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Prevalence of the Metabolic Syndrome using the Modified ATP III Definitions for Workers in Japan, Korea and Mongolia

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Abstract: Prevalence of the Metabolic Syndrome using the Modified ATP III Definitions for Workers in Japan, Korea and Mongolia: Kuninori SHIWAKU, *et al.* Department of Environmental and Preventive Medicine, Shimane University School of Medicine— A clustering of insulin resistance, hypertension and dyslipidemia has been labeled as the metabolic syndrome. Asians have a lower frequency of obesity than do Caucasians, but have an increasing tendency toward metabolic syndrome. Most data on metabolic syndrome are based on studies from Western countries with only limited information derived from Asian populations. We conducted a cross-sectional study of individuals aged 30–60 yr in workplace settings. We examined and analyzed the health data of 1,384 Japanese, Koreans and Mongolians for metabolic syndrome based on the modified definitions of the working definition proposed by the Third Report of the National Cholesterol Educational Program Expert Panel on Detection, Evaluation, and Treatment of High Blood Cholesterol in Adults (ATP III definition). The prevalence of metabolic syndrome using the ATP III-BMI30 and ATP III-BMI25 definitions was 7% and 12% for Japanese, 7% and 13% for Koreans, and 12% and 16% for Mongolians, respectively. With the exception of obesity, the prevalences of individual metabolic abnormalities within each of the three Asian groups were similar to each other and to reported rates of prevalence in the U.S.A. Nevertheless, the values of sensitivity and specificity by the metabolic syndrome definitions are remarkably different relative to ethnicity. A universal metabolic syndrome definition is inappropriate for comparisons of metabolic syndrome among Asian ethnic groups. We believe that the ATP III-BMI25 definition is suitable for the determination of metabolic syndrome among Japanese and Koreans, and that the ATP III-BMI30 is more appropriate for Mongolians.
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Key words: Asian, Metabolic syndrome, Obesity, Body mass index, Cut-off values

The clustering of certain metabolic abnormalities was initially called Syndrome X, and is characterized by resistance to insulin-stimulated glucose uptake, glucose intolerance, hyperinsulinemia, hypertriglyceridemia, hypo-high-density lipoprotein (HDL)- cholesterolemia and hypertension[1]. This clustering was labeled as metabolic syndrome by the World Health Organization (WHO)[2], and it often develops into type 2 diabetes (diabetes) with premature cardiovascular disease, resulting in an increasingly heavy burden on health care systems and a general decrease in the quality of life. In recent years, prevalence of cardiovascular disease has been increasing in Asia. Since cardiovascular disease is characteristically sudden in onset and life threatening in active workers, it is important to develop preventive measures for health management in the workplace[3]. With the goal of eliminating all adverse consequences of metabolic syndrome, the optimal approach would be its prevention, however, this has been complicated by the use of many definitions of metabolic syndrome, and no standard definition has been routinely used. WHO initially proposed a definition for metabolic syndrome[2],

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and the Third Report of the National Cholesterol Educational Program Expert Panel on Detection, Evaluation, and Treatment of High Blood Cholesterol in Adults provided a new working definition (ATP III definition)[4]. Although, most of the data on metabolic syndrome are from studies from Western countries with only limited information derived from Asian populations[5].

Visceral obesity has been proposed as the most important determinant of metabolic syndrome[2–5]. Obesity is increasing rapidly among Asian workers and has become a common health problem in the workplaces in Asia[7–9]. The International Obesity Task Force of WHO proposed a system of classification which selected a BMI of 30.0 for obesity (WHO BMI criteria)[6], This is similar to the classifications used in a number of past studies in Europe and the U.S.A. based on mortality and morbidity outcomes[4]. Obesity, as defined by the WHO BMI 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 U.S.A[7]. While in Asian workers the prevalence of obesity is lower than that in Western countries, obesity-related health risks to Asians increase at a relatively lower BMI[7–9]. Furthermore, a mildly-to-moderately overweight condition in Asians is related to several chronic conditions such as diabetes, stroke, dyslipidemia, osteoarthritis and some cancers[7–13]. The WHO expert consultation report in 2004 stated that the universal BMI criteria developed by WHO[6] are not suitable for Asian populations, as Asian populations have different associations between BMI, percentage of body fat, and health risks than do Caucasian; however, there was no recommendation for new clear BMI cut-off points for Asians in general[14]. Thus, it is of some importance to examine and report on the present day situation of metabolic syndrome in obese and overweight Asians, and to develop simple and reliable measurement indicators for obesity for use in metabolic syndrome definition.

We investigated and compared the prevalence of metabolic syndrome using two modified versions of the ATP III definition adjusted to indices of obesity for Asians in three Asian ethnic populations, which are relatively close genetically[15], but also have relatively large differences in body composition[13, 16, 17].

Subjects and Methods

Subjects

A total of 752 Japanese aged 30–60 yr, (388 men and 364 women) participating in regular health check-ups at manufacturing facilities in Shimane Prefecture, Japan in 1999–2002 were recruited for this study and a total of 418 Koreans (240 men and 178 women) were recruited during regular health check-ups at workplaces by the Health Promotion Center of Dong-A University in Busan, Korea in 2003. The overall survey recovery rate was 95% for the Japanese and 99% for the Korean participants of these health check-ups. We selected a total of 257 Mongolians aged 30–60 yr (102 men and 155 women) by random sampling from lists of workers of two large companies (cashmere factory and power plant) in Ulaanbaatar, Mongolia. Information on each participant's lifestyle was obtained using a self-reported questionnaire, including habits on smoking, alcohol consumption, exercising for over 20 min twice a week, meat intake more than twice a day and fish intake more than once a week. Workers whose data were incomplete were excluded, leaving a total of 1,384 workers (719 Japanese, 408 Koreans and 257 Mongolians) as subjects for the present study.

