Factor Analysis and Defining the Metabolic Syndrome

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Objective: The metabolic syndrome has been referred to as a number of metabolic or physiologic abnormalities that occur together more often than would be predicted by chance. Considerable controversy exists about the exact abnormalities that are a part of this syndrome. The aim of this study was to examine the interrelations between these abnormalities.

Design: National Health and Nutrition Examination Survey (1988–1994), a national cross-sectional health survey.

Setting: United States.

Participants: Persons aged ≥20 years (*N*=6868).

Main Outcome Measurements: Factors composed of variables often associated with the metabolic syndrome derived from principal components analysis.

Results: Depending on the subgroup studied, the analyses suggested that at least 2 or 3 components were needed to explain the majority of variance in a set of variables. Regardless of age group, sex, race or ethnicity, 4 variables (waist circumference, fasting insulin, triglycerides, and high-density lipoprotein cholesterol) consistently loaded together on the first component, which is consistent with a metabolic syndrome factor. Some differences in the number of factors and the loading patterns occurred among 3 age groups and among men and women. Relatively minimal race or ethnic variation was observed when the data were stratified by sex. A subanalysis that included leptin concentrations produced a similar set of factors as the analysis without leptin concentration. Furthermore, leptin concentration did not provide a unifying explanation for the set of factors.

Conclusions: Patterns of factors of variables, often associated with the metabolic syndrome, tended to be similar among Whites, African Americans, and Mexican Americans. (*Ethn Dis*. 2003;13:429–437)

Key Words: Blacks, Ethnic Groups, Factor Analysis, Health Surveys, Leptin, Mexican Americans, Metabolic Syndrome X, Nutrition Surveys, Sex

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Introduction

A number of metabolic or physiologic abnormalities may occur together in people more often than would be predicted by chance. An early report suggested that the triad of hypertension, hyperglycemia, and hyperuricemia constituted a syndrome.[1] In 1988, Reaven proposed the term Syndrome X for the co-occurrence of hypertension, glucose intolerance, hypertriglyceridemia, and low high-density lipoprotein cholesterol concentration.[2] During the ensuing decades, researchers have used at least a dozen terms or variations of terms to refer to a constellation of metabolic abnormalities, and have used a myriad of definitions to define this syndrome. In 1998, the World Health Organization (WHO) proposed a working definition of this syndrome,[3] although this definition does not appear to have been widely adopted. In 2001, the National Cholesterol Education Program (NCEP) Adult Treatment Panel III report proposed another definition.[4]

Although Reaven included 4 abnormalities in Syndrome X, researchers have suggested that many other abnormalities may be part of this syndrome. These abnormalities include measures of central adiposity, dyslipidemia, hypertension, glucose intolerance, insulin resistance, hyperuricemia, coagulation, fibrinolysis, hemostatis, and inflammation. Because many of these variables are closely correlated in people, researchers have used a statistical technique called factor analysis to attempt to discern patterns in constellations of metabolic abnormalities. At least 15 such studies have been published.[5–19] Generally, these studies have utilized 5 to 21 metabolic or physiologic abnormalities as their starting points, and have described as many as 7 factors but more often 2 to 4 factors. Frequently, the factor that explains the largest portion of the variance includes central adiposity, glucose intolerance, insulin resistance, hypertriglyceridemia, and low high-density lipoprotein cholesterol concentrations. A second factor usually includes hypertension and several other abnormalities such as insulin resistance.

Although 7 of these studies have been conducted in the United States,[5,7,8,11,13,17,18] few studies have included substantial numbers of African Americans and Hispanics. Only 2 studies have included measurements of leptin, which has been proposed as playing an important role in the metabolic syndrome.[9,18] Data from the Third National Health and Nutrition Examination Survey (NHANES III) was utilized by the author to examine the interrelations of a set of variables thought to be part of the metabolic syndrome.

Methods

A representative sample of the civilian non-institutionalized US population, selected using a multistage probability design, has participated in an ongoing series of health surveys to provide population-based data on a variety of health topics. Participants in NHANES III were interviewed at home and asked to attend a designated mobile examination center to complete additional questionnaires, undergo a battery of tests, and provide blood and urine specimens for various clinical tests. Participants could attend the mobile examination center in the morning, afternoon, or evening. Reference manuals for

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and details of the plan and operations of NHANES III, conducted during 1988–1994, have been previously published.[20,21]

