Prevalence and Factor Analysis of Metabolic Syndrome in an Urban Korean Population

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OBJECTIVE — The aim of this study was to explore the prevalence and pattern of the metabolic syndrome and its association with hyperinsulinemia in an urban Korean population of 269 men and 505 women.

RESEARCH DESIGN AND METHODS — The National Cholesterol Education Program Adult Treatment Panel (ATP) III guidelines were used to calculate the sex-specific prevalence of the metabolic syndrome. After excluding individuals taking medication for hypertension, diabetes, or dyslipidemia, we used factor analysis to examine the pattern of the metabolic syndrome in 206 men and 449 women.

RESULTS — The prevalence of metabolic syndrome was 16.0% in men and 10.7% in women aged 30–80 years. However, ATP III criteria for central obesity are not optimal for an Asian-Pacific population; when waist circumference is reduced from 102 to 90 cm in men and 88 to 80 cm in women, the prevalence of the metabolic syndrome increased to 29.0 and 16.8%, respectively. Sex-specific factor analysis showed four factors in men (obesity, glucose intolerance, hypertension, and dyslipidemia) and three in women (obesity-hypertension, glucose intolerance, and obesity-dyslipidemia). Insulin resistance estimated from fasting insulin levels clustered with three of the four factors in men and two of the three factors in women. By ATP III or Asian-Pacific waist circumference criteria, the prevalence of the metabolic syndrome increased with increasing tertiles of insulin resistance, which was estimated by a homeostasis model assessment.

CONCLUSIONS — The metabolic syndrome is common in an urban Korean population when using Asian-Pacific waist criteria. The prevalence of the metabolic syndrome increased with increasing tertiles of insulin resistance.

Diabetes Care 27:2027–2032, 2004

The metabolic syndrome, a cluster of central obesity, glucose intolerance, hypertension, and dyslipidemia (1,2), has been observed in many ethnic groups (1–7). Insulin resistance or hyperinsulinemia has been suggested to be the underlying characteristic of the metabolic syndrome (1–4), although a central role for insulin resistance in the metabolic syndrome is still controversial (8,9).

Assessing the relationship of the components of the metabolic syndrome is complex (10,11). Pathophysiologically, the multiple feedback mechanisms involved in the maintenance of glucose and lipid homeostasis make it difficult to establish which events or attributes lead to the cascade of disorders that characterize the syndrome (10). Statistically strong intercorrelations among variables thought to be central features of the metabolic syndrome complicate establishing independent associations using standard multivariate statistical models (11). One statistical method of interpreting clustered risk variables is factor analysis (11–13). Factor analysis reduces a large number of intercorrelated variables to a smaller subset of underlying "independent" variables (factors) that represent statistically independent and physiologically distinct phenotypes. The overlap reveals underlying commonalities between physiological domains (11). When there is a single underlying cause for risk variable clustering, factor analysis can identify the dominant factor.

Several studies of different ethnic groups suggest different patterns of clustering and the central role of insulin resistance in the metabolic syndrome (14–20). These studies commonly identified two to four factors with hyperinsulinemia loaded with one or more metabolic syndrome components, such as obesity, hyperglycemia, or dyslipidemia. Only one study has reported the metabolic syndrome-clustering pattern in Korea using factor analysis (21); in this report, the prevalence of each metabolic component was low, possibly because the subjects were elderly survivors as old as 92 years.

The present study was designed to examine the sex-specific clustering of metabolic syndrome factors and the effect of modifying western criteria for excess waist girth on the prevalence of the syndrome in an urban Korean population. Using factor analysis, we examined whether hyperinsulinemia was a common underlying abnormality of the metabolic syndrome.

RESEARCH DESIGN AND METHODS

— Subjects were selected in 1997 by random cluster sampling in Mokdong, which is located in the southwestern part of Seoul and has a popula-

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Received for publication 30 December 2003 and accepted in revised form 13 May 2004.