No subjects were using prescription medications for diabetes, hyperlipidemia or hypertension. We used the same research design and protocols for all subjects to avoid anthropometric and biochemical methodological errors. The ethics committee of Shimane University School of Medicine approved all study protocols, and all subjects gave written informed consent.

Measurements

We measured height and body weight, with subjects dressed in very light clothing after an overnight fast, as previously described[12, 13]. The body weight of each subject was measured with a standard scale to an accuracy of ± 0.2 kg, and height was measured to an accuracy of ± 0.5 cm using a height bar fixed on a wall, with subjects standing straight with back, buttocks and heels against the wall. BMI was calculated as weight (kilograms) divided by squared height (meters squared). Blood pressure was measured using a standard mercury manometer with the participants seated.

Venous blood was collected from the antecubital vein after a 12-h overnight fast. Blood samples were separated, then frozen at –80°C until used for analysis, all within a three-month period. The concentrations of total cholesterol, HDL-cholesterol (HDL-C), triglyceride and glucose were measured using an enzymatic assay kit (Cholesterol E-test, HDL Cholesterol E-test, Triglyceride G-test and Glucose CII-test, Wako Pure Chemical, Osaka, Japan) at the Shimane University School of Medicine. The levels of low-density lipoprotein cholesterol (LDL-C) were calculated by the following formula: total cholesterol (mg/d*l*) –HDL-C (mg/d*l*) –0.20 × triglyceride, in the case of less than 400 mg/d*l* of triglyceride, or total cholesterol (mg/d*l*) –HDL-C (mg/d*l*) –0.16 × triglyceride, in the case of or more than 400 mg/d*l* of triglyceride[18]. The concentration of insulin was measured by the 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/m*l*) × fasting plasma glucose (mg/d*l*)/405[19].

Table 1. The original metabolic syndrome ATP III definition and the other two modified versions of the ATP III definition

Metabolic abnormality	Visceral obesity WC (cm)	BMI	High BP (mmHg)	High TG (mg/d*l*)	Low HDL-C (mg/d*l*)	High glucose (mg/d*l*)
Original ATP III	≥102 for men ≥88 for women		≥130/85	≥150	<40 for men <50 for women	≥110
ATP III-BMI 30		≥30	≥130/85	≥150	<40 for men <50 for women	≥110
ATP III-BMI 25		≥25	≥130/85	≥150	<40 for men <50 for women	≥110

WC, waist circumference; BP, blood pressure; TG, triglyceride.
Subjects were deemed to have metabolic syndrome if they exhibited three or more of the five criteria.

The ATP III definition clusters risk factors related to obesity and insulin resistance[4]. We investigated and compared the prevalence of metabolic syndrome using two modified versions of the ATP III definition adjusted to indices of obesity for Asians, because of the lack of standardization of waist circumference (WC) for Asians (Table 1). Subjects were deemed to have metabolic syndrome if they had three or more of the following five criteria: ① obesity; ② hypertriglyceridemia, ≥150 mg/d*l*; ③ low HDL-C, <40 mg/d*l* for men and <50 mg/d*l* for women; ④ high blood pressure, ≥130/85 mmHg; and, ⑤ high fasting glucose, ≥110 mg/d*l*. The WC of the ATP III definition was replaced with that of BMI ≥30.0 in the ATPIII-BMI30 definition, according to the WHO criteria[6], with that of BMI ≥25.0 in the ATPIII-BMI25 definition, according to the WPRO BMI criteria[8, 12].

Statistical analyses

Analysis of data was done with SPSS statistical analysis software (Version 12.0J, SPSS Inc, Tokyo, Japan). The results are expressed as mean ± standard deviation. Since the data for triglyceride, insulin and HOMA-IR were significantly skewed, we transformed them logarithmically before performing statistical analyses. The general Kendall test was used for the frequency of the ethnicity and *post hoc* analyses by means of the Kendall test for two independent samples were used for the frequency of each ethnicity using the Japanese group as the reference category. One-way ANOVA for the three ethnic groups were used to assess the differences in anthropometric and metabolic parameters by ethnicity, and *post hoc* analyses were performed by the Bonferroni test for two independent samples, again using the Japanese group as the reference category. The differences in slopes of the regression lines for these relationships by ethnic groups were assessed by using general linear model (GLM) multivariate analyses. A nominal two-sided p-value of less than 0.05 was used to assess the significance.

The validity of the two metabolic syndrome definitions was measured for sensitivity and specificity[20]. With these criterion values, subjects deemed to have a metabolic abnormality, and who were also classified according to the particular metabolic syndrome definition as having a metabolic abnormality, represented the true-positive cases. Metabolically normal subjects classified by the study definition as having a metabolic abnormality represented false-positive cases. Sensitivity (true-positive rate) was determined by calculating the proportion of subjects having a truly abnormal metabolic parameter of the subjects identified as having metabolic syndrome as defined by one of our definitions. Specificity (false-positive rate) was calculated as the proportion of subjects with truly normal metabolic parameters of the subjects who were normally identified by the metabolic syndrome definition.

Results

Lifestyle, anthropometric and metabolic parameters by ethnicity

Lifestyle, anthropometric and metabolic parameters by ethnicity are shown in Table 2. The Korean men had a significantly higher frequency of smoking, compared with the other ethnic groups. The Japanese and Koreans ate fish more frequently, while the Mongolians consumed meat more frequently. The Japanese group contained a greater proportion of blue-collar workers, with the Korean and Mongolian women having the lowest percentages. The Korean men and women had the highest rate of exercising more than twice a week.

