

## PAPER

# Overweight Japanese with body mass indexes of 23.0–24.9 have higher risks for obesity-associated disorders: a comparison of Japanese and Mongolians

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**OBJECTIVE:** The degree of obesity of Asians is less than that of Caucasians. It has been suggested that Japanese, categorized as having normal weight (BMI < 25.0), as defined by WHO (2000), have a tendency toward increased incidences of dyslipidemia and diabetes. Our objective was to analyze parameters constituting obesity-associated disorders in overweight Japanese and Mongolians with a body mass index (BMI) of 23.0–24.9, and to assess the suitability for Asians of the Regional Office for Western Pacific Region of WHO criteria pertaining to obesity (WPRO criteria, 2000).

**DESIGN:** Cross-sectional study in a workplace setting.

**SUBJECTS:** A total of 386 Japanese men and 363 Japanese women, and 102 Mongolian men and 155 Mongolian women.

**MEASUREMENTS:** Anthropometric measurements (weight, height, waist circumference, hip circumference and blood pressure) and metabolic measurements (plasma levels of total cholesterol, HDL cholesterol, triglyceride, glucose and insulin).

**RESULTS:** Graded increases in BMI of Japanese and Mongolians were positively associated with body fat percent, waist circumference, hip circumference and waist/hip ratio. The Japanese were categorized as 22% overweight, 22% obese I, 3% obese II; the Mongolians rated as 18% overweight, 34% obese I, 19% obese II, based on the WPRO BMI criteria. The Mongolians had a higher prevalence of obesity and a higher body fat percent, but a lesser gradation of dyslipidemia, than did the BMI-matched Japanese groups. Overweight Japanese (BMI 23.0–24.9), in comparison to normal Japanese (BMI 18.5–22.9), had significant differences in systolic blood pressure, HDL-cholesterol and triglyceride in men, and in systolic and diastolic blood pressure, HDL-cholesterol, triglyceride, insulin and Homoeostasis model assessment-insulin resistance in women. In contrast, the Mongolians showed no significant differences in metabolic parameters between overweight and normal subjects, except for diastolic blood pressure.

**CONCLUSION:** Since the relationship between abdominal fat mass and BMI is ethnic-specific, a universal BMI cutoff point is inappropriate for Asian populations such as the Japanese and Mongolians. The present investigation suggests that, while the WPRO criteria are suitable for Japanese, the WHO criteria are more appropriate for Mongolians.

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### Introduction

Obesity and overweight have become common health problems globally. Although severe obesity is clearly associated with increased mortality and incidence of cardiovascular disease, type II diabetes mellitus (diabetes), stroke, dyslipidemia, osteoarthritis and some cancers, the health

consequences of being mildly-to-moderately overweight remain controversial.<sup>1</sup> The International Obesity Task Force of WHO proposed a system of classification based on body mass index (BMI), and selected a BMI of 30.0 as the cutoff point for obesity (WHO criteria),<sup>2</sup> similar to classifications used in a number of past studies in Europe and the USA, based on mortality and morbidity outcomes<sup>3</sup> (Table 1).

In recent years, accumulating evidence has suggested that the relationship between BMI and body fat deposits differs between ethnic populations.<sup>4</sup> It has been recognized that the WHO criteria<sup>2</sup> for classifying obesity in adult Caucasians may not be appropriate for Asian populations. Asian

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**Table 1** Proposed classification of weight by BMI

NHLBI (1998)			WPRO (2000)	
WHO (2000) Classification	Terminology	BMI (kg/m <sup>2</sup> )	Classification	BMI (kg/m <sup>2</sup> )
Underweight	Underweight	<18.5	Underweight	<18.5
Normal range	Normal	18.5–24.9	Normal range	18.5–22.9
Preobese	Overweight	25–29.9	Overweight at risk	23–24.9
Obese I	Obese I	30–34.9	Obese I	25–29.9
Obese II	Obese II	35–39.9	Obese II	≥30
Obese III	Obese III	≥40		

WHO (2000): The International Obesity Task Force of WHO proposed the definition of obesity in Obesity: Preventing and Managing the Global Endemic of WHO Technical Report Series in 2000.<sup>2</sup> NHLBI (1998): The Obesity Task Force of the National Heart, Lung and Blood Institute, USA, proposed the definition of overweight and obesity in clinical guidelines on the identification, evaluation and treatment of overweight and obesity in adults—the evidence report in 1998.<sup>3</sup> WPRO (2000): The Steering Committee of the Regional Office for Western Pacific Region of WHO, the International Association for the Study of Obesity and the International Obesity Task Force proposed the appropriateness of the classification of obesity in Asia in 2000.<sup>4</sup>

populations have a high level of abdominal fat at a lower BMI relative to Caucasians, and show an increasing trend toward obesity.<sup>4</sup> Obesity, as defined by the WHO criteria as BMI ≥30.0, exists in no more than 2–3% of the Japanese population, in contrast to 10–20% for Europe and the USA.<sup>5</sup> However, obesity-associated disorders in the mildly-to-moderately overweight may be involved in the onset of cardiovascular diseases in Japanese.<sup>5–7</sup>

