

Waist to Hip Ratio, Body Mass Index, and Glucose Intolerance from Funagata Population-Based Diabetes Survey in Japan

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SEKIKAWA, A., EGUCHI, H., IGARASHI, K., TOMINAGA, M., ABE, T., FUKUYAMA, H. and KATO, T. *Waist to Hip Ratio, Body Mass Index, and Glucose Intolerance from Funagata Population-Based Diabetes Survey in Japan.* Tohoku J. Exp. Med., 1999, 189 (1), 11-20 — To examine the association of body mass index (BMI) and waist-to-hip ratio (WHR) with glucose intolerance among adults age 45 and over, we conducted a population-based study using an oral glucose tolerance test as a primary examination in two areas of Funagata, Japan, in 1990 and 1992. The number of eligible subjects was 1673. The participation rate was 84% (1408/1673). Glucose tolerance was assessed by the 1985 World Health Organization criteria as having diabetes (DM), impaired glucose tolerance (IGT), or normal glucose tolerance (NGT). Analyses by the generalized linear model revealed that both BMI and WHR were higher in the subjects with DM and IGT than those with NGT in both men and women after controlling for age. Analyses employing multiple logistic regression indicated that BMI and WHR were independently associated with IGT and DM in both men and women, except for BMI with IGT for men. The odds ratios for IGT associated with BMI were 1.06 ($p=0.19$) for men and 1.11 ($p<0.01$) for women. Those associated with WHR were 2.14 ($p<0.01$) for men and 1.35 ($p<0.01$) for women. These results imply that WHR plays an important role for developing DM independent of BMI. ——— population-based study; type 2 diabetes mellitus; impaired glucose tolerance; waist to hip ratio; body mass index © 1999 Tohoku University Medical Press

Obesity is an important risk factor for type 2 diabetes mellitus (DM) and many epidemiological studies investigated its association with the disease by cross-sectional and longitudinal studies in various populations (Knowler et al.

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1981; Baldau et al. 1982; Keen et al. 1982; Papoz et al. 1982; Nelson et al. 1988; Ohlson et al. 1988; Morris et al. 1989; Schranz 1989; Haffner et al. 1990; Leena et al. 1990). In general, body mass index (BMI) has been consistently associated with the disease. Meanwhile, data have indicated that central obesity is also a risk for type 2 diabetes (Butler et al. 1982; Nelson et al. 1988; Ohlson et al. 1988; Morris et al. 1989; Schranz et al. 1989; Leena et al. 1990; Dowse et al. 1991; Shelgidar et al. 1991; Cassano et al. 1992). Furthermore, central obesity is considered more important than the mere presence of obesity in having metabolic disturbances such as insulin resistance, hyperlipidemia and atherosclerosis (Krotkiewski et al. 1983; Evans et al. 1984; Emará et al. 1988).

There is, however, only one previous report in Japan describing the association of glucose intolerance and obesity measured as BMI and waist-to-hip ratio (WHR) in a population-based study where an oral glucose tolerance test (OGTT) was employed as a primary examination (Ohmura et al. 1994). That report was based on the survey performed in Hisayama, a suburban area of Japan in 1988. There was no such a report from a rural area of Japan. We performed a population-based DM survey in Funagata, a very rural area of Japan, during 1990 and 1992. In this survey, an OGTT was employed as a primary test and the participation rate was more than 70% (Sekikawa et al. 1993a). We reported the prevalence of diabetes as being around 10% and that of impaired glucose tolerance (IGT) around 15% in both adult men and women (Sekikawa et al. 1993a, b). Here we present the results of analyses on the association of obesity measured as BMI and WHR and glucose intolerance.

MATERIALS AND METHODS

A population-based diabetes survey was performed in Funagata town, Yamagata prefecture, from 1990 to 1992. Yamagata prefecture is predominantly rural and one of the major rice-producers. Most of the families in Funagata are engaged in agriculture. Funagata town consists of three areas: Funagata area in the middle of Funagata town, Horiuchi in the west, and Nagasawa in the east as described previously (Sekikawa et al. 1993a). Funagata area was surveyed in 1990 (Sekikawa et al. 1993b), Horiuchi area in 1991, and Nagasawa area in 1992. In this report, we analyzed the data obtained in 1990 and 1992 because WHR was not measured in the Horiuchi area.

Study population

The subjects of this study were 599 men and 809 women who actually completed an OGTT in this survey. The total population in these two areas age 45 and over was 1961. Among these, 195 with cerebral vascular disease or other disabilities that made examination difficult were excluded. Public health nurses inquired whether remaining the 1766 subjects suffered from DM, and if so, the details of diagnosis and treatment were confirmed by two of the authors (AS, KI).

