

SHORT COMMUNICATION

Comparison of Percent Body Fat Estimated by Near Infra-red Spectrophotometry Method with Body Mass Index in Health Screening of Male Employees

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The relationship of percent body fat (%BF) and body mass index (BMI) to blood pressure, serum lipids, hypertension and self-reported diagnosis of diabetes mellitus was examined in a cross-sectional study of 1,174 male employees at a railway company. The %BF was measured by using the near infra-red (NIR) method. Because of high collinearity between %BF and BMI ($r=0.72$), we categorized %BF into two groups at median within each quartile of BMI, and performed analysis of covariance on serum cholesterol (TC), serum triglycerides (TG), systolic blood pressure (SBP), and diastolic blood pressure (DBP). Age-adjusted means of TC, TG, SBP, and DBP were almost progressively increased with increasing levels of BMI regardless of %BF, but there were nearly significant or significant interactions of %BF and BMI on TC, TG, and DBP; serum lipid levels were higher in the upper %BF group than in the lower %BF group at lower levels of BMI while the difference in DBP was more evident at higher levels of BMI. There was also a significant interaction between %BF and BMI on the prevalence of hypertension ($p=0.03$); the prevalence was much higher in the upper %BF group than in the lower %BF group at the highest BMI level. Diabetes mellitus was not measurably associated with either BMI or %BF. These findings suggest that the measurement of %BF in addition to BMI provides useful information in the evaluation and management of individual's health. *J Epidemiol*, 1994; 4: 47-50.

percent body fat, near infra-red spectrophotometry method, blood pressure, serum lipid, diabetes mellitus

Obesity is a major health problem in many affluent countries¹. Body mass index (BMI), body weight in kilogram divided by squared height in meter, is widely used as a measure of obesity in population surveys as well as in clinical practice. Being a function of height and body weight, the index is generally regarded as insufficient in the measurement of individual's obesity or adiposity. It is a matter of concern whether measures of obesity other than BMI should be included in health screening. The under-water weighing method is a prototype of measuring adipose quantity in human body², but it is not a convenient method in population studies. Likewise, recently

developed methods using computed tomography (CT) scan³ or magnetic resonance imaging (MRI)⁴ are not applicable as a routine procedure, although they can determine directly the true quantity of adipose tissue.

Cornway et al.^{5,6} developed the near infra-red spectrophotometry method (NIR) as a convenient tool of determining percent body fat (%BF), the proportion of fat weight to total body weight. In addition to safety in its use, the method seems to be highly valid; correlation coefficients between %BF estimated by the NIR method and those by under-water weighing and skinfold method range 0.8 to 0.9⁶. It is not clear whether %BF is related to

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cardiovascular risk factors independently of BMI⁷⁻¹⁰. This study examined the relationship of %BF and BMI to blood pressure, serum lipids, and diabetes mellitus in order to evaluate usefulness of the NIR method as a tool of measuring obesity.

MATERIALS AND METHODS

Study subjects were male employees of a railway company in the vicinity of Tokyo. All employees are to receive the health examination biannually (spring and autumn). The health examination includes measurements of height, weight, blood pressure, and urine tests; serum biochemical measurements including total cholesterol (TC) and triglycerides (TG) are also performed for employees aged 30 years or older only in autumn. In April 1991, we measured %BF, in addition to the routine examination items, with 1,230 (1,182 males and 48 females) of 1,970 blue-collar workers (1,879 males and 91 females). Because females were few, we analyzed only male employees. Excluding 8 men with whom biochemical data were not available, a total of 1,174 men was used for the present analysis.

The %BF was measured by the NIR method using BFT-2000 (Kett Electric Laboratory, Tokyo). The probe was placed at the anterior midline of biceps muscle midway in sitting position. Optical densities for the two waves, 937 and 947 nm, were recorded, and %BF was calculated allowing for sex, height, weight and exercise level by a modified formula in accordance with the Cornway's formula⁶. Because test-retest reliability of %BF by the NIR method has been reported to be very high (correlation coefficients 0.96 to 0.97)¹¹, only a single measurement was performed. Body weight in unit of kilogram was measured with subjects wearing light clothes, and height in centimeter was recorded without shoes. Systolic blood pressure (SBP) and diastolic blood pressure (DBP) were determined by an automatic blood pressure recorder based on an oscillometric method (Kenzmedico, Kodama, Saitama). A single measurement was used as an individual's blood pressure. Because the measurements of serum TC and TG were performed only in autumn, the averages of two measurements in the years 1990 and 1991 were used here. Serum TC and TG were enzymatically assayed at an external laboratory (Health Science Research Institute, Yokohama).

