reduction, the cutoff values with the best equilibrium were 80 cm^2 for pre-menopausal women and 110 cm^2 for post-menopausal women. After weight reduction, the target values shifted to 60 cm^2 and 70 cm^2, respectively. Using these values, persons diagnosed with visceral fat obesity can clearly see the benefits of engaging in a diet and exercise program. Furthermore, awareness of a target value makes adherence to the program more likely.

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VI. 予防・治療・管理

ライフスタイルへの介入によるメタボリックシンドロームの予防と治療
運動療法

メタボリックシンドローム診断における運動療法の基本コンセプト

Exercise prescription for people with metabolic syndrome

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Key words：内臓脂肪，運動療法，食事療法，エネルギー消費量

はじめに

メタボリックシンドロームとは，内臓脂肪の過剰蓄積を基盤として，血圧の上昇(正常高値)や糖・脂質代謝の障害が顕在化しつつある状態を指す[1]．したがって，治療や改善のための介入に際しては，内臓脂肪を中心とした体脂肪の減少および血圧や種々の代謝障害の正常化が基本目標となる．

メタボリックシンドロームの診断基準は，①内臓脂肪型肥満を必須とするもの[1,2]，②インスリン抵抗性を必須とするもの[3]，③必須条件を作らないもの[4,5]，の3つに大きく分類できる．そのうち，日本人を対象にしたものでは，内臓脂肪型肥満がメタボリックシンドロームの源泉として強調されている[1]．これらのことから，メタボリックシンドロームの改善を目的とした場合，食事療法(主に食事制限による摂取エネルギー量の減少)とともに，運動の習慣化を通して総消費エネルギー量を増大させる組み合わせ介入が第一選択肢としてあげられよう．

1. 運動だけで内臓脂肪を減らすことは可能か？

肥満を解消するための運動プログラムがテレビや新聞，雑誌などのメディアを通じて頻繁に発信されているが，果たして多くの一般人にとって運動だけで肥満を改善する(内臓脂肪を減らす)ことが可能であろうか．図1において，自転車エルゴメータ運動(またはトレッドミル歩行やウォーキング)と食事制限による体重減少量(1カ月当たり)の理論値を比較した．体重80kgの肥満者が1回30分間，4METs強度で週1回，3回，7回自転車エルゴメータ運動を行った場合，1カ月間の減量の理論値はそれぞれ−0.1kg，−0.2kg，−0.5kgである．一方，減量前の食事による1日総摂取エネルギーを2,500kcalと仮定した場合，この量の10%(250kcal/日)，20%(500kcal/日)，30%(750kcal/日)を減らしたときの1カ月間の減量の理論値はそれぞれ−1.1kg，−2.1kg，−3.2kgである．つまり，週1〜3回程度の運動では体重減少効果は極めて小さく，計算上は毎日(週7回)の運動であっても1日の食事量を10%減らした場合の約半分の効果でしかない．例えば，‘週3回

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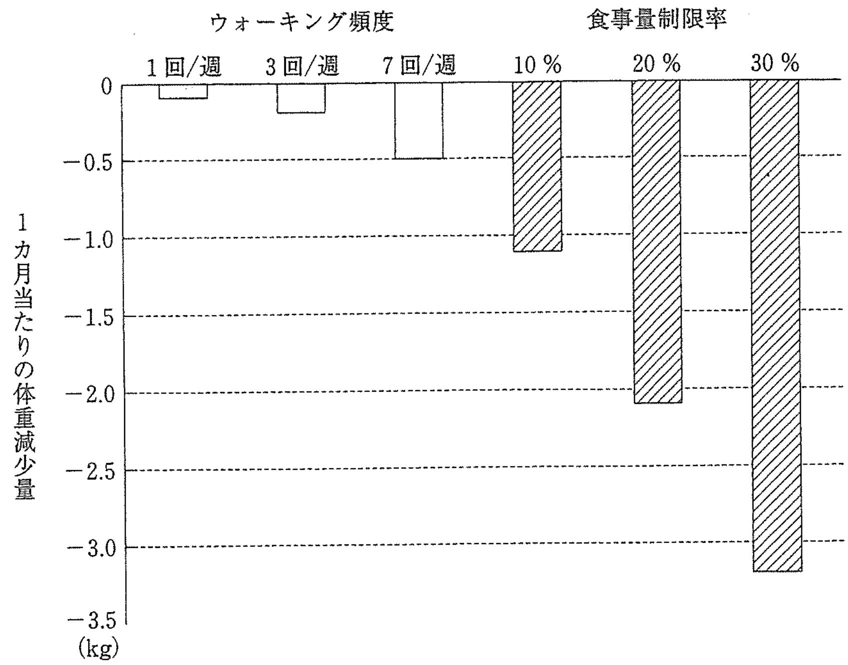

図1 ウォーキングと食事制限による体重減少量(1カ月当たり)の理論値の比較

ウォーキングによる理論値算出に際しては，体重80kgの肥満者が1回30分間，4METs強度で行うものと仮定(条件設定)し，週1回，3回，7回の場合について1カ月間で消費されるエネルギー量に基づき，体脂肪1kgの燃焼エネルギーを7,000kcalとして計算した．また，食事制限による理論値算出は，減量前の1日総摂取エネルギーを2,500kcalと仮定し，この量の10%(250kcal/日)，20%(500kcal/日)，30%(750kcal/日)を減らした場合の体重減少量を推定した．

の自転車エルゴメータ運動またはウォーキング'は臨床現場で頻繁になされる運動処方であるが，この場合の体重減少量は1日の食事量を20%減少させた場合の約1/10にすぎない．恐らく，週3回自転車エルゴメータ運動を行った程度の体重減少量では内臓脂肪の減少量も小さく，メタボリックシンドロームの根本的な改善策としての効果には疑問を呈さずにはいられない．

