Classification of Obesity with Respect to Morbidity (43417)

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Obesity is defined as an excess accumulation of adipose tissue in the body. Since its etiology and pathogenesis are quite heterogenous, classification of disease types by specific purposes is essential for proper clinical management. Although classification by the etiology given in Table I is useful for diagnosing the primary disease inducing obesity, it would be more meaningful to classify simple obesity into subgroups and determine pathological features of each disease type, since simple obesities without specific identifiable cause are much more often encountered in daily medical care.

From this viewpoint, classification by morphological types of fat cells or by sites of adipose tissue accumulation has been carried out as shown in Parts II and III of Table I, and features of each disease type have been reviewed. This paper explains the above in detail, and describes a method of classification that incorporates the concept of visceral fats in comparison with conventional methods. As for the accumulation sites, visceral fat can be analyzed by a newly developed method.

Classification by Cytological Features of Adipose Tissue

This is to classify obesities by cellularity of the adipose tissue biopsied, i.e., by the size and number of fat cells (1). The following classifications are employed because metabolic disorders accompanying obesity are related to the size of fat cells and because of the relationship between the proliferative capacity of fat cells and the onset of obesity.

Hyperplastic Type. Fat cells are normal in size, but are increased in number. Fat cells are said to actively proliferate from the embryonal period (the last trimester of pregnancy) to 1 year after birth, and again during puberty. This type is, therefore, often seen among obese people with onset in youth. Since fat cells are not large, metabolic disorders rarely occur. The treatment for weight reduction is not so effective.

Hypertrophic Type. In this type, fat cells are normal in number, but large in size. Obesity that develops in adulthood is often of this type. In many cases, subjects develop various metabolic disorders, but react to treatment for reducing weight.

Combined Type. Fat cells are hyperplastic as well as hypertrophic. Many of the highly obese subjects fall under this type. In general, there is a limit to the increase in the volume of fat cells, and adipose tissue is accumulated by proliferation of fat cells even in adults as obesity proceeds. Therefore, the highly obese subjects are often of this type and develop metabolic disorders. This is intractable, and therapies for reducing weight have had limited effect.

As discussed above, classification by cellularity is useful to some extent for analyzing the pathogenesis of obesity. However, this method calls for biopsy of fat cells which can be applied only to limited sites, and the method of obtaining a precise fat cell count is not yet established. (The fat volume of the whole body is divided by the mean fat cell volume. It is, however, difficult to accurately measure the fat volume of the whole body.) Therefore, this classification cannot yet be employed in general clinical practice.

Classification by Distribution of Adipose Tissue in the Body

It has long been noted that the incidence of complications among equally obese subjects differs depending on their physique. More scientific assessment in recent years has revealed that complications such as metabolic disorders are related to adipose tissue distribution. In classification of obesity by adipose tissue distribution, indices obtained by measuring the girth and skinfold thickness have been used. These are, however, based on the distribution of subcutaneous fat, and a classification with consideration to abdominal visceral fat which we recently developed is now considered to be useful.

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Upper Body Segment Obesity and Lower Body Segment Obesity. Vague (2) first reported on the relation between adipose tissue distribution and complications in the obese subjects. He calculated the ratio of adipose tissue deposition in the brachium to the deposition in the femoral region (branchiofemoral adipomuscular ratio) from girth and skinfold thickness, and differentiated between android obesity, in which fat is likely to accumulate in the brachium, and gynoid obesity, in which accumulation occurs in the femoral region. He further pointed out that complications are likely to develop in the former.

Later, Kissebah *et al.* (3) simplified the indications of adipose tissue distribution by using the waist to hip ratio (WHR), and defined those with high WHR as being obese in the upper body segment and those with low WHR as being obese in the lower body segment. They found that abnormalities of the oral glucose tolerance test intensify as WHR rises and revealed that those who were obese in the upper body were in the high-risk group.

Krotkiewski *et al.* (4) named a high WHR group as the abdominal obesity group, and confirmed that the incidences of diabetes mellitus, hyperlipemia, hypertension, and ischemic heart disease are higher in this group than in the limb or peripheral obesity group. Generally speaking, android obesity = upper body segment obesity = abdominal obesity, and gynoid obesity = lower body segment obesity = peripheral obesity. Complications are more frequently observed in the former.

For determination of these types, use of the WHR is the simplest and most practical. The reference value of 0.85 for WHR, which is applied to the upper body segment obesity in the Western world, is considerably low for the Japanese people; 1.0 is usually used in Japan.