Regarding anthropometric parameters, the Mongolians had significantly higher values for body weight and BMI, followed by the Koreans, and then the Japanese. The Mongolians also had significantly higher diastolic blood pressure levels, and significantly lower levels of LDL-C than the Japanese. The Mongolians had significantly higher levels of insulin, relative to the Japanese. Relative to the Japanese, the Koreans had significantly higher values for triglyceride and lower values for HDL-C; the Korean men had significantly higher values for LDL-C,

Table 2. Lifestyle, anthropometric and metabolic parameters by gender and ethnicity for three ethnic groups

Gender	Men			*p*	Women			*p*
Ethnicity	Japanese	Koreans	Mongolians		Japanese	Koreans	Mongolians	
Number	368	232	102		351	176	155	
Current smoking (%)	217 (59%)	210 (91)*	59 (58)	<0.001	35 (10)	9 (5)	14 (9)	NS
Current drinking (%)	282 (77)	177 (76)	71 (70)	NS	121 (34)	54 (31)	48 (31)	NS
Fish intake								
(≥once a week, %)	347 (94)	226 (97)	29 (28)*	<0.001	332 (95)	166 (94)	46 (30)*	<0.001
Meat intake								
(≥twice a day, %)	157 (41)	13 (6)*	94 (92)*	<0.001	159 (45)	14 (8)*	126 (81)*	<0.001
Blue collar work (%)	286 (78)	88 (38)*	62 (61)*	<0.001	214 (61)	75 (43)*	61 (39)*	<0.001
Exercise								
(≥twice a week, %)	51 (14)	110 (47)*	10 (10)	<0.001	93 (26)	55 (31)*	22 (14)	0.001
Age	47.5 ± 7.2	43.2 ± 8.3*	44.5 ± 6.5*	<0.001	47.4 ± 6.9	44.8 ± 7.5*	42.0 ± 6.1*	<0.001
Height (cm)	167 ± 6	170 ± 5*	168 ± 6	<0.001	155 ± 5	157 ± 5*	157 ± 5*	0.002
Weight (kg)	64.6 ± 9.9	70.3 ± 9.3*	74.6 ± 1.0*	<0.001	54.3 ± 8.6	58.1 ± 7.7*	62.6 ± 11.5*	<0.001
BMI (kg/m^2)	23.2 ± 3.1	24.4 ± 2.9*	26.2 ± 4.2*	<0.001	22.6 ± 3.4	23.6 ± 3.2*	25.5 ± 4.6*	<0.001
SBP (mmHg)	124 ± 17	120 ± 13*	124 ± 17	0.001	119 ± 17	114 ± 15*	118 ± 22	0.002
DBP (mmHg)	78 ± 11	80 ± 8*	87 ± 13*	<0.001	74 ± 12	75 ± 9	84 ± 13*	<0.001
Total cholesterol (mg/d*l*)	205 ± 38	200 ± 31	186 ± 39*	<0.001	205 ± 35	193 ± 34*	176 ± 33*	<0.001
LDL-C (mg/d*l*)	125 ± 35	143 ± 33*	113 ± 35*	<0.001	128 ± 31	131 ± 34	103 ± 31*	<0.001
HDL-C (mg/d*l*)	54 ± 16	47 ± 10*	50 ± 12*	<0.001	58 ± 14	52 ± 10*	55 ± 12*	<0.001
TG (mg/d*l*)	131 ± 90	144 ± 86*	123 ± 104	0.007	91 ± 52	106 ± 57*	88 ± 54	<0.001
Glucose (mg/d*l*)	100 ± 25	100 ± 22	101 ± 40	NS	96 ± 19	92 ± 16	90 ± 20*	0.010
Insulin (μU/m*l*)	5.9 ± 6.1	7.1 ± 7.0*	7.6 ± 5.7*	<0.001	5.7 ± 4.3	5.3 ± 2.9	6.9 ± 4.3*	<0.001
HOMA-IR	1.5 ± 1.8	1.9 ± 2.3*	2.1 ± 2.2*	0.001	1.4 ± 1.1	1.2 ± 0.8	1.6 ± 1.2*	0.003

SBP, systolic blood pressure; DBP, diastolic blood pressure; TG, triglyceride; HOMA-IR, homeostasis model assessment-insulin resistance; NS: nonsignificant ($p \geq 0.05$)
Data were expressed as mean ± standard deviation. General Kendall test was used for the frequency of the three ethnic groups, then *$p<0.016$ versus Japanese, *post hoc* analyses by means of Kendall test for two dependent samples. One-way ANOVA was used for the mean of the three ethnic groups, then *$p<0.016$ versus Japanese, *post hoc* analyses by means of Bonferroni test for two dependent samples. Statistical analysis performed for logarithmically transformed values for triglyceride, insulin and HOMA-IR.

and the Mongolians had significantly higher values for diastolic blood pressure, insulin and HOMA-IR and lower values for total cholesterol and LDL-C.

Prevalence of anthropometric and metabolic abnormalities

Anthropometric and metabolic abnormalities by ethnicity are shown in Table 3. In anthropometric abnormalities, the Japanese, Korean and Mongolian men respectively were 2%, 4% and 21% ≥30.0 BMI, and 28%, 38% and 61% ≥25.0 BMI; of the Japanese, Korean and Mongolian women, 3%, 4% and 17% respectively, were ≥30.0 BMI, and 20%, 32% and 48% respectively, were ≥25.0 BMI. The Koreans had significantly lower values for BMI, relative to the Mongolians, and were on average 1.3 BMI heavier than the Japanese (Table 2).

The Korean men showed a significantly lower prevalence of high blood pressure and significantly higher prevalence of hypertriglyceridemia, and the Korean women showed a significantly lower prevalence of high blood pressure and higher prevalence of low HDL-C, all relative to their Japanese counterparts. The Mongolian women had a significantly lower prevalence of hypertriglyceridemia and higher prevalence of low HDL-C, relative to the Japanese women (Table 3).