図2は実際に著者らが介入研究を通して収集したデータであり，運動の効果はそれほど大きくないことが理解できよう．メタボリックシンドロームの改善を企図した運動は，有酸素性運動(40〜90分の低強度での運動または20〜60分の中程度〜やや高めの強度での運動)を週に3〜7日(低強度・短時間なら7日，高め強度・長時間なら3〜4日)実践することである．強度の目安は，乳酸，心拍数，血圧，二重積などから探るのが一般的だが，多人数に効率良く運動を勧めるためには，自覚的運動強度(RPE)を利用しながら本人と指導者による協議に基づいて選定する方法も有用である．その場合，AT pointの処方ではなく，AT zoneを示すのがよい．ここでいうAT zoneとは，RPEで11(‘楽である’)〜15(‘きつい’)くらいの範囲を指す．運動時間については，10分×3回と30分×1回を比べると，強度が同じ(低〜中)であれば後者による効果が大きいが，前者では障害を起こす確率が低いというメリットがある．このことにこだわる必要はない．

“内臓脂肪”(腹囲，中性脂肪)や“血糖”を効率良く減らすには，1日当たり1,200〜1,800kcal程度の食事療法を併用することが有効かつ安全で，個人差が大きいとはいえ少量の運動だけでは限界がある．“血圧”を改善するには，食塩感受性，遺伝体質，肥満度，性格などを考慮に入

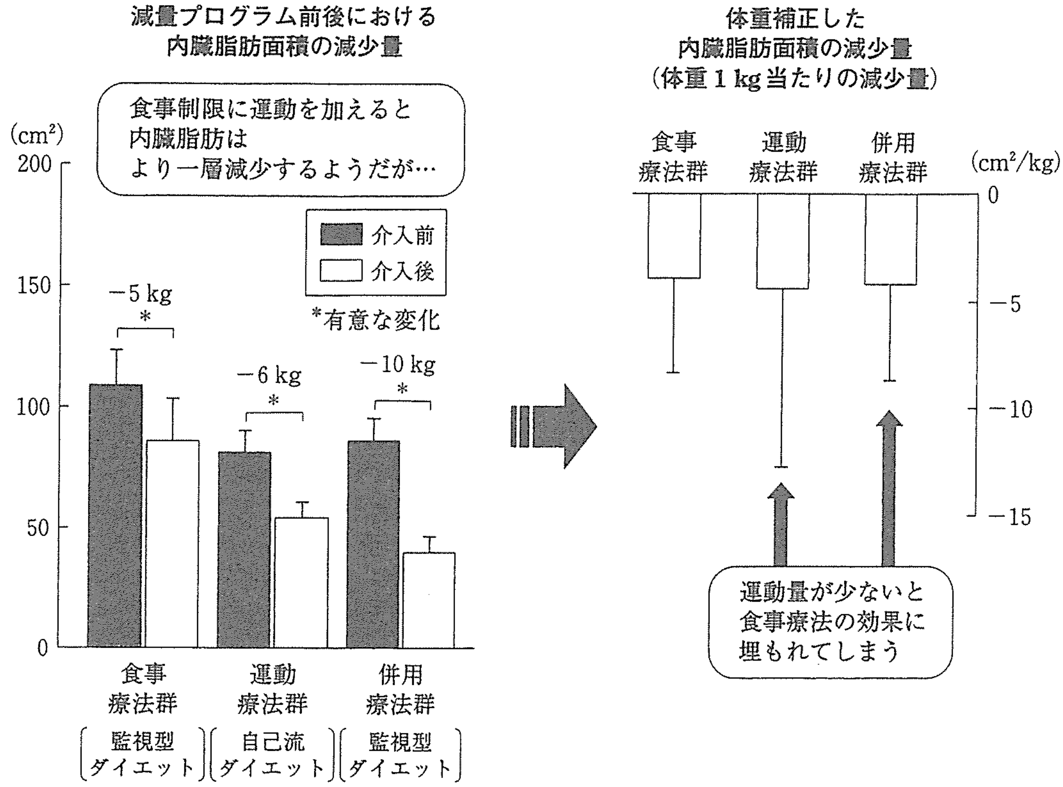

図2　減量プログラム前後における内臓脂肪面積の変化

れながら，個人に合った運動を処方することが肝要で，薬物療法との併用が最も効果的であるとの報告が増えている．“HDLコレステロール”はランナーなどの（最大酸素摂取量の高い）スポーツ選手で最も高く，運動不足の肥満男性で低く，虚血性心疾患の男性で最も低い．HDLコレステロールを高めるには，ジョギングやウォーキング（週に15km程度），水泳，エアロビクス，ダンスなどの有酸素性運動を習慣化・日常化することである．早い人で数カ月，遅い人で数年後に数値が上昇してくる．しかし，運動量が減少し，体脂肪が増えてくると，再び低値に戻りやすい．運動は，有酸素性運動，レジスタンス運動，ストレッチ（または柔軟体操，ヨガ，ピラテスなど）とレクリエーションを上手く組み合わせることが最も適切であろう．世代，季節，天候，仲間の有無，屋内外といった条件に合わせて運動を楽しむ方法を習得することが理想である．

2. 運動と減量は量-反応関係にあるのか？

Ross ら[6]は，1966〜2000年の文献を対象に，‘weight loss’および‘exercise’をキーワードとしたMEDLINEによる検索を行い，ヒットした36の研究についてレビューを行っている．介入期間が16週未満の短期的介入研究におけるエネルギー消費量（運動量）と体重および体脂肪の変化量との関係（相関係数）は，それぞれ r=−0.84とr=−0.76であり，いずれも統計学的に有意（有意確率<0.001）であったことから，短期間の介入では運動量に応じて体重が減少する量-反応（dose-response）関係にあることがうかがえる．一方，介入期間が20週以上の比較的長期間の介入においては，体重および体脂肪ともに運動量との連動はみられなかった（図3）．