These 93 known cases of diabetes were also excluded from the analysis. The overall rate of participation, therefore, was 84.2% (1408/1673).

All study subjects were classified as having normal glucose tolerance (NGT) (484 men and 628 women), IGT (83 men and 136 women), or newly diagnosed DM (32 men and 45 women) using the World Health Organization diagnostic criteria (World Health Organization Diabetes Mellitus 1985).

Data were collected as previously described (Sekikawa et al. 1993b). Body heights and weights were measured while subjects were wearing light clothing without shoes. BMI (kg/m^2) was calculated as weight (kg) divided by the square of height (m). Waist and hip circumferences were measured while subjects were standing relaxed and in underclothes only, by specially trained observers. Waist circumference was measured to the nearest 1 cm at the level of the umbilicus. Hip circumference was measured to the nearest 1 cm at the level of the greatest girth. WHR was calculated as waist divided by hip.

Statistical analysis

Differences in the mean of BMI and WHR across four age groups (45–54, 55–64, 65–74, and 75–) were analyzed employing a generalized linear model (Lindsey 1997). Differences in the mean of BMI and WHR across three status of glucose tolerance taking into account the four age groups were analyzed employing a generalized linear model as well. For multiple comparison, Tukey's multiple comparison was used.

Age-adjusted prevalence of diabetes in quintiles of each of BMI and WHR was calculated employing the direct method using 1985 census aged 45 and over for Japanese as the standard.

Odds ratio (OR) estimates of the relative risk for IGT or DM associated with each factor (age, BMI and WHR as a continuous variable) have been computed by logistic regression for each sex separately. Comparison was with the group with NGT; i.e., the binary dependent variable was DM or IGT (1) vs. NGT (0).

All the analyses were conducted for men and women separately, because the distribution of each of BMI and WHR against age was somewhat different between men and women.

These analyses were conducted with the SAS computer package (SAS Institute, Cary, NC, USA).

RESULTS

BMI and WHR by sex and age group are presented in Table 1. As for BMI, men in age groups 45–54 and 55–64 had higher levels than those in age group 65–74. On the other hand, no differences were observed among age groups in women. As for WHR, men in age groups 45–54 and 55–64 had higher levels than those in age group 65–74 year consistent with BMI results. While WHR in women seemed to have a tendency to increase with age, only the comparisons between those in age

TABLE 1. *Body mass index (BMI) and waist-to-hip ratio (WHR) by age and sex*

Age group (Year)	Number	BMI Mean \pm s.d.	WHR Mean \pm s.d.
Men			
45-54	144	24.4 \pm 2.9 ^a	0.90 \pm 0.05 ^a
55-64	216	24.1 \pm 3.0 ^b	0.90 \pm 0.05 ^b
65-74	183	22.2 \pm 2.7	0.88 \pm 0.06
75-	56	23.0 \pm 3.4	0.92 \pm 0.08
Women			
45-54	192	23.5 \pm 3.1	0.83 \pm 0.08
55-64	313	24.4 \pm 3.4	0.87 \pm 0.08 ^c
65-74	234	24.5 \pm 3.5	0.88 \pm 0.08 ^d
75-	70	23.5 \pm 3.9	0.89 \pm 0.10 ^e

Generalized linear model was employed to compare the values with the Tukey's method as a post hoc test, for men and women separately.

^a45-54 > 65-74, $p < 0.01$; ^b55-64 < 65-74, $p < 0.01$;

^c45-54 < 55-64, $p < 0.01$; ^d45-54 < 65-74, $p < 0.01$;

^e45-54 < 75-, $p < 0.01$.

TABLE 2. *Body mass index (BMI) and waist-to-hip ratio (WHR) in men and women with normal glucose tolerance (NGT), impaired glucose tolerance (IGT), and newly diagnosed diabetes mellitus (DM)*

	NGT	IGT	DM
Men			
Number	484	83	32
BMI (kg/m ²)	23.2 \pm 2.9	24.2 \pm 3.6 ^{a,c}	25.5 \pm 3.6 ^b
WHR	0.89 \pm 0.05	0.92 \pm 0.06 ^a	0.93 \pm 0.05 ^b
Women			
Number	628	136	45
BMI (kg/m ²)	23.7 \pm 3.3	25.3 \pm 3.1 ^a	26.4 \pm 3.9 ^b
WHR	0.86 \pm 0.08	0.89 \pm 0.08 ^a	0.90 \pm 0.08 ^b

Values are means and s.d. Generalized linear model was used to compare the values taking into account age groups (45-54, 55-64, 65-74, and 75-) for men and women separately. Tukey's method was used as a post hoc test.