To develop a starting set of variables, the author included variables that are part of the ATP III and WHO definitions of the metabolic syndrome. A review of 15 studies using factor analysis showed these variables to be frequently used, except a measure of microalbuminuria included in the WHO definition. In order of decreasing frequency, the most commonly utilized variables were: triglycerides (N=15), fasting insulin concentration (N=14), high-density lipoprotein cholesterol concentration (N=14), fasting glucose concentration (N=13), systolic blood pressure (N=12), body mass index (N=10), diastolic blood pressure (N=8), uric acid concentration (N=5), waist-hip ratio (N=5), waist (N=4), 2-hour glucose concentration (N=4), and 2-hour insulin concentration (N=4). The following variables were used as the starting set for principal components analysis: body mass index, waist circumference, waist-hip ratio, fasting glucose, fasting insulin, systolic blood pressure, diastolic blood pressure, high-density lipoprotein cholesterol, triglycerides, and uric acid. Because WHO includes it as part of its definition of the metabolic syndrome, the urinary albumin creatinine ratio (ACR) was also included. In addition, age, sex, and race or ethnicity (White, African American, Mexican American) were used as stratifying variables.

Three readings of systolic and diastolic blood pressure were obtained from participants attending the mobile examination center, and the average of the last 2 measurements was used by the author. Body mass index was calculated from measured weight and height (weight in kilograms divided by height in meters squared). Waist circumference was measured at the high point of the iliac crest at minimal respiration to the nearest 0.1 cm. while hip circumference was measured at the maximal extension of the buttocks.

Serum glucose concentration was measured using an enzymatic reaction (Cobas Mira Chemistry System, Roche Diagnostic Systems, Inc, Montclair, NJ). Serum triglycerides were measured enzymatically after hydrolyzation to glycerol on a Hitachi 704 Analyzer (Boehringer Mannheim Diagnostics, Indianapolis, Ind). High-density lipoprotein cholesterol was measured following the precipitation of other lipoproteins with a heparin-manganese chloride mixture on a Hitachi 704 Analyzer. Urinary albumin was measured using a fluorescent immunoassay on a Sequoia-Turner Fluoremeter (Sequoia-Turner Corp, Mountain View, Calif). In addition, urinary creatinine was measured by the rate of color formation on a Beckman Synchron AS/ASTRA clinical analyzer (Beckman Instruments Inc, Brea, Calif) after creatinine reacted with picrate. Details about the laboratory procedures of all these tests are found elsewhere.[21]

The author used principal components analysis to identify major components (PROC FACTOR in SAS 6.19). Detailed descriptions of factor analysis are available elsewhere.[5,6,9,22] In keeping with most of the other studies, the author used Eigen values of $\geq$1.0 to retain factors, varimax rotation to obtain uncorrelated components, and loading values of 0.4 to decide which variables to retain in a component. In addition, the author produced scree plots to assist in the choice of components. The following participants were excluded from analyses: participants aged $<$20 years, participants with missing values, pregnant women, participants with self-reported diabetes mellitus, and participants who reported current use of antihypertensive medications. The resulting analytic sample included 6868 participants. Separate factor analyses were completed for 3 age groups (20–44 years, 45–64 years, and $\geq$65 years), men and women, and 3 major race or ethnic groups (White, African American, and Mexican American). Because these results were conducted without sampling weights and without the design information, these results should not be interpreted as being representative of the US population.

RESULTS

A total of 3410 men and 3458 women were included in the analyses. Of the men and women participating in the analysis, 2709 were White, 1834 were African American, 2025 were Mexican American, and 300 participants were of other races or ethnic groups. Ages ranged from 20 to over 90 years. Statistical considerations of the metabolic or physiologic variables are provided in Table 1.

Starting with 11 variables, 3 principal components were identified for both men and women (Table 2). Waist circumference, body mass index, waist-hip ratio, fasting insulin, triglycerides, high-density lipoprotein cholesterol, and uric acid loaded on the first component. Systolic blood pressure and diastolic blood pressure loaded on the second factor. Glucose and urinary ACR loaded on the third component. The structures of the first and third components among women differed from that among men. Waist circumference, body mass index, waist-hip ratio, fasting insulin, and uric acid loaded on the first component, whereas triglycerides, high-density lipo-

Table 1. Characteristics of variables used in principal components analysis for 6868 participants aged ≥20 years, National Health and Nutrition Examination Survey III, 1988–1994

	Mean	SD	Median	Minimum	Maximum
High-density lipoprotein cholesterol (mmol/L)	1.3	0.4	1.3	0.3	4.6
Triglycerides (mmol/L)	1.4	1.0	1.2	0.3	16.9
Glucose (mmol/L)	5.3	1.0	5.2	2.4	22.0
Insulin (pmol/L)	61.8	42.4	51.0	10.6	1054.6
Systolic blood pressure (mm Hg)	118.8	17.9	116	72.0	225.0
Waist circumference (cm)	91.2	13.8	90.2	58.6	162.2
Body mass index (kg/m^2)	26.6	5.4	25.7	13.3	67.3
Uric acid (μmol/L)	316.4	83.7	309.3	47.6	749.4
Urinary albumin : creatinine ratio (mg/g)	20.6	180.3	5.4	0.1	10884.3

protein cholesterol and fasting glucose loaded on the third component.