The relationships between BMI and triglyceride or HDL-C are shown in Fig. 1. A positive correlation between BMI and triglyceride was observed, and a significant negative correlation between BMI and HDL-C was observed for the Japanese, Koreans and Mongolians. The slope of the regression line for the relationship between BMI and triglyceride was significant for the Mongolians, relative to the Japanese and Koreans. The slope of the regression line for the relationship

Table 3. Prevalence of individual metabolic abnormalities of metabolic syndrome by gender and ethnicity

Metabolic abnormality	Total subjects	High BMI (≥30)	High BMI (≥25)	High BP	High TG	Low HDL-C	High glucose
Men							
Japanese	368	7 (1.9%)	103 (28.0)	67 (18.2)	90 (24.5)	60 (16.3)	54 (14.6)
Koreans	232	10 (4.3)	88 (37.9)*	24 (10.3)*	79 (34.1)*	48 (20.7)	30 (12.9)
Mongolians	102	21 (20.6)*	62 (60.8)*	23 (22.5)	23 (22.5)	14 (13.7)	16 (15.7)
Women							
Japanese	351	9 (2.6)	71 (20.2)	46 (13.1)	43 (12.3)	91 (25.9)	35 (10.0)
Koreans	176	7 (4.0)	56 (31.8)*	7 (4.0)*	28 (15.9)	83 (47.2)*	8 (4.5)
Mongolians	155	27 (17.4)*	74 (47.7)*	26 (16.8)	10 (6.5)	57 (36.8)*	10 (6.5)

BP, blood pressure; TG, triglyceride; WC, waist circumference
The cut-off values defining metabolic abnormalities were arbitrarily established at 30 BMI for High BMI (≥30), at 25 BMI for High BMI (≥25), 130/85 mmHg blood pressure for High BP, at 150 mg/d*l* triglyceride for High TG, at 40 mg/d*l* for men and 50 mg/d*l* for women for Low HDL-C, and at 110 mg/d*l* for High glucose. The Kendall test was used *post hoc*, and *($p<0.016$) were significant, compared with the same definition for Japanese, after the general Kendall test for the three independent samples.

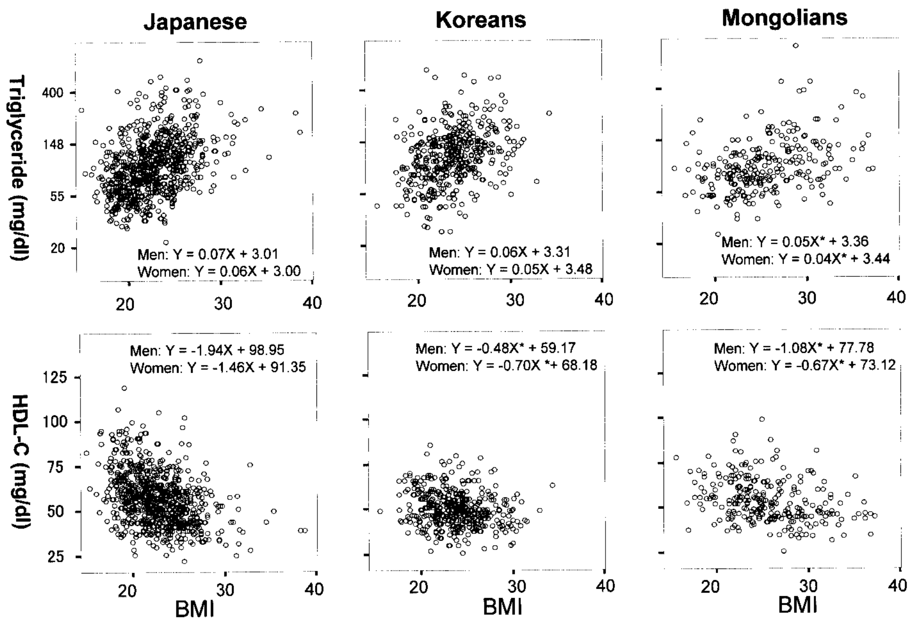

Fig. 1. The relationship between BMI and triglyceride / HDL-C by ethnicity. *p* values of the two comparisons in slopes of the relationship between BMI and two metabolic syndrome parameters by gender using General Lineal Model analysis were expressed as*: $p< 0.016$, compared with the Japanese, after General Lineal Model analysis for the three independent samples.

between BMI and HDL-C was significant for the Japanese, relative to the Koreans and Mongolians.

The prevalence of the one or more metabolic abnormalities of metabolic syndrome except for indices of obesity is shown in Table 4. The prevalence of accumulated metabolic abnormalities was not significant between the three ethnic groups.

Prevalence of metabolic syndrome using the two definitions

The prevalence of metabolic syndrome by definition including indices of obesity is shown in Table 5. The prevalence of metabolic syndrome using the ATP III-BMI30 and ATP III-BMI25 definitions was 7% and 13% for Japanese men, 8% and 14% for Korean men, and 16% and 19% for Mongolian men, respectively; for the women,

Table 4. Prevalence of one or more metabolic abnormalities of metabolic syndrome except for indices of obesity by gender and ethnicity

Metabolic abnormality	Total subjects	Number of metabolic abnormalities ≥1	≥2	≥3	≥4	*p*
Men						
Japanese	368	178 (48.4%)	72 (19.6)	18 (4.9)	3 (0.8)	NS
Koreans	232	122 (52.9)	47 (20.3)	10 (4.3)	2 (0.9)	
Mongolians	102	45 (44.1)	21 (20.6)	8 (7.8)	2 (2.0)	
Women						
Japanese	351	148 (42.2)	50 (14.2)	15 (4.3)	2 (0.6)	NS
Koreans	176	94 (53.4)	28 (15.9)	3 (1.7)	1 (0.6)	
Mongolians	155	73 (47.1)	22 (14.2)	7 (4.5)	1 (0.6)	