The Examination Committee of the Japan Society for the Study of Obesity proposed new guidelines in 2002 for diagnosing 'Obesity Disease'.<sup>5</sup> In these guidelines, obesity is categorized as a BMI ≥25.0. The Regional Office for Western Pacific Region of WHO, the International Association for the Study of Obesity and the International Obesity Task Force also proposed a separate classification of obesity for Asia in 2000. This led to the proposal that adult overweight be specified in Asia as a BMI ≥23.0, and that obesity be specified as a BMI ≥25.0 (WPRO criteria).<sup>4</sup> Although there have been many investigations into the relationship between BMI and obesity-associated disorders in Asians, overweight or obesity continue to be classified as BMI ≥25.0, based on the WHO criteria.<sup>3</sup> Some reports suggest that the cutoff point of BMI for detecting obesity-associated disorders is lower than a BMI of 25.0 for Japanese,<sup>8–10</sup> while the relationship between BMI classifications and adverse health outcomes according to Asian ethnicity is less clear.

We investigate the relationships between BMI classifications and parameters constituting obesity-associated disorders in different population groups of East Asia, to evaluate the suitability of the WPRO criteria<sup>4</sup> for Asians. We chose Japanese and Mongolian populations, who, of the Asian populations, are relatively close genetically,<sup>11</sup> but have relatively large differences in body composition among the Asian ethnic groups.<sup>12</sup>

## Subjects and methods

### Subjects

A total of 749 Japanese aged 30–60y, (386 men and 363 women) participated in regular health check-ups at manu-

facturing factories and offices in Shimane Prefecture, Japan, in 1999–2002, and all volunteered for this study. A total of 257 Mongolians aged 30–60y, (102 men and 155 women), who underwent health check-ups in 2001, volunteered for this study. The recovery rate of participants was 95% of the factory workers in Japan. The Mongolian subjects were chosen by random sampling from lists of workers who worked at two large companies (cashmere factory and power plant) in Ulaanbaatar, Mongolia (Table 1). Participants were not using prescription medications for diabetes, hyperlipidemia or hypertension. Information on the participant's lifestyle was obtained using a self-reported questionnaire: current smoking, current alcohol consumption and exercise for over 20 min twice a week.

The subjects were categorized based on the WPRO criteria into the following groups: below 18.5 BMI as underweight; 18.5–22.9 BMI as normal; 23.0–24.9 BMI as overweight at risk (overweight); 25.0–29.9 BMI as obese I; and 30.0 BMI and above as obese II. We used the same research design and protocols for all subjects to avoid anthropometric methodological errors. The ethics committee of the Shimane Medical University approved all study protocols, and all subjects gave written informed consent.

### Anthropometric measurements

After an overnight fast, body weight was measured to the accuracy of ±0.2 kg with a standard scale while dressed in very light clothing, and height was measured to an accuracy of ±0.5 cm using a height bar fixed on a wall, with subjects standing with back, buttocks and heels pressed together against a wall. Bioelectrical impedance analysis was measured using a leg-to-leg version of a bioimpedance analyzer (ModelBF-631, Tanita, Tokyo, Japan). Waist circumference was measured to the nearest 0.1 cm at the narrowest part of the torso, as seen from the anterior aspect. Hip circumference was measured to the nearest 0.1 cm at the point of maximum extension of the buttocks. The measurement was repeated for waist and hip circumferences, and a third measurement was made if the difference between the first

two readings was more than 0.5 cm. BMI was calculated as weight (kg) divided by squared height (m<sup>2</sup>). Blood pressure was measured twice at the right arm, using a standard sphygmomanometer (Nippon Rinsho Kikikogo, Tokyo, Japan), with the participants seated.

### Blood samples

Venous blood was collected from the antecubital vein after a 12-h overnight fast. The Mongolian blood samples were separated and transported from Ulaanbaatar to Shimane using a freezing coolant, and then frozen at -80°C until used in this study, all within a 3-month period.