^aNGT < IGT, $p < 0.01$; ^bNGT < DM, $p < 0.01$; ^cIGT < DM, $p < 0.05$.

group 45-54 and those in other age groups were statistically significant.

BMI and WHR among glucose tolerant groups by sex are presented in Table 2. Subjects with both IGT and DM had significantly higher values of BMI and WHR than subjects with NGT in both men and women. There were, however, no

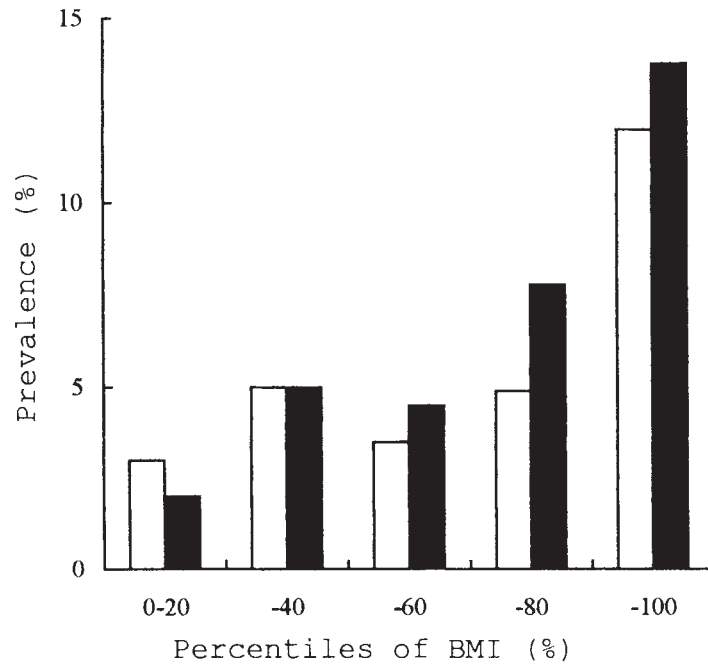


Fig. 1. Age-adjusted prevalence of diabetes mellitus by percentiles of the distribution of body mass index (BMI) in men and women from a population-based cross-sectional study in Funagata, Japan, during 1990 to 1992. Values for 20, 40, 60, and 80 percentiles are 21.0, 22.6, 24.0, and 25.9 for men and 21.3, 23.4, 24.8, and 26.9 kg/m² for women, respectively. □, Men; ■, Women.

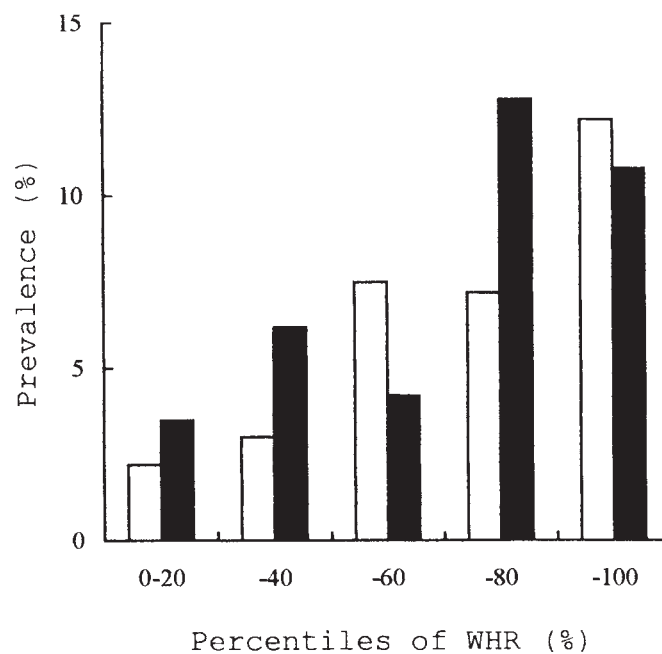


Fig. 2. Age adjusted prevalence of diabetes mellitus by percentiles of the distribution of waist to hip ratio (WHR) in men and women from a population-based cross-sectional study in Funagata, Japan, during 1990 to 1992. Values for 20, 40, 60, and 80 percentiles are 0.85, 0.88, 0.91, and 0.94 for men and 0.79, 0.83, 0.88, and 0.94 for women, respectively. □, Men; ■, Women.