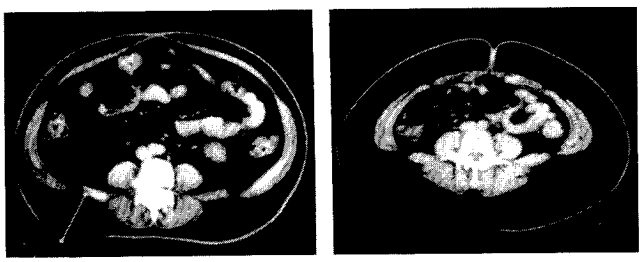
Visceral Fat Obesity and Subcutaneous Fat Obesity. Computed tomography (CT) scanning (5) facilitates analysis of subcutaneous fat as well as adipose tissue in the body cavity, e.g., the thoracic or abdominal cavity. We found that patients with accumulated fat in the abdominal cavity have a higher incidence of complications such as diabetes and hyperlipemia (6, 7). Thus, we are proposing a classification into visceral fat obesity and subcutaneous fat obesity by V (area of visceral fat): S (area of subcutaneous fat) ratios obtained from CT cross-sectional pictures of the umbilical region.

Figure 1 shows CT pictures of two middle-aged obese women. These pictures indicate that there can be a considerable difference in the V:S ratios of the two women despite the similarity in their degrees of obesity and waist size. We divided a large number of the obese subjects at a V:S ratio of 0.4, calling those with 0.4 or more a visceral fat obesity group and those with a V:S ratio of below 0.4 a subcutaneous fat obesity group; we found that clinical pictures differed between the two groups, with disorders of glucose and lipid metabolism being more notable in the former, as shown in Table II.

In order to conveniently use this classification in daily clinical practice, we devised another method for

Table I. Classification of Obesity

I. Classification by etiology
  1. Simple obesity
  2. Symptomatic obesity
    (1) Endocrine obesity
      Insulinoma
      Cushing's syndrome
      Hypothyroidism, etc.
    (2) Hereditary obesity
      Baret-Biedle's syndrome
      Prader-Willi's syndrome
      Biemond's syndrome
      Alström's syndrome, etc.
    (3) Hypothalamic obesity
      Diencephalon tumor (including leukemic invasion)
      Cephalic trauma
      Hypothalamic inflammatory disease
      Empty sella syndrome
      Fröhlich's syndrome, etc.
    (4) Frontal obesity
      Frontal lobe tumor
      Lobotomy, etc.
    (5) Metabolic obesity
      Triglyceride storage disease
      Glycogenosis (von Gierke's disease)
II. Classification by cellularity
  1. Hyperplastic type
  2. Hypertrophic type
  3. Combined type
III. Classification by biological distribution of adipose tissue
  1. Classification by the physique
    (1) Upper body segment obesity
      Lower body segment obesity
    (2) Android obesity
      Gynoid obesity
    (3) Central (abdominal) obesity
      Peripheral (limb) obesity
  2. Classification with consideration to visceral fat
    (1) Visceral fat obesity
    (2) Subcutaneous fat obesity



Visceral fat obesity Subcutaneous fat obesity

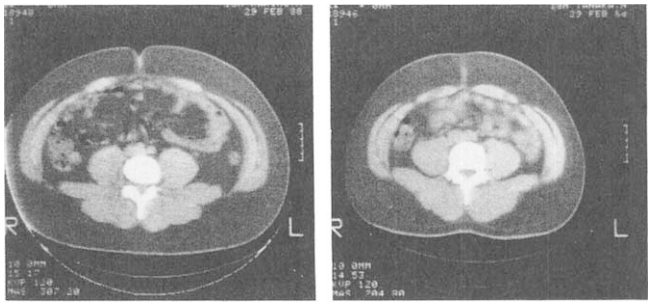
Figure 1. CT scan of types of fat distribution at umbilical level of two obese women.

Table II. Glucose and Lipid Metabolism in Visceral Fat Obesity and Subcutaneous Fat Obesity Groups

	Visceral fat obesity group (V:S ≥ 0.4)	Subcutaneous fat obesity group (V:S < 0.4)
Age	51 ± 15	40 ± 13
Duration of being obese	22 ± 9	20 ± 12
Body mass index (kg/m^2)	34 ± 3	35 ± 6
Blood sugar area ($mg \cdot min/dl) \times 10^{-2}$	391 ± 155[a]	276 ± 111
Insulin area ($\mu U \cdot min/ml) \times 10^{-2}$	148 ± 69	139 ± 84
Total cholesterol (mg/dl)	238 ± 35	222 ± 33
Triglyceride (mg/dl)	251 ± 221[a]	142 ± 52

[a] $P < 0.05$.