Mertens ら[7]は，食事制限をせずに週当たり1,500〜2,000kcalの運動を数年間にわたって処方したところ，年平均の体重減少量は1%（1

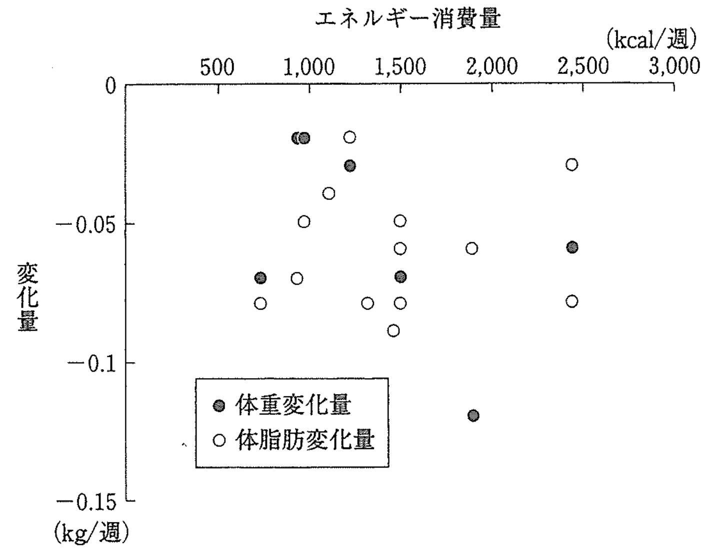

図3　1週当たりのエネルギー消費量と体重および体脂肪変化量との関係(介入期間：20週以上)
(Ross R ら(2001)[6]の報告に基づき著者らが作成)

kg)にも満たなかったと報告している．彼らはこの理由として，食事によるエネルギー摂取量が介入前に比べて8％増加していたことをあげている．日本人を対象とした著者らの取り組みにおいても，同様のことを観察している[8]．また，Leon ら[9]は運動を処方することにより介入期間中の日常生活の活動量が減少することを観察しており，結果的に食事制限を伴わない運動処方は減量に成功せず，冠危険因子を改善することができなかったと述べている．

3．減量介入に性差を考慮すべきか？

食事制限と運動による体重減少量の違いに目を向けてみよう．1969〜84年までに行われた減量に関する研究(メタアナリシス)[10]によると，食事制限による体重減少量は平均−10.7kgであるのに対し，運動のみだと−2.9kgでしかなかった．一方，男性肥満者のみに絞って検討した研究[11]では，食事制限−7.8kgに対して運動−4.6kgと大差は少なく，2つの介入方法による体重減少の違いには性差が存在することも示唆されている．日本人を対象とした著者らの長年の介入研究でも，同様のことを観察している[8]．男性が本格的に運動に取り組んだ場合，運動による総消費エネルギーが大きく増え，かつ暴飲暴食習慣をもっていた人では食事制限の効果も大きくなる．最近では，食事制限と運動の併用介入によって，女性において体重減少の累積的効果(cumulative effect)が得られることも報告されており[12]，少なくとも日本人女性を対象として内臓脂肪の減少を目的とした減量介入を行う際には，運動だけでなく食事制限を併用することの必要性がうかがえる．

メタボリックシンドロームの改善，特に内臓脂肪の減少を目的とする場合には，女性については運動の効果を過大評価せず，食事指導(制限)と運動(主に有酸素性運動)を適切に組み合わせる方法を今後詳細に検討していく必要があるといえる．

4．効果的な運動とは？

一般に脂質燃焼を目的とした場合，最大下(submaximal)強度で行う有酸素性運動をある一定時間継続することが推奨されているが，特に内臓脂肪の減少に関しては，やや高い強度(70〜80％$\dot{V}O_2max$)での運動実践が有効であることが推察される[13,14]．一過性の有酸素性運動時においては，50％$\dot{V}O_2max$と比較して，70％$\dot{V}O_2max$に相当する強度での運動時に，内臓脂肪に由来する脂質の燃焼効率が増大する可能性

が示唆されている[15]．多段階漸増負荷やランプ負荷という特殊なプロトコルでの運動時には，強度が高まるにつれて脂質によるエネルギー供給の割合が低下することは周知の事実であるが，ある程度の時間，運動を継続するという一般的な様式での有酸素性運動時には，高めの強度の方が，総消費エネルギー量(kcal)は大きくなり，脂質の分解・利用の効率が多少低下しても，高い脂肪燃焼効率・少ない消費カロリーの運動時と比較して，実質の脂肪消費量(g)は多くなる．運動中に脂質や糖質が動員される割合の比較にだけ焦点を当てるのではなく，消費されるエネルギーの総量に着目した運動強度の設定や運動処方が重要である．

内臓脂肪型肥満と同様に，メタボリックシンドロームのリスク要因であるインスリン抵抗性などの耐糖能異常は，有酸素性運動だけでなく，筋収縮を強調したレジスタンス運動によっても改善されることが指摘されている．最近の著者らの研究[16]では，一過性の運動においてはやや高めの強度で糖代謝への効果はより増幅されることが明らかとなった．したがって，有酸素性運動とレジスタンス運動の両方を上手く組み合わせて処方することで，より大きな改善が期待できる．また従来より，HDLコレステロールを高めるためには，中程度～高め(最低75％HRmaxまたは60％$\dot{V}O_2$max以上)の強度で週に12.8～16km(3日/週走るとすると1日約4.3～5.4km)以上のジョギングを続けること，すなわち大きな運動量を確保することの必要性が報告されている．ここでいう高めの強度や大きな運動量とは，アスリートの競技レベルを意味するのではなく，一般の人々が実践可能な範囲内の中での‘高いレベル’を指しており，ACSMが推奨する有酸素性運動時の強度範囲を超えるものではない．一般健常者だけでなく，メタボリックシンドロームと診断された場合でも，‘高めの強度’は多くの人に適応可能なレベルといえる．