Subjects are listed according to total number of the following five criteria, according to ATP III: ①hypertriglyceridemia, ≥150 mg/d*l*; ②low HDL-C, < 40 mg/d*l* for men and < 50 mg/d*l* for women; ③high blood pressure, ≥130/85 mmHg; and, ④high fasting glucose, ≥110 mg/d*l*. The Kendall test was used *post hoc*, and $p<0.016$ was significant, compared with the same definition of Japanese, after the general Kendall test for the three independent samples. NS, not significant ($p\geq0.05$)

Table 5. Prevalence of metabolic syndrome by definition, gender and ethnicity

Definition	Total subjects	ATP III-BMI30	*p*	ATP III-BMI25	*p*
Men					
Japanese	368	26 (7.1%)	0.020	49 (13.3)	NS
Koreans	232	18 (7.8)		33 (14.2)	
Mongolians	102	16 (15.7)*		19 (18.6)	
Women					
Japanese	351	22 (6.2)	NS	36 (11.5)	NS
Koreans	176	9 (5.1)		21 (11.9)	
Mongolians	155	15 (9.6)		21 (13.5)	

Subjects were deemed to have metabolic syndrome if they met three or more of the five criteria. The Kendall test used *post hoc*; *: $p<0.016$, compared with the same definition of Japanese, after the general Kendall test for the three independent samples.

it was 6% and 12% for Japanese, 5% and 12% for Korean men, and 10% and 14% for Mongolians, respectively, with no significant differences.

There were no significant differences in the prevalence between the Koreans and Japanese under the ATP III-BMI30 and ATP III-BMI25 definitions. In contrast, the Mongolian men had a significantly higher prevalence under the ATP III-BMI30 definition than the Japanese and Korean men, but there was no significant difference in the prevalence among the three ethnic groups under the ATP III-BMI25 definition.

Sensitivity and specificity of the two metabolic syndrome definitions

The sensitivity and specificity for metabolic abnormalities were calculated to examine the validity of the individual definitions for metabolic syndrome (Table 6).

The higher values of specificity were for the ATP III-BMI30, relative to ATP III-BMI25 definitions for all ethnic men and women. The values of sensitivity for the two definitions were remarkably lower than their values of specificity. For the Japanese and Korean men and women, sensitivity values under the ATP III-BMI25 definition were nearly twice those for ATP III-BMI30, while values of specificity in the ATP III-BMI30 definition were 1–6% higher than those for ATP III-BMI25. In contrast, for the Mongolians, the values of sensitivity in the ATP III-BMI30 were slightly lower, relative to the sensitivity values of ATP III-BMI25

Table 6. Sensitivity and specificity of metabolic syndrome criteria by gender and ethnicity

Definition	Total subjects	ATP III-BMI30 (–)	ATP III-BMI30 (+)	ATP III-BMI30 sensitivity (%)	ATP III-BMI30 specificity (%)	ATP III-BMI25 (–)	ATP III-BMI25 (+)	ATP III-BMI25 sensitivity (%)	ATP III-BMI25 specificity (%)
Japanese men	368	342	26			319	49		
High BP		53 (15%)	14 (54)	20.9	96.0	46 (14)	21 (43)	31.3	90.7
High TG		68 (20)	22 (85)	24.4	98.6	49 (15)	41 (84)	45.6	97.1
Low HDL-C		39 (11)	21 (81)	35.0	98.4	27 (8)	33 (67)	55.0	94.8
High glucose		38 (11)	16 (62)	29.6	96.8	30 (9)	24 (49)	44.4	92.0
Korean men	232	214	18			199	33		
High BP		18 (8)	6 (33)	25.0	94.2	12 (6)	12 (36)	50.0	89.9
High TG		63 (29)	16 (89)	20.3	98.7	50 (25)	29 (88)	36.7	97.4
Low HDL-C		33 (15)	15 (83)	31.3	98.4	25 (13)	23 (70)	47.9	94.6
High glucose		19 (9)	11 (61)	36.7	96.5	16 (8)	14 (42)	46.7	90.6
Mongolian men	102	86	16			83	19		
High BP		16 (19)	7 (44)	30.4	88.6	15 (18)	8 (42)	34.8	86.1
High TG		8 (9)	15 (94)	65.2	98.7	5 (6)	18 (95)	78.3	98.7
Low HDL-C		5 (6)	9 (56)	64.3	92.0	6 (7)	8 (42)	57.1	87.5
High glucose		5 (6)	11 (69)	64.3	92.0	4 (5)	12 (63)	75.0	91.9
Japanese women	351	329	22			285	36		
High BP		34 (10)	12 (55)	26.1	96.7	30 (11)	16 (44)	34.0	92.7
High TG		23 (7)	20 (91)	46.5	99.4	14 (5)	29 (81)	67.4	97.5
Low HDL-C		72 (22)	19 (86)	20.9	98.8	61 (21)	30 (83)	33.3	97.4
High glucose		25 (8)	10 (45)	28.6	96.2	21 (8)	14 (39)	40.0	92.3
Koreans women	176	167	9			155	21		
High BP		3 (2)	4 (44)	57.1	97.0	2 (1)	5 (24)	71.4	90.5
High TG		21 (13)	7 (78)	25.0	98.6	11 (7)	17 (81)	60.7	97.3
Low HDL-C		75 (45)	8 (89)	9.6	98.9	65 (42)	18 (86)	21.7	96.8
High glucose		5 (3)	3 (33)	37.5	96.4	2 (1)	6 (29)	75.0	91.1
Mongolian women	155	140	15			134	21		
High BP		17 (12)	9 (60)	34.6	95.3	13 (10)	13 (62)	29.6	95.0
High TG		4 (3)	6 (40)	60.0	93.8	2 (1)	8 (38)	80.0	91.0
Low HDL-C		43 (31)	14 (93)	24.6	99.0	38 (28)	19 (90)	33.3	98.0
High glucose		1 (1)	9 (60)	90.0	95.9	0 (0)	10 (48)	100.0	92.4

BP, blood pressure; TG, triglyceride

Sensitivity (true-positive rate) was determined by calculating the proportion of subjects having an truly abnormal metabolic parameter of the subjects identified as having metabolic syndrome as defined by one of our definitions. Specificity (false-positive rate) calculated the proportion of subjects with truly normal metabolic parameters of the subjects who were normally identified by the metabolic syndrome definition. The cut-off values to define for metabolic syndrome were established at 130/85 mmHg for blood pressure, at 40 mg/d*l* for men and 50 mg/d*l* for women for HDL-C, at 150 mg/d*l* for triglyceride, at 110 mg/d*l* for glucose, all according to ATP III criteria.

definition.