Fat Distribution and Serum Lipids of Sumo Wrestlers



Height	183cm	Height	180cm
BW	128kg	BW	117kg
V/S	0.411	V/S	0.133
Cholesterol	256mg/dℓ	Cholesterol	132mg/dℓ
TG	268mg/dℓ	TG	110mg/dℓ

Figure 2. CT scan of abdominal fat in sumo wrestlers.

assessing accumulated visceral fat without CT scanning (7). In this method, waist:skinfold thickness (W:SFT), i.e., waist divided by sum of skinfold thickness near the umbilical cord and in the region above the ilium, is obtained as shown in Figure 2. Naturally, this index elevates when visceral fat is large in quantity. On reviewing the relation between W:SFT and V:S, we found a significant correlation between the two. When the obese subjects were divided at W:SFT 17, which corresponds to V:S 0.4, metabolic disorders were more prominent in the group with higher W:SFT, in accordance with the group with higher V:S.

It is not known fully why accumulation of abdominal visceral fat is related to metabolic disorders. For the present, we observed that abdominal visceral fat (mesenteric fat) exerts an intense metabolic activity, which means that fat is easily accumulated and, conversely, easily decomposed, and that free fatty acid is likely to be discharged. The visceral adipose tissues are different from subcutaneous fat in that they are localized in the portal circulatory system, and that the metabolites of mesenteric fat are directly taken into the liver. Therefore, when mesenteric fat is accumulated, free fatty acid concentration in portal blood rises, which is taken into the liver. Resultant accelerated steatogenesis and lowered sensitivity to insulin may trigger development of metabolic disorders.

Visceral Fat Accumulation in the Subjects with Normal Body Weight. Twenty-nine males and 23 females, whose body mass index was 22 on average, were investigated. There was a substantial variation in fat distribution between the intra-abdominal cavity and subcutaneous tissue, even in the subjects with normal weight. The correlations between topographic markers and metabolic markers in the subjects with normal body weight are presented in Table III. The visceral fat area correlated significantly with fasting plasma glucose, triglycerides, and cholesterol, but the V:S ratio had no significant correlation with these metabolic factors. These results are different from those in obese subjects, in which the V:S ratio correlated with metabolic disorders more significantly than the visceral fat area.

Fat Distribution and Metabolic Factors in Japanese Sumo Wrestlers. In Japan, professional sumo wrestling continues to maintain its popularity as a national sport. Sumo wrestlers are very heavy without exception. They eat a very high energy diet (5000–7000 kcal/day) to gain body weight, but at the same time they are forced to perform very hard physical exercise every day. In this study, fat distribution was investigated in young sumo wrestlers with respect to morbidity. Table IV shows metabolic profiles and the regional fat distribution of young sumo wrestlers compared with obese subjects in our clinics. The average V:S ratio of sumo wrestlers was 0.25, which is comparable to subcutaneous obesity. Most of them still maintain normal plasma glucose and triglycerides and have unexpectedly low cholesterol, even compared with normal controls. Figure 2 shows the CT scan imaging at the level of the umbilicus of representative young sumo wrestlers. Most

Table III. Correlation of Age, Body Mass Index and Fat Area with Metabolic Profile in Subjects with Normal Weight ($n = 52$)[a]

	Correlation coefficient				
	Age	Body mass index	Visceral fat	Subcutaneous fat	V:S
FPG	0.08	0.20	0.43[b]	0.22	0.21
TG	0.06	0.27	0.45[b]	0.21	0.27
T-ch	0.22	0.24	0.35[c]	0.27	0.13
HDL-ch	−0.11	−0.03	−0.03	0.15	−0.01

[a] Abbreviations used in table: FPG, —; TG, triglycerid; T-ch, total cholesterol; HDL-ch, high density lipoprotein cholesterol.
[b] $P < 0.01$.
[c] $P < 0.05$.

Table IV. Metabolic Profiles in Young Sumo Wrestlers and Obese Subjects[a]

	Sumo wrestlers (n = 15)	Obese (male)		Control
		VFO (n = 18)	SFO (n = 16)	
Age (years)	18 ± 2	42 ± 15	23 ± 8	23 ± 2
BMI (kg/m^2)	36 ± 6	32 ± 4	38 ± 5	23 ± 4
T-ch (mg/dl)	160 ± 29	252 ± 58	195 ± 35	189 ± 17
TG (mg/dl)	105 ± 13	282 ± 166	143 ± 60	79 ± 44
HDL-ch (mg/dl)	38 ± 7	43 ± 8	47 ± 18	52 ± 14
FPG (mg/dl)	95 ± 21	129 ± 62	88 ± 8	92 ± 5
FIRI (mU/ml)	22 ± 15	12 ± 6	22 ± 12	11 ± 2
Wt:Ht	0.93 ± 0.04	1.05 ± 0.07	1.03 ± 0.06	
V:S	0.25 ± 0.13	0.77 ± 0.27	0.25 ± 0.08	

[a]Data are expressed as mean ± SD. Abbreviations used in table: VFO, visceral fat obesity; SFO, subcutaneous fat obesity; BMI, body mass index; T-ch, total cholesterol; TG, triglyceride; HDL-ch, high density lipoprotein cholesterol; FPG, —; FIRI, —; W:H, waist to hip ratio.