運動だけで効果を求める場合，大きな運動量を多頻度で実践することが必要となり，コンプライアンスとアドヒアレンスのいずれを考えるにしても，対象者にとって継続が困難となる．冒頭で述べたように，運動のみでメタボリックシンドロームを改善しようとするのではなく，食習慣の改善と運動習慣の定着の両者を踏まえた日常生活自体の改善の気づき(脳のスイッチ‘オン’)が肝要である．

5. 運動処方のパラダイムシフト

専門の運動指導者による導きは有効であるが，運動実践者(クライアント)の体の中で起こっている異常・違和感を運動指導者や医師が常に的確に感じ取ることは困難である．できるだけ運動に伴うケガを起こさず，習慣化につなげていくためには，周囲の者(高齢者体力つくり支援士や健康運動指導士，理学療法士などのコメディカル)が運動実践者に対して自分のからだと対話するよう，繰り返しアドバイスすることが肝要である．自分のからだの内なる声に耳を傾けるといった運動処方[17]はまさに主観的であって，客観性に欠けるとの指摘を受けるが，安価で，随時可能で，時間的ズレがないということを考えれば，これ以上の事故予防チェック方法はほかにない．

また，公衆衛生分野でいわれているinformed choice(多くの情報の中から個人が自分に合ったものを選択すること)を円滑に進めるための多方面からの情報提供や，自らのからだとの対話の勧めが重要である一方で，専門家の別視(蔑視，結果的に差別)に基づく不適切な運動の禁忌指令(逆支援)は避けなければならない．そのためには，専門家は有益な情報を与えつつも，それを選択するかどうかについては不必要に口を挟まないアプローチが望まれる．すなわち，個人の主体性を最優先し，‘押しつけない’あるいは‘過度に規制しない’，そして‘大いに楽しませる’柔軟な運動処方指針の啓発が必要である．

おわりに

運動療法によってメタボリックシンドロームの改善介入を行う場合，一般に運動によって得られる2つの効果(①一時的な急性効果，②慢

性的な持続効果)，および2つの生理的変化(①体脂肪の減少に代表される器質的変化，②分子レベルへの働きかけによる機能的変化)の両側面に関する考察が必要であろう．しかし，本稿では誌面の制約があり，直ちに臨床現場で役立つ食事療法の有効性を強調するとともに，運動療法の基本コンセプトに焦点を絞って述べた．運動それ自体が内臓脂肪の減少にどれほど有効であるかについて解説しながら，血圧や糖・脂質代謝(メタボリックシンドローム)へ与える直接的な効果，およびメタボリックシンドロームの改善にこだわらない広義の健康支援策についても言及した．

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原著

肥満度と介入方法の違いが内臓脂肪型肥満者の減量効果に及ぼす影響

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索引用語：BMI，減量方法，内臓脂肪型肥満，冠危険因子

内臓脂肪型肥満者を対象として肥満度の違い(BMI25以上30未満群とBMI30以上群)および介入方法(食事制限のみのDO群と食事制限に運動を併用したDE群)の違いが内臓脂肪減少や冠危険因子の改善に与える影響を検討することを目的とした．対象者はBMI25以上および内臓脂肪面積100cm²以上の21歳から67歳までの肥満女性145名であり，BMIに応じてDO群とDE群をそれぞれDOⅠ群とDEⅠ群(25≦BMI<30)，DOⅡ群とDEⅡ群(BMI≧30)の4群に分けた．CTスキャンを用いて内臓脂肪面積(VFA)と皮下脂肪面積(SFA)を計測した．冠危険因子は安静時収縮期血圧，安静時拡張期血圧，総コレステロール，中性脂肪，高比重リポ蛋白コレステロール，低比重リポ蛋白コレステロールと空腹時血糖を測定した．これらの項目は14週間の介入期間の前後に測定した．VFAの変化量については運動の有無とBMIの違いの交互作用が見られたが($p=0.01$)，SFAの変化量においては運動の有無とBMIの違いの交互作用は見られなかった．各冠危険因子の変化量に運動の有無とBMIの違いの交互作用が見られたのは空腹時血糖のみであった($p=0.02$)．これらの結果から，BMIの高い内臓脂肪型肥満者は食事制限に運動を加えることによって，より効果的に内臓脂肪の減少や血糖の改善がもたらされることが示唆された．

はじめに

世界保健機構(World Health Organization：WHO)は「成人の体重過多に対するbody mass index(BMI)による分類」をグローバルスタンダードとして，BMI25以上をPreobese，30以上をObeseとする基準を提唱した[1]．一方，日本肥満学会による「新しい肥満の判定と肥満症の診断基準」の中では，わが国の肥満に関する民族的・人種的特異性を考慮に入れた上で，BMI25以上30未満を肥満(1度)と判定している．また，内臓脂肪の蓄積が肥満合併症の大きな要因であることから，BMI25以上かつcomputed tomography(CT)画像分析による内臓脂肪面積(visceral fat area：VFA)100cm²以上の内臓脂肪型肥満を「肥満症」と定義している[2]．

内臓脂肪の減少を目的とするいくつかの介入研究[3～5]によると，食事制限のみの群でも食事制限に有酸素性運動またはレジスタンス運動を併用した群でも体重減少に応じて内臓脂肪が減少することが報告されている．一方，食事制限は行わずに有酸素性運動を継続させたところ，運動が内臓脂肪の減少に効果があったとする報告[6～9]となかったとする報告[10,11]の両方があり，内臓脂肪の減少に対する運動の有用性は明らかではない．