Abbreviations: ATP, Adult Treatment Panel; HOMA, homeostasis model assessment; PAI-1, plasminogen activator inhibitor-1.

A table elsewhere in this issue shows conventional and Système International (SI) units and conversion factors for many substances.

Table 1—*Clinical and biochemical characteristics in men and women*

	Men	Women
n	269	505
Age (years)	47.7 ± 12.2	46.6 ± 12.2
BMI (kg/m^2)	24.8 ± 2.8	23.3 ± 2.9*
Waist circumference (cm)	87.3 ± 7.3	76.1 ± 7.7*
Waist-to-hip ratio	0.88 ± 0.05	0.80 ± 7.1*
Systolic blood pressure (mmHg)	125.1 ± 18.8	119.4 ± 18.3*
Diastolic blood pressure (mmHg)	80.4 ± 11.7	75.1 ± 10.5*
Fasting glucose (mmol/l)	5.4 ± 1.5	5.0 ± 1.2†
Postchallenge glucose (mmol/l)	6.7 ± 3.6	6.2 ± 2.6‡
Fasting insulin (pmol/l)	57.2 ± 32.8	54.4 ± 31.3
Triglycerides (mmol/l)	2.0 ± 1.5	1.3 ± 0.8*
HDL cholesterol (mmol/l)	1.1 ± 0.2	1.3 ± 0.3*
HOMA of insulin resistance	2.22 ± 2.29	2.07 ± 1.63

Data are means ± SD. *$P < 0.001$, †$P < 0.01$, and ‡$P < 0.05$ vs. men.

tion of ~22,000, as part of a study of the prevalence of diabetes in community-dwelling adults (22). We randomly selected 13 of 124 apartment complexes. Of a total 1,804 age-eligible apartment residents, 43% (269 men, 505 women aged 30–80 years) participated in the Mokdong Study of Diabetes Prevalence. The age and sex distribution of respondents was similar to that of nonrespondents. The institutional review board of Ewha Womans University Mokdong Hospital approved the study. Informed consent was obtained from all participants.

Of the 269 men and 505 women in the prevalence study, 63 men and 56 women taking medication for hypertension, diabetes, or dyslipidemia were excluded from the factor analysis (because of the potential effect of medications on metabolic values), leaving 206 men and 449 women for the factor analysis. A 75-g oral glucose tolerance test was performed in the morning after a minimum 8-h overnight fast. Fasting and 2-h postchallenge plasma glucose levels were measured using the glucose oxidase method. Fasting plasma insulin was measured using a human insulin-specific radioimmunoassay double antibody kit (Diagnostic Products, Los Angeles, CA). Total cholesterol, HDL cholesterol, and triglycerides were measured by enzymatic methods using a Hitachi 7150 autoanalyzer (Hitachi, Tokyo, Japan). Homeostasis model assessment (HOMA), a reliable marker for insulin resistance in large epidemiological studies (23), was calculated as fasting glucose (mmol/l) × fasting insulin (μU/ml)/22.5 (24).

Height and weight were measured in subjects wearing lightweight clothing and without shoes; BMI also was calculated (kg/m^2). Waist and hip girth were measured in centimeters over single-thickness clothing with the participant standing in an erect position with feet together. Waist circumference was measured on bare skin during midrespiration at the narrowest indentation between the 10th rib and the iliac crest to the nearest 0.1 cm.