Because the 3 anthropometric variables measures overlap considerably and because systolic blood pressure and diastolic blood pressure are highly correlated, another set of models that excluded body mass index, waist-hip ratio, and diastolic blood pressure was analyzed. The resulting factors differed from those in Table 2, however. Among men, the first and third factors had similar loadings; the second factor included high-density lipoprotein cholesterol and systolic blood pressure. Among women, only 2 factors instead of 3 emerged from the analysis. High-density lipoprotein cholesterol, triglycerides, fasting glucose, fasting insulin, waist circumference, and uric acid loaded on the first factor. High-density lipoprotein cholesterol, systolic blood pressure, and urinary ACR loaded on the second factor.

To compare the effects of using waist circumference or body mass index as anthropometric measures, 2 models that included the full sample were run (Table 3). Waist circumference, fasting insulin, triglycerides, and high-density lipoprotein cholesterol loaded on the first component. Waist circumference, systolic blood pressure, and uric acid loaded on the second component, whereas glucose and urinary ACR loaded on the third component. When body mass index was substituted for waist circumference, only 2 factors were retained. Body mass index, fasting insulin, triglycerides, high-density lipoprotein cholesterol, and uric acid loaded on the first component. Glucose, urinary ACR, and systolic blood pressure loaded on the second component. However, when the Eigen value threshold was relaxed to 0.95, 3 factors with identical loadings to those of the analysis with waist circumference emerged.

Different factor patterns emerged when the data were stratified by age (Table 4). The youngest and oldest age groups had 3 components, whereas the middle age group had 2 components. The first factor for all 3 age groups included high-density lipoprotein cholesterol, triglycerides, insulin, and waist circumference. In addition, glucose and uric acid loaded on the first component among participants aged 45–64 years, whereas uric acid loaded on the first component for participants aged ≥65 years.

Three components had Eigen values ≥1 among men (Table 5), whereas 2 such factors occurred among women (Table 6). The results from these 2 tables are presented graphically in Figures 1 and 2. For all 3 groups of men, waist circumference, fasting insulin, triglycerides, and high-density lipoprotein cholesterol loaded on the first component. Among African-American men, glucose also loaded on the first component. Among White and Mexican-American men, uric acid loaded on the first com-

Table 2. Factor loadings for initial models using 11 variables, National Health and Nutrition Examination Survey III, 1988–1994

	Men (*N*=3410)			Women (*N*=3458)		
	Factor 1	Factor 2	Factor 3	Factor 1	Factor 2	Factor 3
High-density lipoprotein cholesterol (mmol/L)	**−0.59**	0.36	−0.13	−0.26	0.30	**−0.63**
Triglycerides (mmol/L)	**0.54**	−0.05	0.32	0.11	0.21	**0.80**
Glucose (mmol/L)	0.20	0.08	**0.78**	0.22	0.21	**0.49**
Insulin (pmol/L)	**0.66**	0.02	0.13	**0.68**	−0.08	0.25
Systolic blood pressure (mm Hg)	0.09	**0.82**	0.16	0.18	**0.84**	0.07
Diastolic blood pressure (mm Hg)	0.18	**0.76**	−0.01	0.30	**0.68**	−0.05
Waist circumference (cm)	**0.87**	0.26	0.03	**0.92**	0.15	0.16
Body mass index (kg/m^2)	**0.84**	0.20	−0.04	**0.91**	0.03	0.05
Waist-hip ratio	**0.69**	0.25	0.15	**0.54**	0.29	0.35
Uric acid (μmol/L)	**0.48**	0.11	−0.19	**0.45**	0.24	0.22
Urinary albumin : creatinine ratio (mg/g)	−0.06	0.06	**0.76**	−0.12	0.32	0.14
% Total variance	0.3054	0.1613	0.1311	0.3161	0.1455	0.1202
% Cumulative variance	0.3054	0.4667	0.5978	0.3161	0.4616	0.5818

Note: Values with a factor loading ≥0.40 are shown in bold type.