BMIは体脂肪量をよく反映することが知られている[12]．先行研究[13,14]によると，運動による消費エネルギーが同じであっても，ベースラインの体脂肪量が多いほど体脂肪はより多く減少することが報告されている．また，日本肥満学会は腹部CTにて計測した皮下脂肪面積(subcutaneous fat area：SFA)およびVFAとBMIとの関連について，BMIとSFAには高い相関が認められているが，BMIとVFAとの相関は弱く，

特にBMI25以上の肥満者では相関がなく，大きな個人差が存在することを示している[2]．しかしながら，BMIは身長と体重を計測するだけで値を求めることのできる簡便な指標であり，対象に適した介入方法を提案するための簡便なスクリーニングとして活用できる可能性がある．

そこで，本研究ではVFA 100cm^{2}以上の肥満症女性を対象として，肥満度の違い(BMI25以上30未満群とBMI30以上群)および食事療法に運動を加えること(食事制限のみ群と食事制限に運動を併用する群)がVFA減少や冠危険因子の改善にいかなる影響を与えるかを検討することとした．

対象と方法

1．対象者

対象者は地域情報誌を用いて募集し，14週間の食事制限または食事制限に運動実践を加えた減量プログラムを受けた368名であり，その中から日本肥満学会が設定する肥満の判定基準BMI25以上とCTスキャンによるVFA 100cm^{2}以上の内臓脂肪型肥満であることの条件を満たした21歳から67歳までの女性145名をデータ解析の対象とした．対象者に重篤な疾患を有する者は含まれておらず，本研究の目的および検査内容に関する説明を口頭および文書により行い，研究参加への同意(署名)を得た．なお，これらの研究手続については筑波大学倫理委員会において承認を得た．

本研究の対象者145名は，食事制限のみ(diet only：DO)の群51名と有酸素性運動に食事制限を加えた(diet + exercise：DE)群94名に分けられた．月経の有無については，DO群は閉経前63%，閉経後37%であり，DE群は閉経前51%，閉経後49%であった．χ^2検定の結果，DO群とDE群の間に有意差はなかった．DO群およびDE群はBMIの初期値によってDOⅠ群とDEⅠ群(25≦BMI<30)，DOⅡ群とDEⅡ群(BMI≧30)に分けられた．

2．測定項目および測定方法

1)身体組成

体重は0.1kg単位，身長は0.1cm単位で測定し，BMIは体重(kg)を身長(m)の二乗で除することで算出した．体脂肪の測定には，Sekisui製インピーダンス計(Bio impemeter SS103)を用い，測定された電気抵抗値からTanaka et al.[15]の成人肥満女性用の式により身体密度を求め，Brozek et al.[16]の式により体脂肪量(fat mass)，体脂肪率(% fat mass)と除脂肪量(fat-free mass)を算出した．

2)腹部脂肪面積

VFAおよびSFAは仰臥位でCTスキャン(SCT-6800TX, Shimadzu)を用いて臍高位(およそL4-L5)を撮影し，内臓脂肪計測ソフトFat Scan(ver. 2.0, N2システム)を用いて算出した．

3)冠危険因子

安静時収縮期血圧(systolic blood pressure：SBP)と安静時拡張期血圧(diastolic blood pressure：DBP)は20分以上安静にした後で計測した．12時間以上の絶食絶飲状態で採血し，総コレステロール(total cholesterol：TC)，中性脂肪(triglycerides：TG)，高比重リポ蛋白コレステロール(high-density lipoprotein-cholesterol：HDL-C)，低比重リポ蛋白コレステロール(low-density lipoprotein-cholesterol：LDL-C)，空腹時血糖(fasting plasma glucose：FPG)を測定した．

4)最大酸素摂取量

最大酸素摂取量($\dot{V}O_2max$)および無酸素性代謝閾値(anaerobic threshold：AT)を測定するための運動負荷テストは，自転車エルゴメータ(818E, Monark)を使用し，1分ごとに摩擦負荷を0.25kpずつ高める多段階漸増負荷法にて行った．ペダルの回転数は60rpmで一定とした．運動中の各呼気ガス指標の分析には，Mijnhardt製代謝測定装置(Oxycon Alpha)を用いた．$\dot{V}O_2max$は症候性限界を呈した時点の酸素摂取量と定義した．DE群に対する運動指導における強度の目安となるATは，漸増負荷運動時1分ごとに正中肘皮静脈より血液を約0.5mlずつ採取し，血中乳酸濃度の分析(YSI製乳酸分析器1500L)により決定される乳酸閾値(lactate threshold：LT)とした．採血が困難であった際は，$\dot{V}O_2$に対する$\dot{V}CO_2$の上昇開始点(V-slope法)により決定し，その他の呼気ガス指標とともに，Okura & Tanaka[17]による全身持久性体力推定式を補助的に利用した．

3．食事指導および運動指導内容

1)食事指導

DO群とDE群ともに1食あたり400～600kcalのバランスのとれた食事を4群点数法[18]を用いて指導した．4群点数法は，食品に含まれている栄養素と体内での働きによって，食品を4つの群に分類し，各群から食品を選択することによって，必要な栄養素が過不足なく満たされるようにする栄養計算法である．1群は卵や乳製品，2群は肉や魚介類や豆製品，3群は緑黄色野菜や淡色野菜や芋類，果物，4群は穀物や油，砂糖や調味料である．計算単位は点数で表し，80キロカロリー(kcal)＝1点として計算させた．

本研究は1食(400kcal＝5点)ごとに「1群：2群：3群：4群」の点数比率を「1：1：1：2」になるよう指導し，1日あたりの総摂取エネルギーを1,200kcalとした．対象者には1食ごとの食事内容を記録させ，教室参加時に提出させた．食事記録をもとに摂取エネルギー量を確認するとともに，食事のとり方や栄養バランス，食習慣な