Definitions and statistical analyses

According to the National Cholesterol Education Program Adult Treatment Panel (ATP) III (25), the diagnosis of metabolic syndrome is made when three or more of the following risk factors are present: a waist circumference >102 cm in men and >88 cm in women, fasting glucose ≥110 mg/dl (6.1 mmol/l), systolic blood pressure ≥130 mmHg or diastolic blood pressure ≥85 mmHg, fasting triglycerides ≥150 mg/dl (1.7 mmol/l), and HDL cholesterol <40 mg/dl (1.0 mmol/l) in men and <50 mg/dl (1.3 mmol/l) in women. ATP III definitions were based on the association of factors with subsequent coronary heart disease in Caucasian cohorts. Because Koreans tend to have a lower average BMI and smaller waist circumference than North Americans, analyses were repeated using lower definitions of optimal levels of waist circumference (based on suggested Asia-Pacific guidelines [26]). Waist circumference is the only component of body size in the ATP III definition of metabolic syndrome, but we added BMI to our cluster to account for the fact that these participants were not obese. We did not adjust for BMI in other analyses.

Data were analyzed using SAS version 8.1 (SAS Institute, Cary, NC). Because fasting plasma insulin, triglycerides, and HDL cholesterol showed slightly skewed distributions, *P* values are based on logarithmic data, but mean values are presented for untransformed data.

Bivariate associations between insulin resistance and the metabolic syndrome were evaluated with χ^2 test. Neither insulin nor insulin resistance are components of the metabolic syndrome according to ATP III criteria. To study the relation of insulin resistance to the factor components and the metabolic syndrome, we used fasting insulin as a surrogate for insulin resistance, because it correlates well with insulin resistance estimated from HOMA ($r = 0.94$ in men and 0.96 in women in the present study) and because including HOMA in the cluster analysis is not appropriate because the metabolic syndrome components also include glucose. To further assess the centrality of insulin resistance to this syndrome and its components, we also stratified the clusters and the prevalence of the metabolic syndrome by tertiles of HOMA values. BMI-adjusted prevalences of metabolic syndrome according to age categories were evaluated with Cochran-Mantel-Haenszel χ^2 test. Factor analysis was performed to describe sex-specific clusters of metabolic syndrome factors and to evaluate whether hyperinsulinemia was an underlying abnormality of metabolic syndrome. Principal component analysis with orthogonal (varimax) rotation was used, and variables with factor loadings ≥0.30 were used in interpretation. (Variables with factor loadings of at least 0.3 are usually included, although it has been suggested that only higher loadings ≥0.4, which share at least 15% of variance with the factor, should be used [27].) All *P* values were two-tailed, and statistical significance was defined as $P < 0.05$.

RESULTS — The age- and sex-specific distribution of study participants was similar to the distribution of the residents living in the catchment area (data not shown). Table 1 shows the relevant characteristics of these subjects. The mean age of both men and women was 47 years. Men had less favorable levels of all factors (weight, central obesity, blood pressure,

plasma glucose, triglycerides, and HDL cholesterol) than women. Fasting insulin and HOMA did not differ between men and women.

By ATP III criteria (25), the prevalence of the metabolic syndrome was 16.0% in men and 10.7% in women, and only 1.1% of men and 6.3% of women had central obesity. The prevalence of hyperglycemia was 15.2 and 6.7%, hypertension was 43.1 and 29.7%, low HDL cholesterol was 37.6 and 53.1%, and high triglycerides was 42.8 and 23.0%, respectively. Because ATP III criteria for central obesity probably are not optimal for the leaner Asian population (26), we reduced the criteria for central obesity to a waist circumference of 90 cm in men and 80 cm in women. This change raised the prevalence of central obesity to 33.1% in men and 25.7% in women, and the prevalence of the metabolic syndrome almost doubled to 29.0 and 16.8%, respectively. When the Asia-Pacific criteria for central obesity were used, 13% ($n = 35$) of men and 6.1% ($n = 31$) of women who did not have the metabolic syndrome according to ATP III waist criteria now had the syndrome. Men with hypertension, low HDL, hypertriglyceridemia, or glucose intolerance numbered 26, 11, 27, and 6, respectively, and women, 19, 18, 18, and 7, respectively. In an analysis stratified into four age-groups (<40, 40–49, 50–59, and ≥60 years), the BMI-adjusted prevalence of the metabolic syndrome modified with Asia-Pacific waist girths increased significantly with increasing age in both sexes (men = 19.7, 25.9, 34.9, and 45.5%, $P < 0.05$; women = 4.3, 9.1, 23.4, and 50.0%, $P < 0.001$), as shown in Fig. 1.