TABLE 3. *Independent odds ratios (ORs) by sex for newly diagnosed non-insulin dependent diabetes mellitus (DM) and impaired glucose tolerance (IGT) from multiple logistic regression*

		IGT		DM	
		OR	95%CI	OR	95%CI
Men	BMI	1.06	0.97-1.16	1.22	1.05-1.41
	WHR	2.14	1.33-3.45	2.53	1.47-6.18
Women	BMI	1.11	1.05-1.18	1.17	1.07-1.29
	WHR	1.35	1.06-1.73	1.57	1.05-2.34

Dependent variable is 1 for IGT and DM and 0 for NGT. OR for BMI represents multiplicative risk factor per 1 kg/m². OR for WHR represents multiplicative risk factor per 0.1. CI, Confidence interval; BMI, body mass index; WHR, waist-to-hip ratio.

differences between subjects with IGT and DM, except BMI in men. Men with DM had higher values of BMI than those with IGT.

Fig. 1 shows the age-adjusted prevalence of diabetes according to percentiles of the distribution of BMI. In both sexes, the prevalence was the highest in the fifth quintile, which was more than 10%. Fig. 2 shows age-adjusted prevalence of diabetes according to percentiles of the distribution of WHR. Prevalence in men's fifth quintile and women's fourth and fifth quintiles was more than 10%. In both sexes, there seemed to be a tendency that the higher both BMI and WHR were, the higher was the prevalence of diabetes.

To assess the independence of BMI and WHR in association with DM, independent ORs were computed from multiple logistic regression equations. As shown in Table 3, both BMI and WHR conveyed significant, therefore, independent ORs for DM in both men and women. Logistic regression models for IGT were shown in Table 3 as well. ORs of WHR were statistically significant for both men and women and were smaller than those for DM. ORs of BMI were statistically significant for women only and not for men. ORs of BMI were also smaller than those for DM.

DISCUSSION

Research results from population-based studies can be much more generalizable than those from clinical research or other epidemiological designs such as a case-control study. This is mainly because the population includes individuals with a wide range of social and biologic characteristics, and this variation is helpful in generalizing the results (Eaton 1998).

Whether the study population is representing the target population is critical in interpreting the results from a population-based study as well as other epidemiological studies. Rate of participation is one way to judge the representativeness of the study population in the population-based study. Rate of

participation in the current research was 84%. This number is considered to be high enough and comparable with other population-based diabetes epidemiological studies where an OGTT was scheduled as a primary examination: 78% in the Pima Indian study (Knowler et al. 1978), 70% in the San Antonio study (Stern et al. 1982), 83% in the Nauru study (Zimmet et al. 1984), and 79% in the Hisayama study (Ohmura et al. 1993).

Our study showed for the first time that BMI and WHR were independently associated with the disease in a rural population in Japan. This conclusion is in accordance with that of the Hisayama study (Ohmura et al. 1994), which is also a cross-sectional population-based study conducted in much less rural area of Japan. It is very likely that inhabitants in Hisayama are much more likely to be exposed to western lifestyle than people in Funagata. Because Hisayama is a town which neighbors Fukuoka, one of seven metropolitans in Japan, whereas the nearest big city of Funagata, Shinjo, has population less than 50 000. The much higher prevalence of diabetes and IGT in Hisayama compared with Funagata supports this hypothesis as well (Sekikawa et al. 1993a, b; Ohmura et al. 1994).

In our study, IGT comprised 60% of all glucose intolerance (Sekikawa et al. 1993b). Development of type 2 diabetes might require a journey from normoglycemia through IGT. Therefore, IGT may be the appropriate time to intervene in the natural history of type 2 diabetes. We found that the degree of obesity in subjects with IGT, as measured by both BMI and WHR, was significantly higher than those with NGT, and was the same with those with DM. The finding on relationship between IGT and NGT was observed in other studies (Harris et al. 1985; Leena et al. 1990; Dowse et al. 1991). However it should be noted that from the result of multiple logistic analysis WHR seemed more important in determining of lesser degree of glucose intolerance in both men and women. This implies that insulin resistance precedes the development of type 2 diabetes in this population.

Epidemiological studies were conducted among Japanese-Americans to investigate the association of insulin resistance with glucose intolerance and coronary heart disease, cross-sectionally (Bergstrom et al. 1990a; Fujimoto et al. 1990, 1994) and prospectively (Bergstrom et al. 1990b). These studies imply that with current westernized lifestyle in younger generation in Japan, insulin resistance which associates the developments of glucose intolerance and coronary heart disease will be one of major health problems in near future. There is a need for further epidemiological studies to correlate insulin resistance measured by anthropometric characteristics and others as well as other risk factors with development of glucose intolerance as well as coronary heart disease in Japanese population in Japan.

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