表1　対象者の身体的特徴，介入前後の変化と4群間の比較

	Diet only group		Diet plus exercise group		DO I vs. DO II vs. DE I vs. DE II [a]
	DO I (n=28)	DO II (n=23)	DE I (n=62)	DE II (n=32)	
Age, years	51.8±8.3	49.2±8.0	52.7±6.8	48.2±9.5	DE II <DE I
Height, cm	156.2±5.1	153.0±5.8	155.5±4.5	155.6±5.8	n.s
Body weight, kg	67.0±5.2	76.0±8.4	67.0±4.7	78.0±8.0	DO I, DE I <DO II, DE II
change	−7.2±2.0*	−6.2±4.0*	−8.5±2.8*	−10.3±3.5*	DO I <DE II, DO II <DE I, DE II
BMI, kg/m^2	27.4±1.3	32.4±2.4	27.7±1.5	32.1±2.3	DO I, DE I <DO II, DE II
change	−3.0±0.9*	−2.6±1.6*	−3.5±1.1*	−4.2±1.4*	DO I <DE II, DO II <DE I, DE II
Fat mass, %	36.2±4.2	38.4±3.1	36.6±4.9	40.5±4.5	DO I, DE I <DE II
change	−5.4±3.7*	−4.4±4.2*	−6.3±4.3*	−6.7±3.2*	n.s
Fat mass, kg	24.2±3.0	29.1±3.4	24.5±3.9	31.7±5.9	DO I, DE I <DO II, DE II
change	−5.8±2.6*	−5.2±2.9*	−6.8±3.2*	−8.6±2.9*	DO I, DO II, DE I <DE II
Fat-free mass, kg	42.8±4.7	46.9±6.3	42.4±4.1	46.3±4.8	DO I, DE I <DO II, DE II
change	−1.4±2.5*	−1.0±3.5	−1.7±2.6*	−1.7±2.8*	n.s
VO_2 max, ml/kg/min	24.4±4.3	23.3±4.0	25.1±3.4	23.1±4.1	n.s
change	3.2±2.8*	2.4±2.6*	4.4±3.7*	6.1±4.3*	DO I, DO II <DE II
VFA, cm^2	128.0±23.5	171.0±45.4	130.4±25.2	139.3±28.2	DO I, DE I, DE II <DO II
change	−39.1±16.2*	−31.7±21.8*	−49.8±28.5*	−48.3±25.9*	DO II <DE I
SFA, cm^2	253.5±69.7	298.6±69.2	248.3±56.0	355.3±91.0	DO I <DE II, DE I <DO II <DE II
change	−55.8±30.6*	−32.2±36.8*	−62.4±36.5*	−71.4±42.3*	DO II <DE I, DE II

BMI：body mass index，VFA：visceral fat area，SFA：subcutaneous fat area，n.s.: not significant.
I：BMI 25以上30未満，II：BMI 30以上.
[a]暦年齢を共変量とした共分散分析.
*p<0.05：介入前後の有意な変化.

について定期的に管理栄養士が指導した．なお，この方法を筆者らはSMART (A study on Strategy for the MAde-to-order weight Reduction in Tsukuba) Dietと称している．

2）運動指導

DE群には食事指導に加え，週1回の監視型運動プログラムまたは週3回の監視型運動プログラムを提供した．週1回の監視型運動は自宅でも実践できるように配慮したウォーキングであり，運動指導がない日は自宅付近で原則として毎日ウォーキングを30分以上実践するよう指示した．運動日誌によって確認した運動頻度は週2～6回，1回あたりの平均時間は約20～60分と個人差がみられたものの，全員が継続的に運動を実践していた．アメリカスポーツ医学会が推奨する運動処方の指針(METs表)[19]に基づいて推定した消費エネルギー量は1回あたり約80～120kcalと推定された．

週3回の監視型運動プログラムであるベンチステップエクササイズ[20]はaerobic danceのひとつで，個人の体力に合わせて高さが調節できるベンチを用い，リズムにあわせて昇降する運動である．運動量は60分間あたり約270 kcalである．週3回の運動指導の時間は準備運動15分間，主運動60分間，整理運動15分間で合わせて90分間とした．

運動中の強度は，全身持久性体力の向上と脂質代謝の改善を図ることを目的として，LTから求められたAT水準付近になるように配慮した．対象者には，自覚的運動強度(rating of perceived exertion：RPE)で12～14("ややきつい")あたりを保つように指導した．また，1週間あたりの消費エネルギー量はウォーキングであってもベンチステップエクササイズであっても700～1,000kcalと推定された．

4．統計処理

同一群間内の介入前後における平均値の差の有意性については対応のあるt-testを施した．また4群間の変化量の群間差異の検討には，暦年齢を共変量とした共分散分析，多重比較にはBonferroniの方法を用いた．VFAとSFA，冠危険因子の変化については二元配置(対応のない因子と対応のない因子)の分散分析を用い，運動併用の有無とBMIの違いの交互作用を検定した．すべての統計学的有意水準は5％とした．

結　果

対象者の身体的特徴，介入前後の変化およびその変化量について，4群間で比較した結果を表1にまとめた．図1にVFAの初期値を共変量にし，運動の有無とBMIの違いがVFAの変化量に与える影響を示した．運動の有無

とBMIの違いの交互作用が見られたが，SFAの変化量においては運動の有無とBMIの違いの交互作用は見られなかった(図2)．

冠危険因子の初期値と変化量を表2に示した．介入前の値で有意な群間差が見られる項目はなかった．介入前後の変化においては，DEⅠ群は全ての項目において有意な改善が見られたが，DOⅠ群とDOⅡ群，DEⅡ群においてはHDL-CとLDL-Cが有意な改善を示さなかった．冠危険因子の変化量において4群間に有意差が見られたのはHDL-CとFPGのみであった．また，運動の有無とBMIの違いの交互作用が見られたのはFPGのみであった(図3)．