The concentrations of total cholesterol, high-density lipoprotein-cholesterol (HDL-C), triglyceride and glucose were measured using an enzymatic assay kit (Wako Pure Chemical, Osaka, Japan). The level of low-density lipoprotein-cholesterol (LDL-C) was calculated by the following formula: total cholesterol (mg/dl) - HDL-C (mg/dl) - triglyceride/5, in the case of less than 400 mg/dl of triglyceride.<sup>13</sup> The concentration of insulin was measured by Insulin-EIA test (Wako Pure Chemical, Osaka, Japan). Homoeostasis model assessment-insulin resistance (HOMA-IR) was calculated by the following formula: fasting plasma insulin (μU/ml) × fasting plasma glucose (mg/dl)/405.<sup>14</sup> HOMA-IR has been proposed as a simple and inexpensive technique for estimating the insulin resistance,<sup>14</sup> and has been validated for epidemiological studies.<sup>15</sup>

### Statistical analyses

Analysis of data was carried out using SPSS statistical analysis software (Version 10.0J, SPSS Inc, Tokyo, Japan). The results are expressed as the mean ± standard error. Since the data for triglyceride, insulin and HOMA-IR were significantly skewed, they were transformed logarithmically before performing a statistical analysis. Comparisons between two groups were performed by Student's *t*-test to assess the differences in anthropometric and metabolic parameters by ethnicity or gender. One-way ANOVA was used to compare the ages of the five BMI groups, and *post hoc* analysis was carried out, using a reference category of BMI of 18.5–22.9. General linear measurement (GLM) was used to compare the anthropometric parameters adjusted for age, or metabolic parameters adjusted for age, smoking, drinking and exercise habits, and *post hoc* analysis was carried out, using a reference category of BMI of 18.5–22.9. The Kendal test was used for the frequency of five BMI classes. A nominal two-sided *P*-value of less than 0.05 was used to assess the significance.

## Results

### BMI and anthropometric parameters in Japanese and Mongolians

Lifestyle and anthropometric parameters by BMI classes in the Japanese and Mongolian subjects are shown in Table 2.

The Japanese men and Mongolian men and women in progressively higher BMI categories were negatively associated with current smoking habit ( $P < 0.05$ ). Graded increases in BMI for both the Japanese and Mongolians were positively related to the indicators of fat mass, such as body fat percent, waist circumference, hip circumference and waist/hip ratio after age adjustment ( $P < 0.001$ ).

The Japanese were categorized as 22% overweight (men 25%, women 18%), 22% obese I (men 26%, women 17%) and 3% obese II (men 2%, women 3%), based on the WPRO criteria. The Mongolians were rated as 18% overweight (men 15%, women 20%), 34% obese I (men 40%, women 30%), 19% obese II (men 21%, women 17%) and were heavier than the Japanese (Japanese men  $23.3 \pm 0.2$  and women  $22.5 \pm 0.2$  BMI; Mongolian men  $26.2 \pm 0.4$  and women  $25.5 \pm 0.4$  BMI,  $P < 0.001$ ). Mongolians of both genders also had significantly higher values for body fat percent, waist circumference, hip circumference and waist/hip ratio than did the Japanese ( $P < 0.001$ ).

### BMI and metabolic parameters in Japanese and Mongolian subjects

The relationships between BMI classes and metabolic parameters are shown after adjustment for age, smoking, drinking and exercise habits in Table 3 (Japanese) and Table 4 (Mongolians). The Japanese of both genders in progressively higher BMI categories were positively associated with systolic and diastolic blood pressure, triglyceride, insulin and HOMA-IR, and were negatively related with HDL-C. Additionally, LDL-C in the Japanese men ( $P = 0.039$ ) and glucose in the Japanese women ( $P < 0.001$ ) increased in relation to the BMI. Mongolians of both genders in progressively higher BMI categories were positively associated with systolic and diastolic blood pressure, triglyceride, insulin and HOMA-IR, and were negatively related with HDL-C. Additionally, total cholesterol and glucose increased relative to BMI in the Mongolian women ( $P = 0.033$  and  $0.035$ , respectively). The Mongolians had significantly lower levels of total cholesterol and LDL-C ( $187 \pm 4$  and  $113 \pm 4$  mg/dl in men,  $176 \pm 3$  and  $103 \pm 2$  mg/dl in women,  $P < 0.003$ ), compared with those of the Japanese ( $205 \pm 2$  and  $125 \pm 2$  mg/dl in men,  $205 \pm 2$  and  $128 \pm 2$  mg/dl in women).

In the overweight Japanese (BMI 23.0–24.9), significant differences from the normal Japanese (BMI 18.5–22.9) were observed in systolic blood pressure, HDL-C and triglyceride in the men, and in systolic and diastolic blood pressure, HDL-C, triglyceride, insulin and HOMA-IR in the women. In contrast, the overweight and normal Mongolians showed no significant differences between one another in metabolic parameters, except for diastolic blood pressure. However, the obesity I and normal Mongolians groups did have significant differences in systolic and diastolic blood pressure, HDL-C, insulin and HOMA-IR for both genders, as well as in total cholesterol and triglyceride for the women.