Regarding individual metabolic abnormality, the higher sensitivity values in the two metabolic syndrome definitions were low HDL-C (35–55%) and high glucose (30–44%), followed by high triglyceride (24–46%), and high blood pressure (21–31%) in the Japanese men. In the Japanese women, the higher values of sensitivity in the definitions were high triglyceride (47–67%), followed by high glucose (29–40%), high blood pressure (26–34%), and low HDL-C (21–33%). In the Korean men, the higher values of sensitivity in the two metabolic definitions were high glucose (37–47%), low HDL-C (31–48%) and high blood pressure (25–50%), followed by high triglyceride (20–37%). In the Korean women, the higher sensitivity values were high blood pressure (57–71%) and high glucose (38–75%), followed by high triglyceride (25–60%), and low HDL-C (10–22%). In contrast, the higher values of sensitivity in the two metabolic syndrome definitions for the Mongolian men were high glucose (64–75%) and high triglyceride (65–78%), followed by low HDL-C (57–64%), and high blood pressure (30–35%). In the Mongolian women, the higher values of sensitivity were high glucose (90–100%) and high triglyceride (60–80%), followed by low HDL-C (25–33%), and high blood pressure (30–35%).

Discussion

We have previously reported Mongolians as having a higher prevalence of obesity and higher body fat percent, in comparison with the Japanese population[13]. The present study shows that the Korean groups had significantly lower values for BMI, compared with those of the Mongolians, but were 1.3 BMI heavier than the Japanese.

The present results demonstrate that the relationships between the metabolic syndrome definitions including BMI and predicted metabolic abnormalities are remarkably different relative to ethnicity. The Koreans and Japanese had significantly higher values for triglyceride, total cholesterol and LDL-C, compared with the Mongolians, who had greater BMI values. Metabolic conditions promoting the onset of obesity are characterized by reduced clearance in the plasma and higher production rates of very low-density lipoprotein in the liver, resulting in a higher level of triglyceride in the plasma[21]. Recent evidence indicates that a high carbohydrate diet for rodents and humans affects levels of plasma triglyceride by induction of stearoyl-CoA desaturase activity in the liver[22]. Randomized clinical trials have revealed that a carbohydrate-restricted diet results in remarkable decreases in plasma triglyceride levels[23]. Koreans and Japanese intake large amounts of dietary carbohydrate[24, 25], while Mongolians consume large quantities of meat and dairy products[26]. These differences in carbohydrate intake would appear to contribute to the higher levels of triglycerides in the Japanese and Korean groups, relative to the BMI-matched Mongolians[27]. In the present study, values of total cholesterol and LDL-C levels were similar for the Koreans and Japanese. Total cholesterol values for Korean adults increased by 39% from 1964 to 1993, reaching levels similar to those in Japan and the U.S.A.[24, 28], likely as a result of rapid industrialization and urbanization in Korea which promoted an accelerated nutrition transition including increases in intake of animal food products[24]. The resulting increases in hypercholesterolemia have induced an increased incidence of coronary heart disease in Korea[28].

In contrast, the Mongolians had a higher BMI level but a lesser gradation of dyslipidemia than the Japanese and Korean groups. Mongolia has undergone a dramatic social transition since 1990, with a growing urban population consuming meat and dairy products less frequently than the pastoral population[29]. Further, consumption of alcohol and tobacco and lack of exercise are becoming increasingly common[30]. This urbanization and the attendant relatively unhealthy lifestyles may have contributed to the remarkable adiposity, despite the lower levels of plasma triglyceride and total cholesterol in our Mongolian subjects.

The prevalence of metabolic syndrome using the ATP III-BMI30 and ATP III-BMI25 definitions was 7% and 12% for the Japanese, 7% and 13% for the Koreans, and 12% and 16% for the Mongolians, respectively. There were no significant differences in the prevalence of metabolic abnormalities except for obesity among the three Asian ethnic groups, in spite of great differences both in BMI and in the metabolic parameters. Nevertheless, the values of sensitivity and specificity by the metabolic syndrome definitions are remarkably different relative to ethnicity. Our Japanese and Korean subjects showed the ATP III-BMI25 definition had higher values of sensitivity and slightly lower values of specificity, relative to the ATP III-BMI30. Under the ATP III-BMI25 definition, the prevalence of metabolic syndrome doubles to 12% in the Japanese up from the 6% for the ATP III-BMI30, and drawing the figure closer to levels of metabolic syndrome in the U. S. A.[31–33] The Mongolian men showed a significantly higher prevalence of metabolic syndrome under the ATP III-BMI30 definitions than did the Japanese and Korean men, but this significant difference vanished under ATP III-BMI25. For the women, there were no significant differences in the prevalence of metabolic syndrome under any of the two definitions.