考 察

内臓脂肪の減少に関するいくつかの介入研究[3-5]は，食事制限，食事制限＋有酸素性運動あるいは食事制限＋レジスタンス運動を比較した結果，介入方法の違いは内臓脂肪の変化量に影響を与えず，体重減少に応じて内臓脂肪が減少することを報告している．Leenen et al.[21]は内臓脂肪の減少は内臓脂肪量の初期値と関連があり，内臓脂肪を多く持っている者ほど内臓脂肪が優先的に減少することを報告している．また，Okura et al.[22]は内臓脂肪型肥満者と皮下脂肪型肥満者において，減量が内臓脂肪と冠危険因子に及ぼす影響について検討し，7～10kgの体重減少に応じて皮下脂肪型肥満者より内臓脂肪型肥満者のVFAがより大きく減少することを明らかにしている．そこで，本研究では対象者をBMI 25以上かつVFA 100cm²以上の肥満症女性に限定し，食事制限に運動を併用することでVFAの変化量に差が生じるかどうかを検討した．その結果，BMI 30以上の集団においては食事制限に運動を併用することによってVFAの減少量がより大きくなることが示された(図1)．

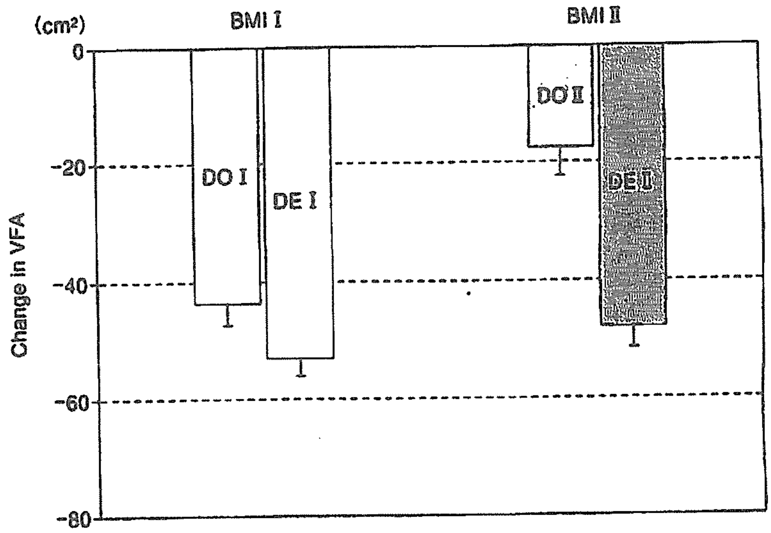

図1 運動の有無とBMIの違いによるVFA変化量の比較
VFAの初期値を共変量とした共分散分析．平均値±標準誤差で表す．
交互作用：p=0.01，BMIの主効果：p=0.0002，介入方法の主効果：p=0.000001．
VFA：visceral fat area，BMI：body mass index．
Ⅰ：BMI 25以上30未満，Ⅱ：BMI 30以上．

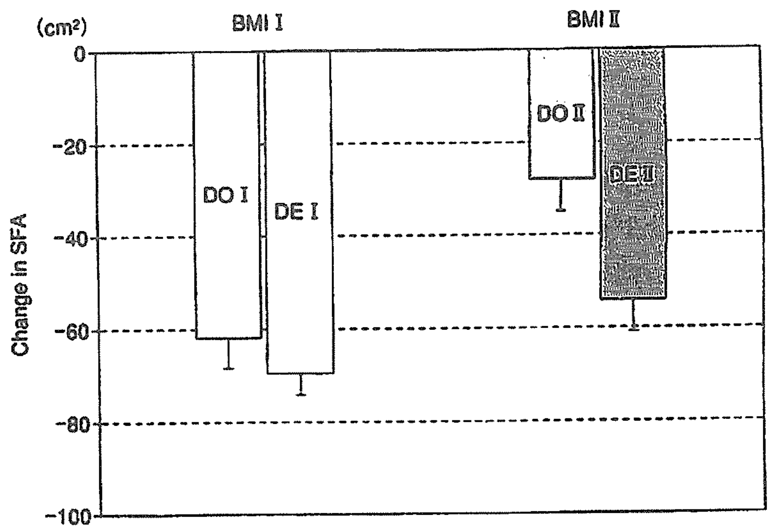

図2 運動の有無とBMIの違いによるSFA変化量の比較
SFAの初期値を共変量とした共分散分析．平均値±標準誤差で表す．
交互作用：p=0.13，BMIの主効果：p=0.0003，介入方法の主効果：p=0.01．
SFA：subcutaneous fat area，BMI：body mass index．
Ⅰ：BMI 25以上30未満，Ⅱ：BMI 30以上．

運動による内臓脂肪減少効果がBMI 25以上30未満の集団では見られず，BMI30以上の集団において見られた背景には，骨格筋と脂肪細胞のlipoprotein lipase(LPL)活性の影響が考えられる．脂肪組織が過剰に蓄積した状態では脂肪細胞のサイズが大きくなり[23]，脂肪細胞のLPL活性が亢進することが知られている[24]．したがって，BMIの高い集団においては脂肪分解が進みにくく，その結果としてVFAの減少が抑制されていると考えられる．しかし