Table 3. Factor loadings for models using either waist circumference or body mass index, National Health and Nutrition Examination Survey III, 1988–1994

	Model with Waist Circumference			Model with Body Mass Index	
	Factor 1	Factor 2	Factor 3	Factor 1	Factor 2
High-density lipoprotein cholesterol (mmol/L)	**−0.77**	0.12	0.02	**−0.66**	0.08
Triglycerides (mmol/L)	**0.62**	0.17	0.20	**0.58**	0.27
Glucose (mmol/L)	0.31	0.19	**0.66**	0.28	**0.65**
Insulin (pmol/L)	**0.67**	0.16	0.08	**0.73**	0.06
Systolic blood pressure (mm Hg)	−0.09	**0.85**	0.20	0.15	**0.60**
Waist circumference (cm)	**0.60**	**0.51**	0.06	—	—
Body mass index (kg/m^2)	—	—	—	**0.71**	0.07
Uric acid (μmol/L)	0.38	**0.60**	−0.12	**0.52**	0.20
Urinary albumin:creatinine ratio (mg/g)	−0.05	−0.04	**0.84**	−0.14	**0.71**
Eigen value					
% Total variance	0.3205	0.1459	0.1264	0.3034	0.1487
% Cumulative variance	0.3205	0.4663	0.5928	0.3034	0.4521

Note: Values with a factor loading ≥0.40 are shown in bold type.

ponent. The second component for White and Mexican-American men contained glucose and urinary ACR, whereas the second component for African-American men contained systolic blood pressure, waist circumference, and uric acid. The third component for both White and Mexican-American men included high-density lipoprotein cholesterol and systolic blood pressure. In addition, the third component for Mexican-American men included waist circumference, as well. The third component for African-American men included glucose and urinary ACR.

The first component for the 3 groups of women all included the same set of variables: waist circumference, fasting insulin, triglycerides, high-density lipoprotein cholesterol, glucose, and uric acid. In addition, the second component also contained similar loadings.

In a sub-analysis of 4641 participants with leptin measurements, 3 factors that differed in order and loadings were identified for both men and women (Table 7). Among men, triglycerides, fasting insulin, systolic blood pressure, waist, uric acid, and leptin loaded on the first factor. Glucose and urinary ACR loaded on the second factor while high-density lipoprotein cholesterol, triglycerides, and systolic blood pressure loaded on the third factor. Among women, fasting insulin, waist, uric acid, and leptin loaded on the first factor. High-density lipoprotein cholesterol, triglycerides, and fasting glucose loaded on the second factor. Systolic blood pressure and urinary ACR loaded on the second factor.

DISCUSSION

This analysis of a set of metabolic or physiologic variables showed that at least 2 or 3 components explain a significant portion of the underlying variance of these variables. These findings are similar to the findings of other stud-

Table 4. Factor loadings by age groups, National Health and Nutrition Examination Survey III, 1988–1994

	Age (years)							
	20–44 (*N*=4294)			45–64 (*N*=1511)		≥65 (*N*=1063)		
	Factor 1	Factor 2	Factor 3	Factor 1	Factor 2	Factor 1	Factor 2	Factor 3
High-density lipoprotein cholesterol (mmol/L)	**−0.75**	0.01	0.04	**−0.69**	0.14	**−0.63**	−0.11	0.28
Triglycerides (mmol/L)	**0.66**	0.13	0.14	**0.63**	0.09	**0.47**	0.38	−0.15
Glucose (mmol/L)	0.32	0.09	**0.69**	**0.53**	−0.01	0.27	**0.75**	−0.04
Insulin (pmol/L)	**0.70**	0.17	0.10	**0.65**	0.08	**0.69**	0.15	0.02
Systolic blood pressure (mm Hg)	−0.01	**0.85**	0.17	0.13	**0.73**	0.05	0.05	**0.95**
Waist circumference (cm)	**0.62**	**0.49**	0.08	**0.68**	0.27	**0.77**	−0.02	0.07
Uric acid (μmol/L)	0.29	**0.73**	−0.10	**0.45**	**0.40**	**0.60**	0.00	0.12
Urinary albumin : creatinine ratio (mg/g)	−0.08	0.00	**0.84**	−0.09	**0.70**	−0.11	**0.81**	0.10
% Total variance	0.3345	0.1455	0.1289	0.3017	0.1440	0.2954	0.1507	0.1268
% Cumulative variance	0.3345	0.4800	0.6089	0.3017	0.4457	0.2954	0.4461	0.5729

Note: Values with a factor loading ≥0.40 are shown in bold type.