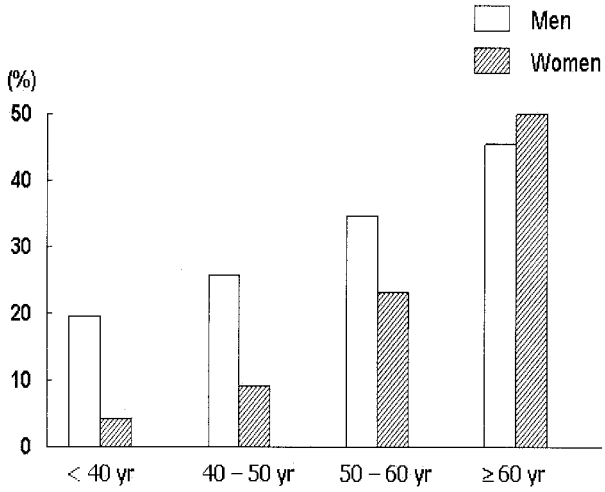

Figure 1—*BMI-adjusted prevalence of metabolic syndrome modified with Asia-Pacific guidelines according to age categories in men and women.* P *for trend <0.05 in men and <0.001 in women by Cochran-Mantel-Haenszel χ^2 test.*

Table 2 shows the sex-specific correlation matrices of metabolic parameters. In both sexes, most variables were significantly correlated with other factors. In men, HOMA was positively correlated with waist circumference, fasting and postchallenge glucose, and triglycerides; in women, it was positively correlated with obesity, blood pressure, glucose levels, and triglycerides and negatively with HDL cholesterol. In both sexes, correlations with HOMA were slightly stronger than with fasting insulin.

Factor analysis of the metabolic syndrome variables reduced nine highly intercorrelated variables to four separate factors in men and three in women (Table 3). In men, BMI, waist circumference, and fasting insulin clustered as factor 1, fasting glucose and insulin and postchallenge glucose as factor 2, systolic and diastolic blood pressure as factor 3, and triglycerides, HDL cholesterol, and fasting insulin as factor 4. The cumulative percentages of the total variance were 31.2, 48.9, 64.2, and 75.8%, respectively. In women, BMI, waist circumference, and systolic and diastolic blood pressure clustered as factor 1, fasting glucose and insulin and postchallenge glucose as factor 2, and BMI, waist circumference, fasting insulin, triglycerides, and HDL cholesterol as factor 3. The cumulative percentages of the total variance were 36.6, 52.4, and 66.8%, respectively.

Insulin resistance, defined as the highest quartile of HOMA, was significantly more prevalent in men and women with the metabolic syndrome than those without this syndrome (46.5 vs. 21.2% in

Table 2—*Correlation coefficients of metabolic syndrome variables in men and women*

Men/women	BMI	Waist	Systolic blood pressure	Diastolic blood pressure	Fasting plasma glucose	Postchallenge 2-h glucose	Fasting plasma insulin	HOMA insulin resistance	Triglycerides	HDL
BMI	—	0.81*	0.28*	0.28*	0.10	0.10	0.04	0.07	0.26*	−0.19†
Waist	0.83*	—	0.31*	0.28*	0.13‡	0.22*	0.14‡	0.18†	0.33*	−0.19†
Systolic blood pressure	0.39*	0.39*	—	0.80*	0.16†	0.18†	0.06	0.13	0.13‡	−0.05
Diastolic blood pressure	0.31*	0.33*	0.75*	—	0.07	0.12	0.05	0.08	0.16‡	−0.10
Fasting plasma glucose	0.21*	0.31*	0.18*	0.17*	—	0.80*	0.12	0.44*	0.05	−0.07
Postchallenge 2-h glucose	0.29*	0.39*	0.29*	0.22*	0.78*	—	0.08	0.33*	0.14‡	−0.08
Fasting plasma insulin	0.19*	0.20*	0.07	0.09	0.17†	0.20*	—	0.94*	0.09	0.01
HOMA of insulin resistance	0.25*	0.28*	0.13†	0.14†	0.44*	0.39*	0.96*	—	0.10	−0.03
Triglycerides	0.37*	0.46*	0.27*	0.16†	0.21*	0.31*	0.19*	0.24*	—	−0.26*
HDL	−0.13†	−0.14†	0.03	0.06	−0.06	−0.07	−0.06	−0.06	−0.37*	—