**Table 2** BMI classification and anthropometric parameters for Japanese and Mongolian subjects

Classification		Underweight	Normal	Overweight	Obese I	Obese II	P-value		Underweight	Normal	Overweight	Obese I	Obese II	P-value
BMI	Total	<18.5	18.5–22.9	23.0–24.9	25.0–29.9	30.0≥	ANOVA	Total	<18.5	18.5–22.9	23.0–24.9	25.0–29.9	30.0≥	ANOVA
Ethnic	Japanese													
Gender		Male							Female					
Number (%)	386	20(5.2)	158(40.9)	97(25.1)	102(26.4)	9(2.3)		363	28(7.7)	196(54.0)	66(18.2)	63(17.4)	10(2.8)	
Age	47.2±0.4	45.1±1.5	47.0±0.6	46.9±0.7	48.1±0.7	49.6±2.0	NS	47.3±0.4	46.1±1.2	45.8±0.5	50.5±0.8*	49.8±0.9*	43.2±2.9	<0.001
Smoking (%)	222 (57.5)	17 (85.0)	94 (59.5)	60 (61.9)	48 (47.1)	3 (33.3)	0.014	34 (9.4)	1 (3.6)	22 (11.2)	4 (6.1)	6 (9.5)	1 (10.0)	NS
Drinking (%)	296 (76.7)	15 (75.0)	128 (81.0)	70 (72.2)	77 (75.5)	6 (66.6)	NS	124 (34.2)	5 (17.9)	65 (33.2)	25 (37.9)	23 (36.5)	6 (60.0)	NS
Exercise (%)	54 (14.0)	4 (20.0)	22 (13.9)	13 (13.4)	11 (10.8)	4 (44.4)	NS	94 (25.9)	5 (17.9)	41 (20.9)	27 (40.9)	19 (30.2)	2 (20.0)	0.032
Length (cm)	167±0	167±1	166±1	167±1	167±1	168±2	NS	155±0	156±1	155±0	155±1	155±1	157±2	NS
Weight (kg)	65.0±0.5	48.7±1.3*	58.1±0.4	67.3±0.6*	74.5±0.6*	91.2±1.9*	<0.001	54.4±0.5	43.8±0.8*	50.3±0.3	57.4±0.5*	63.9±0.5*	85.6±1.3*	<0.001
BMI (kg/m <sup>2</sup> )	23.3±0.2	17.4±0.3*	21.0±0.1	23.8±0.1*	26.6±0.1*	32.3±0.4*	<0.001	22.5±0.2	17.9±0.2*	20.8±0.1	24.0±0.2*	26.6±0.2*	34.4±0.4*	<0.001
Body fat (%)	22.7±0.5	15.4±1.1*	19.2±0.4	24.2±0.5*	27.3±0.5*	32.3±1.4*	<0.001	28.0±0.4	20.1±0.8*	25.5±0.3	30.8±0.5*	33.1±0.5*	41.5±1.5*	<0.001
WC (cm)	79.7±0.9	66.4±1.8*	72.8±0.7	82.1±0.8*	89.0±0.9*	100.0±2.1*	<0.001	71.5±0.6	60.4±0.9*	66.8±0.4	74.3±0.6*	80.8±0.6*	102.8±1.6*	<0.001
HC (cm)	92.3±0.6	83.8±1.3*	88.1±0.5	93.6±0.6*	98.3±0.7*	104.0±1.6*	<0.001	91.5±0.4	83.7±0.7*	88.8±0.3	92.8±0.5*	97.9±0.5*	111.1±1.3*	<0.001
W/H	0.86±0.01	0.79±0.01*	0.83±0.01	0.88±0.01*	0.90±0.01*	0.96±0.02*	<0.001	0.78±0.00	0.72±0.01*	0.75±0.00	0.80±0.01*	0.83±0.01*	0.92±0.02*	<0.001
Ethnic	Mongolian													
Gender		Male							Female					
Number (%)	102	3(2.9)	22(21.6)	15(14.7)	41(40.2)	21(20.6)		155	6(3.9)	41(26.5)	31(20.0)	47(30.3)	27(17.4)	
Age	44.5±0.6	37.3±2.4	42.5±1.2	45.7±1.7	45.3±1.1	45.2±1.2	NS	41.7±0.5	40.7±2.2	41.5±0.8	42.8±1.2	43.5±0.9	42.7±1.2	NS
Smoking (%)	58 (56.9)	1 (33.3)	16 (72.7)	10 (66.7)	23 (56.1)	8 (38.1)	0.025	14 (9.0)	0 (0.0)	6 (14.6)	5 (16.1)	3 (6.4)	0 (0.0)	0.012
Drinking (%)	71 (69.6)	2 (66.7)	14 (63.6)	12 (80.0)	30 (73.2)	13 (61.9)	NS	95 (61.3)	3 (50.0)	37 (90.2)	13 (41.9)	31 (66.0)	11 (40.7)	NS
Exercise (%)	10 (9.8)	0 (0.0)	3 (13.6)	1 (6.7)	3 (7.3)	3 (14.3)	NS	22 (14.2)	0 (0.0)	6 (14.6)	4 (12.9)	8 (17.0)	4 (14.8)	NS
Length (cm)	168±1	164±4	168±1	165±2	170±1	168±1	NS	157±0	156±2	157±1	156±1	156±1	156±1	NS
Weight (kg)	74.5±1.3	48.5±3.9*	61.0±1.4	65.6±1.7	78.2±1.0*	91.4±1.4*	<0.001	62.6±1.0	42.8±2.2*	52.8±0.8	58.6±1.0*	66.9±0.8*	80.0±1.0	<0.001
BMI (kg/m <sup>2</sup> )	26.2±0.4	18.1±0.9*	21.6±0.3	24.0±0.4	27.0±0.2*	32.3±0.3*	<0.001	25.5±0.4	17.5±0.6*	21.3±0.2	24.0±0.3*	27.3±0.2*	32.9±0.3*	<0.001
Body fat (%)	29.7±0.8	15.5±2.9*	21.7±1.1	25.7±1.3*	31.2±0.8*	40.0±1.1*	<0.001	38.8±0.8	26.6±2.3	30.4±0.8	35.5±1.0*	42.0±0.8*	53.2±1.1*	<0.001
WC (cm)	90.5±1.2	69.1±4.0*	77.5±1.5	84.7±1.7*	93.4±1.1*	105.3±1.5*	<0.001	82.0±0.9	68.4±2.4	71.5±0.9	79.3±1.1*	85.6±0.8*	98.4±1.1*	<0.001
HC (cm)	97.1±0.7	81.5±2.3*	90.3±0.8	93.0±1.0*	98.8±0.6*	105.8±0.8*	<0.001	95.8±0.8	85.8±1.8	88.7±0.7	92.9±0.8*	98.4±0.6*	108.2±0.8*	<0.001
W/H	0.93±0.01	0.85±0.03	0.86±0.01	0.91±0.01*	0.95±0.01*	0.99±0.01*	<0.001	0.85±0.01	0.80±0.02	0.81±0.01	0.86±0.01*	0.87±0.01*	0.90±0.01*	<0.001