Use of antihypertensive drugs was ascertained, and hypertensives were defined as those on antihypertensives or those who had SBP of at least 160 mmHg or DBP of at least 95 mmHg. Reported physician's diagnosis of diabetes mellitus was used as the prevalence of this disease.

Analysis of covariance was used to obtain age-adjusted means of serum lipids and blood pressure and to assess independent effects of %BF, BMI and their interaction.

Because of the collinearity between %BF and BMI (see below), we categorized %BF into two groups at median within each quartile of BMI to examine an independent effect of %BF in addition to BMI. Numbers of hypertensives and diabetics were small, and so the tertile classification of BMI was used in studying the prevalence of hypertension and diabetes mellitus. Logistic regression analysis was used to estimate odds ratios of hypertension or diabetes mellitus according to categories of %BF and BMI. Trend of the association with BMI levels and possible interaction between BMI and %BF were assessed by assigning ordinal values 0-3 or 0-2 to BMI values. Reported p-values are always two-sided, and p-values less than 0.05 were regarded as statistically significant. All computations were done using Statistical Analysis System^{12,13}.

RESULTS

Characteristics of study subjects were summarized in Table 1. There were 41 men (3.5%) taking antihypertensive drugs, and 141 were classified as hypertensives (12.0%). A total of 73 men (6.2%) reported that they had been diagnosed as having diabetes mellitus. Correlation coefficient between %BF and BMI was 0.72.

Figure 1 shows age-adjusted means of blood pressure and serum lipids for the upper and lower %BF groups in each quartile of BMI, based on analysis of covariance including age (years), %BF (dichotomous) and BMI (four categories) as independent variables. Men taking antihypertensive drugs were excluded in the analysis on blood pressure. Blood pressure and serum lipids were almost progressively increased with increasing levels of BMI, and the increasing trends with allowance for %BF were highly significant: $p=0.0001$ for all of the four dependent variables. Both SBP and DBP tended to be higher in the upper %BF group at higher levels of BMI; the interaction between %BF and BMI was significant for DBP ($p=0.007$) but not for SBP ($p=0.18$). TC and TG levels were consistently higher in the upper %BF group than in the

Table 1. Physical characteristics of study subjects.

(n = 1,174)	
Variable (unit)	Mean ± S.D.
Age (year)	39.3 ± 10.7
Height (cm)	168.3 ± 6.2
Body weight (kg)	65.9 ± 9.9
Body mass index (kg/m ²)	23.4 ± 3.0
Percent body fat (%)	17.3 ± 3.7
Systolic blood pressure (mmHg)	129.5 ± 13.3
Diastolic blood pressure (mmHg)	79.3 ± 10.9
Serum total cholesterol (mg/dl)	198.6 ± 33.8
Serum triglycerides (mg/dl)	152.0 ± 97.0

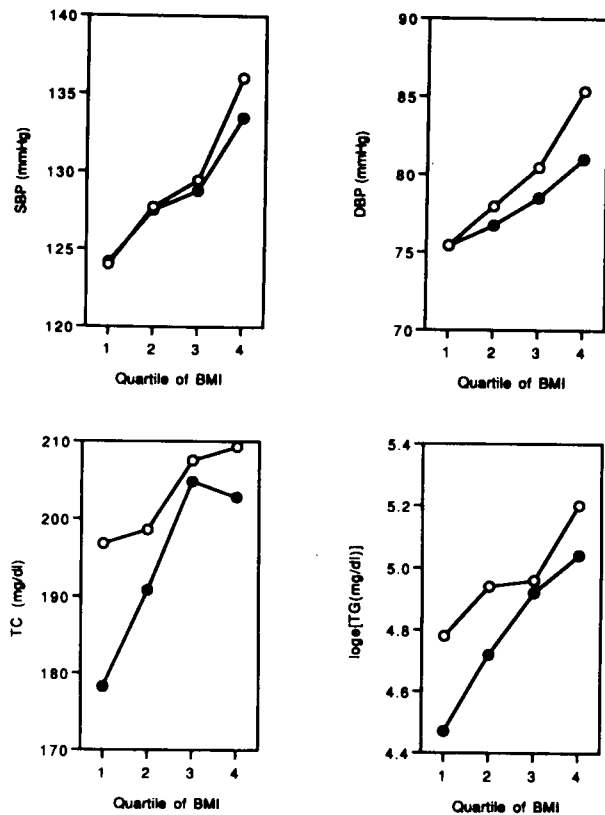


Figure 1. Age-adjusted means of systolic blood pressure (SBP), diastolic blood pressure (DBP), serum total cholesterol (TC), and serum triglycerides (TG) for the upper (open circle) and lower (closed circle) percent body fat (%BF) groups according to quartiles of body mass index (BMI).