*$P < 0.001$; †$P < 0.01$; ‡$P < 0.05$.

Table 3—*Factor analysis after orthogonal rotation of principal components*

	Men				Women		
Variable	1	2	3	4	1	2	3
BMI	**0.88**	0.01	0.15	0.21	**0.66**	0.15	**0.48**
Waist circumference	**0.90**	0.11	0.14	0.18	**0.66**	0.26	**0.51**
Systolic blood pressure	0.12	0.13	**0.93**	0.02	**0.87**	0.13	−0.04
Diastolic blood pressure	0.11	0.01	**0.93**	0.08	**0.85**	0.09	−0.15
Fasting glucose	0.07	**0.91**	0.07	0.01	0.15	**0.90**	−0.03
Postchallenge glucose	0.06	**0.88**	0.06	0.14	0.20	**0.89**	0.08
Fasting insulin	**0.49**	**0.40**	−0.06	**0.49**	0.02	**0.37**	**0.32**
Triglycerides	0.14	0.29	0.15	**0.53**	0.14	0.18	**0.72**
HDL cholesterol	−0.21	0.03	0.04	**−0.78**	0.14	0.09	**−0.73**
Cumulative percentage total variance	31.2	48.9	64.2	75.8	36.6	52.4	66.8

Factor loadings ≥0.3 (in bold) are considered to have an important association between the measured variable and the factor.

men, $P < 0.001$; 50.0 vs. 22.2% in women, $P < 0.0001$). The results were the same in both sexes when the Asia-Pacific waist circumference guidelines were applied. The prevalence of the metabolic syndrome increased significantly by increasing tertiles of HOMA in both men (8.9, 14.6, and 24.4%, $P < 0.01$) and women (5.9, 7.3, and 18.8%, $P < 0.001$) with similar results using the Asia-Pacific guidelines (20.0, 25.8, and 41.1%, $P < 0.005$ in men; 10.0, 10.9, and 29.4%, $P < 0.0001$ in women).

CONCLUSIONS — In the present study, only 16.0% of men and 10.7% of women had the metabolic syndrome by ATP III criteria, and central obesity was much less common than in other studies—only 1.1% in men and 6.3% in women. In contrast, in the National Health and Nutrition Examination Survey sample (28), age-adjusted prevalences of the metabolic syndrome were 24.0 and 23.4% in men and women, respectively; age-adjusted prevalences of central obesity were 30.5 and 43.5% in Caucasian men and women, 23.3 and 62.1% in African-American men and women, and 30.6 and 62.7% in Mexican-American men and women, respectively. In another study, 24 and 42% of urban Iranian men and women (29) had the metabolic syndrome, as did 7.9 and 17.5% of urban Indian men and women (30). Reducing the criteria for central obesity in this Korean cohort to an Asian waist circumference of >90 cm for men and >80 cm for women increased the prevalence of central obesity to 33.1% in men and 25.7% in women. This had the effect of almost doubling the prevalence of the metabolic syndrome in both sexes (29.0% in men, 16.8% in women). The latter values are similar to the U.S. prevalence of the metabolic syndrome in men (24.0%) but still less than the prevalence in women (23.4%) (28).