Smoking, current smoking; drinking, current drinking; exercise, ≥20 min twice a week; WC, waist circumference; HC, hip circumference; W/H, waist/hip ratio. Data are means ± standard errors. *P*-values of the two comparisons of lifestyle using the Kendall test were expressed as \**P*<0.012, compared with a normal of 18.5–22.9 BMI, after general Kendall test for the four BMI groups. *P*-values for age were calculated using ANOVA for five BMI groups, and were calculated using GLM univariate analysis for five BMI groups after adjustment for age, then \**P*<0.0012 vs BMI of 18.5–22.9. NS: nonsignificant (*P*≥0.05).

**Table 3** BMI classification and metabolic parameters for Japanese subjects

Classification	Underweight	Normal	Overweight	Obese I	Obese II	P-value	Underweight	Normal	Overweight	Obese I	Obese II	P-value
BMI	<18.5	18.5–22.9	23.0–24.9	25.0–29.9	30.0≥	ANOVA	<18.5	18.5–22.9	23.0–24.9	25.0–29.9	30.0≥	ANOVA
Gender			Male						Female			
Number (%)	20(5.2)	158(40.9)	97(25.1)	102(26.4)	9(2.3)		28(7.7)	196(54.0)	66(18.2)	63(17.4)	10(2.8)	
Systolic blood pressure (mmHg)	122±3	121±1	126±1*	128±2*	142±5*	<0.001	111±3	118±1	126±2*	125±2*	136±5*	<0.001
Diastolic blood pressure (mmHg)	76±2	76±1	78±1	81±1*	86±4*	<0.001	68±2	73±1	78±1*	77±1*	86±4*	<0.001
Total cholesterol (mg/dl)	194±8	205±3	205±4	206±4	214±13	NS	202±6	208±2	209±4	210±4	214±11	NS
LDL cholesterol (mg/dl)	112±8*	125±3	128±4	125±4	132±12	0.039	117±6	129±2	134±4	135±4*	133±10	NS
HDL cholesterol (mg/dl)	65±4	58±2	52±2*	48±1*	40±5*	<0.001	67±3	62±1	54±2*	52±3*	46±4*	<0.001
Triglyceride (mg/dl)	90±22	113±7	126±10*	162±9*	173±30*	<0.001	78±10	84±4	103±7*	107±6*	184±15*	<0.001
Glucose (mg/dl)	88±8	97±3	99±4	103±4	116±10	NS	86±4	94±1	96±2	102±2*	121±6*	<0.001
Insulin (μU/ml)	9.3±2.0	4.6±0.7	5.3±1.0	7.7±0.8*	15.5±2.6*	<0.001	4.0±0.9*	5.4±0.4	6.3±0.6*	6.6±0.6*	10.1±1.6*	0.001
HOMA-IR	2.14±0.59	1.11±0.20	1.24±0.30	2.14±0.26*	5.00±0.80*	<0.001	0.87±0.25*	1.24±0.10	1.51±0.16*	1.60±0.17*	3.05±0.43*	<0.001