表2　冠危険因子の介入前後の変化と4群間の比較

	Diet only group		Diet plus exercise group		
	DOⅠ (n=28)	DOⅡ (n=23)	DEⅠ (n=62)	DEⅡ (n=32)	DOⅠ vs. DOⅡ vs. DEⅠ vs. DEⅡ [a]
SBP, mmHg	141.6±17.7	139.4±15.4	138.5±17.5	140.6±20.5	n.s
change	−14.4±14.0*	−8.1±12.0*	−11.8±11.9*	−13.3±10.6*	n.s
DBP, mmHg	89.1±10.6	88.9±13.2	84.7±11.0	85.4±11.2	n.s
change	−7.4±9.7*	−4.8±10.6*	−6.6±10.1*	−8.7±7.8*	n.s
TC, mmol/l	222.3±28.8	222.0±36.7	222.3±28.4	227.4±32.1	n.s
change	−14.6±24.4*	−15.8±31.2*	−20.5±23.7*	−19.4±29.7*	n.s
HDL-C, mmol/l	59.7±15.1	55.1±12.3	58.8±12.9	60.5±10.7	n.s
change	1.2±7.0	−1.2±7.4	2.2±8.2*	−2.6±8.2	DEⅡ<DEⅠ
LDL-C, mmol/l	139.7±29.2	138.6±35.3	138.3±27.2	141.7±27.8	n.s
change	−8.3±25.4	−8.7±29.5	−13.2±20.1*	−7.6±26.2	n.s
TG, mmol/l	114.7±52.8	141.5±65.0	126.1±65.5	125.9±51.1	n.s
change	−37.3±46.0*	−30.2±52.0*	−47.4±60.9*	−46.5±44.1*	n.s
FPG, mmol/l	105.2±23.0	96.5±11.6	105.1±26.5	113.4±34.0	n.s
change	−11.3±13.3*	−0.6±9.6	−11.8±19.0*	−16.9±26.9*	DOⅡ<DEⅡ

SBP : systolic blood pressure, DBP : diastolic blood pressure, TC : total cholesterol, HDL-C : high-density lipoprotein-cholesterol, LDL-C : low-density lipoprotein-cholesterol, TG : triglycerides, FPG : fasting plasma glucose, n.s.: not significant.
Ⅰ : BMI 25以上30未満，Ⅱ : BMI 30以上.
[a]暦年齢を共変量とした共分散分析.
*$p<0.05$: 介入前後の有意な変化.

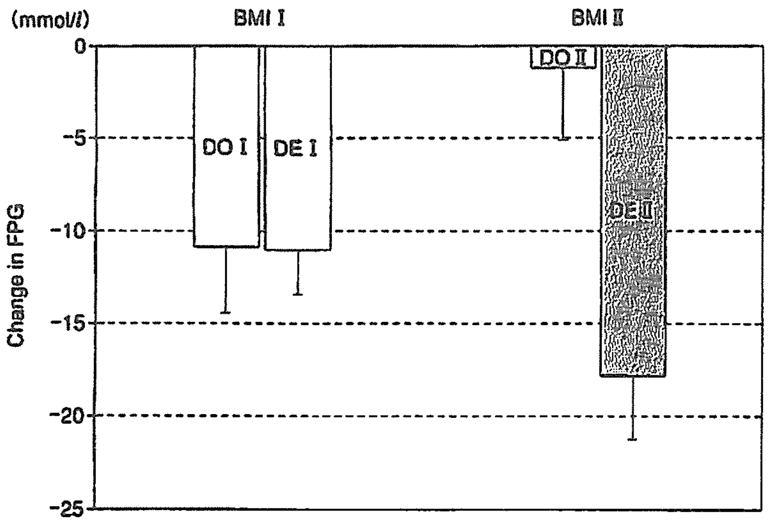

図3　運動の有無とBMIの違いによるFPG変化量の比較
暦年齢を共変量とした共分散分析．平均値±標準誤差で表す．
交互作用 : p=0.02，BMIの主効果 : p=0.67，介入方法の主効果 : p=0.01.
FPG : fasting plasma glucose，BMI : body mass index.
Ⅰ : BMI 25以上30未満，Ⅱ : BMI 30以上.

がら，DEⅡ群においてはDOⅡ群に比べVFAの減少抑制は見られていない．このことは，内臓脂肪組織におけるLPLのmRNA発現量が運動によって抑えられたことに起因するものと考えられる[25]．また，運動を行うと骨格筋のLPL活性が亢進されることが報告されている[26, 27]．すなわち，BMIの高い者であっても運動を行うことで骨格筋のLPL活性の亢進により脂肪分解が高まることに加えて，脂肪細胞のLPL活性が抑制されて脂肪が合成されにくくなるという二重効果により，BMI25以上30未満の集団と同等のVFA減少につながったものと考えられる．このような運動効果は内臓脂肪において見られる特異的な効果であり，そのことはSFAについて同様の結果が見られなかったことにおいても説明することができる(図2)．

先行研究[23～31]によると，5～10%の減量で冠危険因子は大幅に改善する．本研究における体重の減少率は8～12%であり，介入前後で多くの冠危険因子が有意に改善した(表2)．その中で，FPGについては，運動の有無とBMIの違いの交互作用が見られた(図3)．血糖調節に障害をもたらす原因のひとつとして内臓脂肪の蓄積が指摘されている[29]．いくつかの研究[23, 30～33]は食事制限や食事制限と運動の併用による内臓脂肪の減少がインスリン抵抗性の改善につながることを報告している．本研究において，FPGの改善に「運動の有無」と「BMIの大小」という2要因の交互作用が見られたことは，運

動によるインスリン抵抗性の改善効果はBMIの大小によって違いがある可能性を示唆している．本研究の結果からは，そのメカニズムの詳細を明らかにすることはできないが，このことは，運動を併用することでBMI30以上の対象者の内臓脂肪が，BMI30未満の対象者に比べて有意に多く減少したという本研究の結果によって，部分的に裏付けられるかもしれない．

まとめ

本研究は，食事制限に運動を併用することによって得られる効果がBMIの違いによって異なるかどうかを検討した．その結果，BMI30以上の肥満症女性はBMI25以上30未満の集団に比べてVFAが減少しにくいが，運動を併用することによってVFAをより大きく減少させられることが示唆された．したがってBMIの高い内臓脂肪型肥満者を減少させる際，食事制限だけでなく運動を併用することが，より効果的な内臓脂肪の減少につながり，その結果として，冠危険因子も好転させられると考えられる．

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