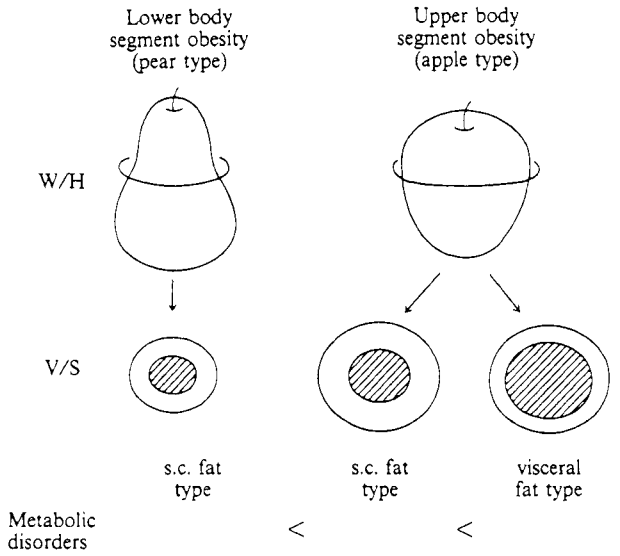


Figure 3. Classification of obesity according to fat distribution.

Table V. Relations of Fat Cell Volume, Waist to Hip Ratio and V:S Ratio with Blood Sugar Area and Serum Lipid

	Correlation coefficient		
	Cell volume	W:H	V:S
Blood sugar area	0.297	0.185	0.411[a]
Triglyceride	0.028	0.167	0.435[a]
Total cholesterol	0.006	0.341	0.439[a]

[a]$P < 0.05$.

of them had fat accumulation only in the subcutaneous area, with marked muscularity, as shown in the right panel (Fig. 2). Only one out of 15 wrestlers had visceral fat accumulation, and he was the only one in this study who was designated as visceral fat type with hyperlipidemia (Fig. 2). These data suggest that physical exercise or development of muscularity may prevent the accumulation of visceral fat, even with a very high energy intake.

Comparison of the New Classification (Visceral Fat Obesity and Subcutaneous Fat Obesity) and Conventional Methods. As has been seen, among the classification methods according to distribution of adipose tissue, the one which encompasses the concept of visceral fat is considered most useful because the relation to pathogenesis can be scientifically examined. We conducted a comparative study with the conventional methods described above.

When subjects (obese women) were classified by WHR into the upper body segment obesity group (WHR ≥ 1.0) and the lower body segment obesity group (WHR < 1.0), the blood sugar area and serum lipid tended to be higher in the former than in the latter. The V:S ratio of the former was 0.42 ± 0.38, whereas that of the latter was 0.28 ± 0.20, indicating that upper body segment obesity and lower body segment obesity are respectively comparable to visceral fat obesity and subcutaneous fat obesity in the disease types involved (8). Actually, a study on white women in the Western countries revealed a strong correlation between WHR and the V:S ratio (9).

Our investigation, however, found, even in the upper body segment obesity group with WHR of above 1.0, a substantial number of the obese subjects whose site of accumulation was mainly in the subcutaneous tissue and who thus cannot be included in the visceral fat obesity type. When those subjects who were predominantly obese in the upper body were further classified by V:S ratio, approximately one third of them belonged to the subcutaneous fat group and their metabolic disorders were relatively slight. In other words, the factors that determine the physique of Japanese people are different from those for Western people, and fat which raises WHR is not necessarily visceral fat. Accordingly, the classification shown in Figure 3 is considered reasonable in view of adipose tissue distribution.

Regarding cellularity, although metabolic disorders tended to be more intense and V:S ratios were somewhat higher in the hypertrophic type than in the hyperplastic type, these differences were not significant.

Table V shows the relationships among parameters for metabolic disorders and fat cell volume, W:H ratio, and V:S ratio. The V:S ratio alone demonstrated a significant positive correlation with blood sugar area and serum lipid. Therefore, it is concluded that classification into visceral fat obesity and subcutaneous fat obesity is most useful for pathological classification, at least for the Japanese.

Conclusion

A new method of classifying obesity by adipose tissue distribution was introduced, particularly with consideration to visceral fat accumulation, and this method has been compared with other methods.

The likelihood that visceral fat obesity induces metabolic disorders was also discussed. Elucidation of the etiology and pathogenesis of this type of obesity will certainly contribute to the clinical study of obesity and to explication of the mechanism for development of noninsulin-dependent diabetes mellitus or hyperlipemia.

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