Data are means ± standard errors. Triglyceride, insulin and HOMA-IR were transformed logarithmically before performing a statistical analysis. *P*-values were calculated using GLM univariate analysis for five BMI groups after adjustment for age, smoking, drinking and exercise habits, then \**P*<0.012 vs BMI of 18.5–22.9. NS: nonsignificant (*P*≥0.05).

**Table 4** BMI classification and metabolic parameters for Mongolian subjects

Classification	Underweight	Normal	Overweight	Obese I	Obese II	P-value	Underweight	Normal	Overweight	Obese I	Obese II	P-value
BMI	<18.5	18.5–22.9	23.0–24.9	25.0–29.9	30.0≥	ANOVA	<18.5	18.5–22.9	23.0–24.9	25.0–29.9	30.0≥	ANOVA
Gender			Male						Female			
Number (%)	3(2.9)	22(21.6)	15(14.7)	41(40.2)	21(20.6)		6(3.9)	41(26.5)	31(20.0)	47(30.3)	27(17.4)	
Systolic blood pressure (mmHg)	112±9	115±9	121±4	128±2*	132±3*	0.002	108±9	113±3	119±4	120±3	128±4*	0.042
Diastolic blood pressure (mmHg)	72±7	79±3	88±3*	89±2*	96±3*	<0.001	80±5	78±2	82±2	89±2*	91±2*	<0.001
Total cholesterol (mg/dl)	154±22	173±8	191±10	186±6	202±8	NS	177±13	167±5	169±6	181±5*	189±6*	0.033
LDL cholesterol (mg/dl)	81±21	100±8	120±9	112±6	128±7	NS	99±12	94±5	101±5	107±4	114±6	NS
HDL cholesterol (mg/dl)	52±7	56±3	51±3	49±2*	43±2*	0.013	62±5	59±2	55±2	53±2*	52±2	0.036
Triglyceride (mg/dl)	97±61	82±23	99±27	134±16	158±23*	0.023	81±21	72±8	66±10	104±8*	116±10*	<0.001
Glucose (mg/dl)	75±23	88±9	93±10	107±6	110±9	NS	88±8	87±3	87±3	92±3	100±4*	0.035
Insulin (μU/ml)	5.3±3.7	4.6±1.1	5.5±1.3	7.5±0.8*	12.8±1.1*	<0.001	3.5±1.5	5.1±0.5	5.0±0.6	7.4±0.5*	11.5±0.7*	<0.001
HOMA-IR	0.97±1.50	1.07±0.46	1.29±0.54	2.10±0.35*	3.88±0.45*	<0.001	0.75±0.44	1.15±0.17	1.08±0.20	1.75±0.17*	2.90±0.22*	<0.001

Data are means ± standard errors. Triglyceride, insulin and HOMA-IR were transformed logarithmically before performing a statistical analysis. *P*-values were calculated using GLM univariate analysis for five BMI groups after adjustment for age, smoking, drinking and exercise habits, then \**P*<0.012 vs BMI of 18.5–22.9. NS: nonsignificant (*P*≥0.05).

## Discussion

In the present study, we observed remarkable differences in BMI and fat mass between the Japanese and Mongolian populations. Obesity, defined by the WHO criteria as BMI  $\geq 30.0$ , was observed in 19% of the Mongolian subjects, in contrast to only 3% of our Japanese subjects. The Mongolians also had greater abdominal fat deposits than the Japanese, as indicated by the significantly higher levels of body fat percent, waist circumference and waist/hip ratio. Anthropometric comparisons have shown that Asians have more subcutaneous and abdominal fat than Caucasians.<sup>16</sup> Such high abdominal fat at low BMI levels in Asians can be partly explained by the differences in trunk-to-leg-length ratio, physical activity level and diet.<sup>17</sup> However, the Mongolian subjects in our study had high abdominal fat and high BMI levels, which may be assumed to be similar to those in Caucasians relative to parameters constituting obesity-associated disorders.<sup>4</sup>

Over 70% of our Japanese subjects had BMI  $< 25.0$  and overweight (BMI 23.0–24.9) accounted for 22% of the population. The Japanese subjects had greater fat mass in the upper body and abdominal obesity, as indicated by significantly larger waist circumferences and waist/hip ratios,<sup>7</sup> in association with elevated BMI, but the extent of the magnitude of parameters was less than that of the Mongolians. A comparison of anthropometric parameters of the two ethnic groups shows the Japanese subjects having lower body fat and lower BMI relative to the Mongolians.