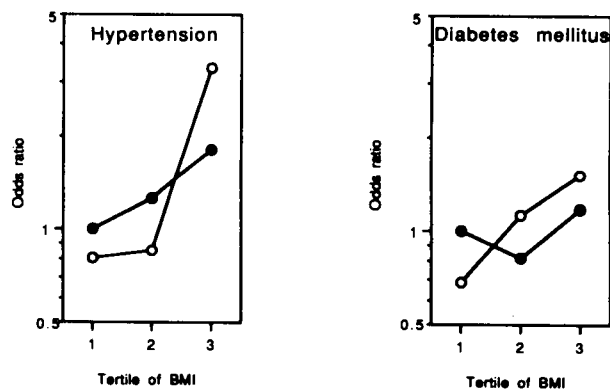


Figure 2. Age-adjusted odds ratios of hypertension and diabetes mellitus for the upper (open circle) and lower (closed circle) percent body fat (%BF) groups according to tertiles of body mass index (BMI).

lower %BF group at each quartile of BMI; and there was a nearly significant interaction on TC ($p=0.05$) and a significant interaction on TG ($p=0.04$).

Age-adjusted odds ratios of hypertension and diabetes

mellitus for the two groups of %BF and tertiles of BMI are depicted in Figure 2. Trend in the association between BMI and hypertension was significant ($p=0.0001$), and there was also a significant interaction between %BF and BMI ($p=0.03$). Diabetes mellitus was not materially associated with either BMI ($p=0.13$) or %BF ($p=0.61$), and there was no interaction ($p=0.40$) between %BF and BMI.

DISCUSSION

The %BF measured by the NIR method was found to be highly correlated with BMI. Because there was an appreciable interaction between %BF and BMI on TC, TG and DBP, it is difficult to estimate the overall effect of %BF independent of BMI. The comparison between the upper and lower %BF groups in each quartile of BMI showed that effects of %BF on TC, TG and DBP were differential according to BMI levels. The %BF seems to be more important among men with lower BMI with regard to serum lipids, and among men with higher BMI with respect to blood pressure; the latter is also suggested by findings on hypertension. These apparently differential effects of %BF may be ascribed to chance, but our data suggest that %BF is important in the relation of obesity to blood pressure and serum lipids.

The %BF estimated by the NIR method is a recently developed method and has been well validated against skinfold method and under-water weighing method^{11,14-16}. It is, however, important to evaluate the value of %BF in addition to BMI in predicting disease risk and risk factors. Several population studies suggested that %BF was an important determinant of blood pressure and serum lipids^{8,9}, but these studies did not evaluate the relative importance of %BF compared with BMI. In a study of male air crewmembers, both BMI and %BF were correlated with blood pressure, TC, TG, and serum uric acid to almost the same degree¹⁰. Another population study of men and women in fact observed that %BF was correlated with blood pressure and serum glucose independent of BMI; serum lipids were not examined in this study⁷.

There are several weaknesses in the present study. Our study subjects were male employees of a company. We cannot address the usefulness of %BF in women. Male employees may differ from men in the general population in their constitutions. Hypertensives included men taking antihypertensive drugs, and it is possible that they may have been under weight control. The relation of %BF and BMI to blood pressure was, however, examined after exclusion of antihypertensive users. We used a self-reported diagnosis of diabetes mellitus; again, men knowing diabetes mellitus or under the treatment tend to reduce obesity. It is thus likely that any positive relation between %BF or BMI and diabetics was biased toward the null

association with reported diabetes mellitus. Our observed relation between BMI and diabetes is much weaker than reported elsewhere¹⁷. If men developing cardiovascular diseases have left the company, then the relation of BMI and %BF to hypertension and hyperlipidemia would be weaker than the true association.

Our study cannot address a question as to whether %BF is predictive of cardiovascular disease risk independently of BMI. Our observed additional effects of %BF on several cardiovascular risk factors indicate that the measurement of %BF in addition to BMI provides useful information in measuring individual's health at least in male employees in Japan.

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