Our Japanese and Korean subjects showed the ATP III-BMI25 definition had higher values of sensitivity and slightly lower values of specificity, relative to the ATP III-BMI30, but the Mongolian subjects showed the ATP III-BMI30 definition had higher values of specificity and slightly lower values of sensitivity, relative to the ATP III-BMI25. We reported that optimal cut-off values predicting multiple metabolic disorders were estimated at 23–24 BMI for Japanese and 27 BMI for Mongolians[34]. Therefore, we believe that the ATP III-BMI25 definition is suitable for comparisons of metabolic syndrome among Japanese and Koreans, and that the ATP III-BMI30 is more appropriate for the Mongolians. In our previous study, the Japanese showed an association between BMI ≥25.0 and higher values for blood pressure, triglyceride insulin and HOMA-IR, and lower values for HDL-C[12, 13]. Furthermore, as BMI is the commonly used indicator of body fatness for persons having a BMI ≥25.0[35, 36], BMI may be useful in making comparisons pertaining to metabolic syndrome among Japanese and Koreans as the index of obesity.

This is the first report to demonstrate the prevalence of metabolic syndrome under the modified ATP III definitions in Asian ethnic groups, while using the same research design and protocols for all subjects to avoid anthropometric and biochemical methodological errors. Our methods do have some limitations. Recently, visceral obesity was clinically diagnosed through use of CT of the visceral fat areas. Although the use of CT is expensive, further investigation of the effects of differences in the visceral fat areas should provide more insight into the roles of adiposity in metabolic syndrome. The cross-sectional approach to estimate the relationship of the metabolic syndrome definitions to the metabolic abnormalities means that we examined no data on causality. Another limitation is the relatively small number of subjects. We minimized the potential for a selection bias with a greater than 95% recovery rate of surveys from participants among the workers in Japan and Korea, and by randomly choosing participants from lists of workers in Ulaanbaatar, Mongolia. Mean values of 22–23 BMI for the Japanese and Koreans and 26 BMI for Mongolians have been reported in several population-based investigations in Japan[7, 10, 11, 37–39] and by national surveys in Korea[17, 40, 41] and Mongolia[16], all in line with our results for values for BMI in our ethnic groups. Mean values of plasma lipids for Japanese and Koreans have also been reported by national surveys—Japanese[7, 10, 11, 37–39]; —Koreans[17, 40, 41], again in line with our results for lipid profiles of the Japanese and Korean subjects. For Mongolians, a lipid profile is not yet available. Further investigation of the effects of differences in genetic background, social status and diet should provide more insight into their roles in metabolic syndrome.

In conclusion, we believe that our ATP III-BMI25 definition is suitable for the determination of metabolic syndrome among Japanese and Koreans, and that the ATP III-BMI30 is more appropriate for Mongolians. The present investigation also suggests that metabolic abnormalities are affected by obesity and may be affected by the metabolic component of the diet, which in turn may have some impact on metabolic syndrome in an ethnic-specific manner.

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References

1) GM Reaven: Role of insulin resistance in human disease. Diabetes 37, 1595–1607 (1988)
2) KG Alberti and PZ Zimmet: Definition, diagnosis and classification of diabetes mellitus and its complications. Part 1. Diagnosis and classification of diabetes mellitus, provisional report of a WHO consultation. Diabet Med 15, 539–553 (1998)
3) T Nakamura, Y Tsubono, K Kameda-Takemura, T Funahashi, S Yamashita, S Hisamichi, T Kita, T Yamamura and Y Matsuzawa: Magnitude of sustained multiple risk factors for ischemic heart disease in Japanese employees: a case-control study. Jpn Circ J 65, 11–17 (2001)
4) National Institute of Health: Third Report of the National Cholesterol Educational Program Expert Panel on Detection, Evaluation, and Treatment of High Blood Cholesterol in Adults (Adult Treatment Panel III). Executive Summary. Bethesda, MD, National Institute of Health, National Heart, Lung and Blood Institute, 2001.
5) JY Oh, YS Hong, YA Sung and E Barrett-Connor: Prevalence and factor analysis of metabolic syndrome in an urban Korean population. Diabetes Care 27, 2027–2032 (2004)
6) World Health Organization. Obesity. Preventing and Managing the Global Endemic. WHO Technical Report Series no 894. Geneva: WHO, 2000.
7) 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. 66, 987–992 (2002)
8) WHO/IASO/IOTF. The Asia-Pacific Perspective: Redefining Obesity and its Treatment. Health Communications Australia Pty Ltd, 2000.
9) K Shiwaku, E Anuurad, B Enkhmaa, K Kitajima and Y Yamane: Appropriate BMI for Asian populations. Lancet 363, 1077 (2004)
10) K Nakamura, S Shimai, S Kikuchi, A Maeda, Y Motohashi, M Tanaka and S Nakano: Associations between anthropometric indices of adiposity and atherogenic risk factors in Japanese working women aged 21–40 years. Eur J Epidemiol 14, 663–668 (1998)
11) SD Hsieh, H Yoshinaga, T Muto, Y Sakurai and K Kosaka: Health risks among Japanese men with moderate body mass index. Int J Obes 24, 358–362 (2000)
12) E Anuurad, K Shiwaku, A Nogi, K Kitajima, B Enkhmaa, K Shimono and Y Yamane: The new BMI criteria for asians by the regional office for the western pacific region of WHO are suitable for screening of overweight to prevent metabolic syndrome in elder Japanese workers. J Occup Health 45, 335–343 (2003)
13) K Shiwaku, E Anuurad, B Enkhmaa, A Nogi, K Kitajima, K Shimono, Y Yamane and T Oyunsuren: Overweight Japanese with body mass indexes of 23.0 to 24.9 have higher risks for obesity-associated disorders: a comparison of Japanese and Mongolians. Int J Obes 27, 152–158 (2003)
14) WHO expert consultation: Appropriate body-mass index for Asian populations and its implications for policy and intervention strategies. Lancet 363, 157–163 (2004)
15) T Katoh, S Mano, T Ikuta, B Munkhbat, K Tounai, H Ando, N Munkhtuvshin, T Imanishi, H Inoko and G