For both the Japanese and Mongolian populations, our study showed an association between BMI  $\geq 25.0$  and higher values for blood pressure, triglyceride, insulin and HOMA-IR, and lower values of HDL-C. BMI represents an effort to derive a measure of adiposity by adjusting the body weight for individual differences in stature, and is the most popular and best indicator of body fatness for persons having a BMI  $\geq 25.0$ .<sup>18,19</sup> Although most epidemiological investigations in Europe, the USA and Asia have clarified significant increases of mortality and incidence of cancer and cardiovascular disease in persons having BMI  $\geq 25.0$ ,<sup>1–3</sup> the health consequences of being mildly-to-moderately overweight remain controversial. Since most studies in Europe and the USA have used the WHO or NHLBI criteria,<sup>3</sup> these studies have not distinguished overweight from normal, as these terms are defined by the WPRO criteria.

Some recent investigations have reported that even mildly-to-moderately overweight persons in the USA with BMI  $< 25.0$  had increased mortality and incidence of cardiovascular disease and diabetes.<sup>20</sup> This overweight condition of BMI  $< 25.0$  in Asians, especially in Japanese, has been linked to elevated risks of obesity-associated disorders,<sup>5</sup> although the validity of this finding remains in dispute,<sup>21</sup> due to divergent results among investigators attributed to classifications of BMI, and differences in ethnicity, gender and age of populations.

Our results indicate that the Japanese overweight with BMI of 23.0–24.9 have higher risks of obesity-associated disorders, than do those with BMI of 18.5–22.9 as normal, while there are no differences in these metabolic parameters between overweight and normal for the Mongolians, except for diastolic blood pressure. In the Japanese population in Japan, BMI only slightly increased in men, but slightly decreased in women during the period of 1976–1995 according to national surveys, but the prevalence of diabetes and dyslipidemia was increasing.<sup>22</sup> Therefore, the WPRO criteria are useful for identifying overweight Japanese, who account for 22% of the Japanese population in our study, and for detecting and preventing obesity-associated disorders.

Our methods in this study have some limitations. A cross-sectional approach to estimate the relationship of elevated BMI classes to obesity-associated disorders means that we examined no data on causality. Another limitation was the relatively small number of subjects. We minimized the potential for a selection bias by 95% recovery rate of participants from the factory workers in Shimane Prefecture, Japan, and by randomly choosing participants from lists of workers in the two factories in Ulaanbaatar, Mongolia. The mean values of 22–23 BMI for the Japanese and 26 BMI in Mongolians were reported by several population-based investigations in Japan,<sup>10,21–23</sup> and by a national survey in Mongolia,<sup>12</sup> in line with our results for values for BMI in both ethnicities.

In conclusion, we report and compare the differences in anthropometric and metabolic characteristics in overweight Japanese and Mongolians. The Mongolian group had a higher prevalence of obesity and a higher level of abdominal fat, but a lesser gradation of dyslipidemia than did BMI-matched Japanese. The relationship between BMI and metabolic parameters was ethnic-specific, as has between the two East Asia populations. Despite the proposal for the WPRO criteria factors in differences in body composition between Caucasians and Asians,<sup>4</sup> a universal BMI cutoff point is inappropriate for comparisons of obesity characteristics among Asian ethnic groups. The present investigation, based on increasing risks to overweight with a BMI of 23.0–24.9, suggests that the WPRO criteria are suitable for Japanese, while the WHO criteria are more appropriate for Mongolians.