Our study cohort was small. Although the age- and sex-specific characteristics of the respondents were comparable with those of total residents, we have no information about individuals who did not participate. Therefore, the true prevalence of the metabolic syndrome is uncertain. A Korean National Health and Nutrition Survey performed in 1998 yielded a metabolic syndrome prevalence of 19.9% in men and 23.7% in women (31). The waist-revised prevalence of the metabolic syndrome in our study was higher in men but lower than in women compared with the Korean National Health and Nutrition Survey. It would be informative to consider the large ethnic differences in body size and particularly in waist circumference when reporting the prevalence of the metabolic syndrome.

We also observed that the prevalence of the metabolic syndrome was lower in women than men until after age 60 years. A report from the U.S. National Health and Nutrition Examination Survey (28) also showed this reversal of metabolic syndrome prevalence by sex after age 60 years. This difference might reflect survivor bias with an earlier average death in men than in women (32), or it might reflect an effect of middle age or menopause on central obesity. In a U.S. Caucasian cohort (Rancho Bernardo), men reached their peak waist circumference before age 50 years, whereas women reached their peak circumference between ages 60 and 65 years (unpublished data). In the present cross-sectional study, men showed no significant increase in the prevalence of central obesity, hypertriglyceridemia, or low HDL cholesterol levels with age, although the prevalence of hypertension and hyperglycemia did increase significantly with age. In women, the prevalence of central obesity, hypertension, high triglycerides, and glucose intolerance each increased significantly with age; only the prevalence of low HDL cholesterol did not vary by age. The lower HDL levels in women than in men possibly reflect the higher male alcohol intake.

The four metabolic syndrome factors (obesity, dyslipidemia, glucose intolerance, and hypertension) observed in Korean men are similar to those reported in other populations (15,18). Hyperinsulinemia clustered with obesity, glucose intolerance, and dyslipidemia but not with blood pressure. Dyslipidemia was clustered with hyperinsulinemia only in men. The clustering of HDL cholesterol and triglycerides without glucose intolerance has been shown to be a separate factor in other nondiabetic populations (15,16,18), whereas in individuals with diabetes, dyslipidemia was clustered with glucose intolerance or hyperinsulinemia (16,17). One study reported that dyslipidemia was clustered with hyperinsulinemia in black and white youth without diabetes (17).

The finding that blood pressure was a separate factor in men in our study is consistent with other reports (18,33,34), including a study of elderly Koreans (21). High plasminogen activator inhibitor-1 (PAI-1) is one possible mechanism for

this association (35). Elevated PAI-1 levels in hypertensive subjects without any clinical features of the insulin resistance metabolic syndrome have been reported (35). Angiotensin II and IV are able to stimulate the increase in PAI-1 expression in endothelial cells in vitro (36,37) or in vivo (38).

In women, only three independent factors emerged; obesity as well as hyperinsulinemia appeared to be an underlying abnormality in two of the three factors (obesity-hypertension, glucose intolerance, obesity-dyslipidemia). Nevertheless, insulin resistance was more common in both men and women with metabolic syndrome compared with those without, supporting a central pathophysiological role for insulin.

In conclusion, the prevalence of the metabolic syndrome using the Asia-Pacific guideline for central obesity was 29.0% in men and 16.8% in women, which was similar to the prevalence of the metabolic syndrome in nonobese Caucasians. Hyperinsulinemia was a common underlying abnormality in both men (three of four factors) and women (two of three factors) in this population but was not associated with hypertension in either sex.

Currently, it appears that much of the variation in the prevalence of the metabolic syndrome and diabetes among ethnic groups reflects central adiposity with or without generalized obesity. The relevance of ethnic-specific definitions can only be assured when the ability of these definitions to predict later diabetes or coronary heart disease has been determined, but it seems unlikely that a single definition will be applicable to all racial or ethnic groups.

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