Tamiya: Genetic isolates in East Asia: a study of linkage disequilibrium in the X chromosome. Am J Hum Genet 71, 395–400 (2002)
16) J Suvd, B Gerel, H Otgooloi, D Purevsuren, H Zolzaya, G Roglic and H King: Glucose intolerance and associated factors in Mongolia: results of a national survey. Diabetic Med 19, 502–508 (2002)
17) JY Park, KU Lee, CH Kim, HK Kim, SK Hong, KS Park, HK Lee and HK Min: Past and current obesity in Koreans with non-insulin-dependent diabetes mellitus. Diabetes Res Clin Pract 35, 49–56 (1997)
18) WT Friedewald, RI Levy and D Fredrickson. Estimation of the concentration of low-density lipoprotein cholesterol in plasma, without use of the preparative ultracentrifuge. Clin Chem 18, 499–502 (1972)
19) DR Matthews, JP Hosker, AS Rudenski, BF Naylor, DF Treacher and RC Turner. Homeostasis model assessment: insulin resistance and beta-cell function from fasting plasma glucose and insulin concentrations in man. Diabetologia 28, 412–419 (1985)
20) R Beaglehole, R Bonita and T Kjellstrom. Basic epidemiology. Geneva: WHO, 93–96, 1993.
21) CJ Packard, T Demant, JP Stewart, D Bedford, MJ Caslake, G Schwertfeger, A Bedynek, J Shepherd and D Seidel: Apolipoprotein B metabolism and the distribution of VLDL and LDL subfractions. J Lipid Res 41, 305–318 (2000)
22) AD Attie, RM Krauss, MP Gray-Keller, A Brownlie, M Miyazaki, JJ Kastelein, AJ Lusis, AF Stalenhoef, JP Stoehr, MR Hayden and JM Ntambi: Relationship between stearoyl-CoA desaturase activity and plasma triglycerides in human and mouse hypertriglyceridemia. J Lipid Res 43, 1899–1907 (2002)
23) FF Samaha, N Iqbal, P Seshadri, KL Chicano, DA Daily, J McGrory, T Williams, M Williams, EJ Gracely and L Stern: A low-carbohydrate as compared with a low-fat diet in severe obesity. N Engl J Med 48, 2074–2081 (2003)
24) S Kim, S Moon and BM Popkin. The nutrition transition in South Korea. Am J Clin Nutr 71, 44–53 (2000)
25) M Nakamura, S Tajima and N Yoshiike: Nutrient intake in Japanese adults—from The National Nutrition Survey, 1995–99. J Nutr Sci Vitaminol 48, 433–441 (2002)
26) M Gill: Meat production in developing countries. Proc Nutr Soc 58, 371–376 (1999)
27) K Shiwaku, M Hashimoto, K Kitajima, A Nogi, E Anuurad, B Enkhmaa, JM Kim, IS Kim, SK Lee, T Oyunsuren, O Shido and Y Yamane: Triglyceride levels are ethnic-specifically associated with an index of stearoyl-CoA desaturase activity and n-3 PUFA levels in Asians. J Lipid Res 45, 914–922 (2004)
28) KL Khoo, H Tan, YM Liew, JP Deslypere and E Janus: Lipids and coronary heart in Asia. Atherosclerosis 169, 1–10 (2003)
29) J Fu, T Takano, K Nakamura, JF Yang and M Watanabe: Changes in the lifestyle of Mongolian pastoralists in China in connection with urbanization. J Med Dent Sci 47, 123–132 (2000)
30) Government of Mongolia and United Nations Development Programme. Human development report Mongolia 2000. Ulaanbaatar, Mongolia: United Nations Development Programme in Mongolia, 2000.
31) ES Ford, WH Giles and WH Dietz: Prevalence of the metabolic syndrome among US adults: findings from the third National Health and Nutrition Examination Survey. JAMA 287, 356–359 (2002)
32) ES Ford and WH Giles: A comparison of the prevalence of the metabolic syndrome using two proposed definitions. Diabetes Care 26, 575–581 (2003)
33) JB Meigs, PW Wilson, DM Nathan, RB Sr D'Agostino, K Williams and SM Haffner: Prevalence and characteristics of the metabolic syndrome in the San Antonio Heart and Framingham Offspring Studies. Diabetes 52, 2160–2167 (2003)
34) K Shiwaku, E Anuurad, E Byambaa, A Nogi, K Kitajima, M Yamasaki, T Yoneyam, T Oyunsuren and Y Yamane: Predictive values of anthropometric measurements for metabolic syndrome in Asian populations. Diab Res Clin Practice, in press (2005)
35) WC Willett, WH Dietz and GA Colditz: Guideline for healthy weight. N Engl J Med 341, 427–434 (1999)
36) NG Norgan: Population differences in body composition in relation to the body mass index. Eur J Clin Nutr 48 (Supple 3), S10–S25 (1994)
37) K Shiwaku, TQ Gao, A Isobe, T Fukushima and Y Yamane: A Trp64Arg mutation in the β3-adrenergic receptor gene is not associated with moderate overweight in Japanese workers. Metabolism 47, 1528–1530 (1998)
38) S Tsugane, S Sasaki and Y Tsubono: 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 26, 529–537 (2002)
39) N Yoshiike, F Seino, S Tajima, Y Arai, M Kawano, T Furuhata and S Inoue: Twenty-year changes in the prevalence of overweight in Japanese adults: The National Nutrition Survey 1976–95. Obes Rev 3, 183–190 (2002)
40) OR Moon, NS Kim, SM Jang, TH Yoon and SO Kim: The relationship between body mass index and the prevalence of obesity-related diseases based on the 1995 National Health Interview Survey in Korea. Obes Rev 3, 191–196 (2002)
41) EJ Sung, S Sunwoo, SW Kim and YS Kim. Obesity as a risk factor for non-insulin-dependent diabetes mellitus in Korea. J Korean Med Sci 16, 391–396 (2001)