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## References

- 1 Willett WC, Dietz WH, Colditz GA. Guideline for healthy weight. *N Engl J Med* 1999; **341**: 427–434.
- 2 World Health Organization. *Obesity: preventing and managing the global epidemic*, WHO Technical Report Series No. 894 WHO: Geneva, 2000.
- 3 The Obesity Task Force of the National Heart, Lung and Blood Institute. Clinical guidelines on the identification, evaluation, and treatment of overweight and obesity in adults—the evidence report. *Obes Res* 1998; **6**: 51S–209S.
- 4 WHO/IASO/IOTF. *The Asia-Pacific Perspective: Redefining Obesity and its Treatment*. Health Communications Australia Pty Ltd; 2000.
- 5 The Examination Committee of Criteria for ‘Obesity Disease’ in Japan, Japan Society for the Study of Obesity. New criteria for ‘obesity disease’ in Japan. *Circ J* 2002; **66**: 987–992.
- 6 Ohmura T, Ueda K, Kiyohara Y, Kato I, Iwamoto H, Nakayama K, Nomiya K, Ohmori S, Yoshitake T, Shinkawa A, Hasuo Y, Fujishima M. Prevalence of type 2 (non-insulin-dependent) diabetes mellitus and impaired glucose tolerance in the Japanese general population: the Hisayama study. *Diabetologia* 1993; **36**: 1198–1203.
- 7 Tokunaga K, Matsuzawa Y, Kotani K, Keno Y, Kobatake T, Fujioka S, Tarui S. Ideal body weight estimated from the body mass index with the lowest morbidity. *Int J Obes Relat Metab Disord* 1991; **15**: 1–5.
- 8 Nakamura K, Shimai S, Kikuchi S, Maeda A, Motohashi Y, Tanaka M, Nakano S. Associations between anthropometric indices of adiposity and atherogenic risk factors in Japanese working women aged 21–40 years. *Eur J Epidemiol* 1998; **14**: 663–668.
- 9 Hsieh SD, Yoshinaga H, Muto T, Sakurai Y, Kosaka K. Health risks among Japanese men with moderate body mass index. *Int J Obes Relat Metab Disord* 2000; **24**: 358–362.
- 10 Ito H, Nakasuga K, Ohshima A, Maruyama T, Kaji Y, Harada M, Fukunaga M, Jingu S, Sakamoto M. Detection of cardiovascular risk factors by indices of obesity obtained from anthropometry and dual-energy X-ray absorptiometry in Japanese individuals. *Int J Obes Relat Metab Disord* 2003; **27**: 232–237.
- 11 Katoh T, Mano S, Ikuta T, Munkhbat B, Tounai K, Ando H, Munkhtuvshin N, Imanishi T, Inoko H, Tamiya G. Genetic isolates in East Asia: a study of linkage disequilibrium in the X chromosome. *Am J Hum Genet* 2002; **71**: 395–400.
- 12 Suvd J, Gerel B, Otgoooloi H, Purevsuren D, Zolzaya H, Roglic G, King H. Glucose intolerance and associated factors in Mongolia: results of a national survey. *Diabet Med* 2002; **19**: 502–508.
- 13 Friedewald WT, Levy RI, Fredrickson D. Estimation of the concentration of low-density lipoprotein cholesterol in plasma, without use of the preparative ultracentrifuge. *Clin Chem* 1972; **18**: 499–502.
- 14 Matthews DR, Hosker JP, Rudenski AS, Naylor BA, Treacher DF, Turner RC. Homeostasis model assessment: insulin resistance and beta-cell function from fasting plasma glucose and insulin concentrations in man. *Diabetologia* 1985; **28**: 412–419.
- 15 Han TS, Williams K, Sattar N, Hunt KJ, Lean ME, Haffner SM. Analysis of obesity and hyperinsulinemia in the development of metabolic syndrome: San Antonio Heart Study. *Obes Res* 2002; **10**: 923–931.
- 16 Wang J, Thornton JC, Russell M, Burastero S, Heymsfield S, Pierson Jr RN. Asians have lower body mass index (BMI) but higher percent body fat than do whites: comparisons of anthropometric measurements. *Am J Clin Nutr* 1994; **60**: 23–28.
- 17 Deurenberg P, Deurenberg-Yap M, Guricci S. Asians are different from Caucasians and from each other in their body mass index/body fat per cent relationship. *Obes Rev* 2002; **3**: 141–146.
- 18 Luke A, Durazo-Arvizu R, Rotimi C, Prewitt TE, Forrester T, Wilks R, Ogunbiyi OJ, Schoeller DA, McGee D, Cooper RS. Relation between body mass index and body fat in black population samples from Nigeria, Jamaica, and the United States. *Am J Epidemiol* 1997; **145**: 620–628.
- 19 Norgan NG. Population differences in body composition in relation to the body mass index. *Eur J Clin Nutr* 1994; **48** (Suppl 3): S10–25.
- 20 Manson JE, Willett WC, Stampfer MJ, Colditz GA, Hunter DJ, Hankinson SE, Hennekens CH, Garrison RJ, Kannel WB. A new approach for estimating healthy body weights. *Int J Obes Relat Metab Disord* 1993; **17**: 417–423.
- 21 Tsugane S, Sasaki S, Tsubono Y. Under- and overweight impact on mortality among middle-aged Japanese men and women: a 10-y follow-up of JPHC study cohort I. *Int J Obes Relat Metab Disord* 2002; **26**: 529–537.
- 22 Yoshiike N, Seino E, Tajima S, Arai Y, Kawano M, Furuhashi T, Inoue S. Twenty-year changes in the prevalence of overweight in Japanese adults: The National Nutrition Survey 1976–95. *Obes Res* 2002; **3**: 183–190.
- 23 Adachi H, Goetz FC, Jacobs DR, Tsuruta M, Hirai Y, Fujiura Y, Imaizumi T. The role of obesity in the association of cardiovascular risk factors and glucose intolerance in small Japanese and North American communities. *Diabetes Res Clin Pract* 2000; **49**: 41–51.