Table 5. Factor loadings among men, by race or ethnicity, National Health and Nutrition Examination Survey III, 1988–1994

	White (*N*=1315)			African American (*N*=867)			Mexican American (*N*=1090)		
	Factor 1	**Factor 2**	**Factor 3**	**Factor 1**	**Factor 2**	**Factor 3**	**Factor 1**	**Factor 2**	**Factor 3**
High-density lipoprotein cholesterol (mmol/L)	**−0.60**	−0.11	**0.50**	**−0.75**	0.07	0.04	**−0.71**	−0.07	**0.44**
Triglycerides (mmol/L)	**0.63**	0.30	−0.13	**0.65**	0.12	0.17	**0.71**	0.20	−0.07
Glucose (mmol/L)	0.23	**0.82**	0.10	**0.40**	−0.10	**0.71**	0.14	**0.80**	0.15
Insulin (pmol/L)	**0.75**	0.15	0.06	**0.72**	0.21	0.02	**0.66**	0.09	0.22
Systolic blood pressure (mm Hg)	0.17	0.13	**0.86**	−0.05	**0.70**	0.26	0.11	0.16	**0.84**
Waist circumference (cm)	**0.76**	0.07	0.24	**0.62**	**0.51**	0.02	**0.67**	0.04	**0.44**
Uric acid (μmol/L)	**0.59**	−0.21	0.06	0.25	**0.71**	−0.11	**0.56**	−0.31	0.18
Urinary albumin : creatinine ratio (mg/g)	−0.06	**0.83**	0.03	−0.11	0.17	**0.75**	0.01	**0.78**	0.04
% Total variance	0.3172	0.1720	0.1296	0.3133	0.1417	0.1285	0.2990	0.1770	0.1301
% Cumulative variance	0.3172	0.4892	0.6188	0.3133	0.4550	0.5835	0.2990	0.4760	0.6061

Note: Values with a factor loading ≥0.40 are shown in bold type.

ies. The first component typically included a number of the variables that have been used previously to define the metabolic syndrome. Looking at the results from models that included 8 variables, 4 variable (waist circumference, fasting insulin, triglycerides, and high-density lipoprotein cholesterol) consistently loaded together on the first component regardless of age group, sex, race or ethnicity. When the data were stratified by age group and by sex, some results were observed to be heterogeneous. Among men, the results showed some heterogeneity when the analyses were stratified by race or ethnicity. Among women, however, minimal race or ethnic variation were present in the results.

The analyses also suggested that the interpretation of the data was not always straight forward. First, a number of criteria to determine the number of relevant components have been suggested. These include Eigen values of ≥1.0, explained variance of ≥10%, cumulative variance of ≥70%, and interpretation of scree plots. These thresholds are not absolute,[22,23] and the interpretation of scree plots does not inevitably produce clarity. The number of factors identified by the use of Eigen values in the NHANES III analyses was not always consistent with the number of factors that would have been identified using either of the 2 variance criteria. In general, use of the variance criteria would have led to the addition of one factor. Second, the number and choice of a starting set of variables can affect the number and loadings of the final solution of the principal components analysis. The results from the models with 11 and 8 variables produced different interpretations, especially for women. Adding more variables generally resulted in a larger final set of components. These considerations strongly suggest that the results of factor analyses need to be cautiously interpreted.

WHO and the NCEP have produced working definitions of the metabolic syndrome in recent years.[3,4] The

Table 6. Factor loadings among women, by race or ethnicity, National Health and Nutrition Examination Survey III, 1988–1994

	White (*N*=1394)		African American (*N*=1834)		Mexican American (*N*=2025)	
	Factor 1	Factor 2	Factor 1	Factor 2	Factor 1	Factor 2
High-density lipoprotein cholesterol (mmol/L)	**−0.52**	**0.53**	**−0.56**	**0.53**	**−0.54**	**0.47**
Triglycerides (mmol/L)	**0.69**	−0.02	**0.59**	0.06	**0.65**	0.09
Glucose (mmol/L)	**0.52**	0.25	**0.57**	0.14	**0.50**	0.24
Insulin (pmol/L)	**0.73**	−0.14	**0.69**	−0.16	**0.78**	−0.09
Systolic blood pressure (mm Hg)	0.38	**0.71**	0.29	**0.73**	0.38	**0.70**
Waist circumference (cm)	**0.79**	0.07	**0.74**	0.20	**0.75**	0.12
Uric acid (gmmol/L)	**0.62**	0.13	**0.51**	**0.42**	**0.60**	0.16
Urinary albumin : creatinine ratio (mg/g)	−0.02	**0.54**	−0.02	**0.40**	0.03	**0.62**
% Total variance	0.3376	0.1459	0.3015	0.1458	0.3379	0.1435
% Cumulative variance	0.3376	0.4835	0.3015	0.4474	0.3379	0.4815

Note: Values with a factor loading ≥0.40 are shown in bold type.

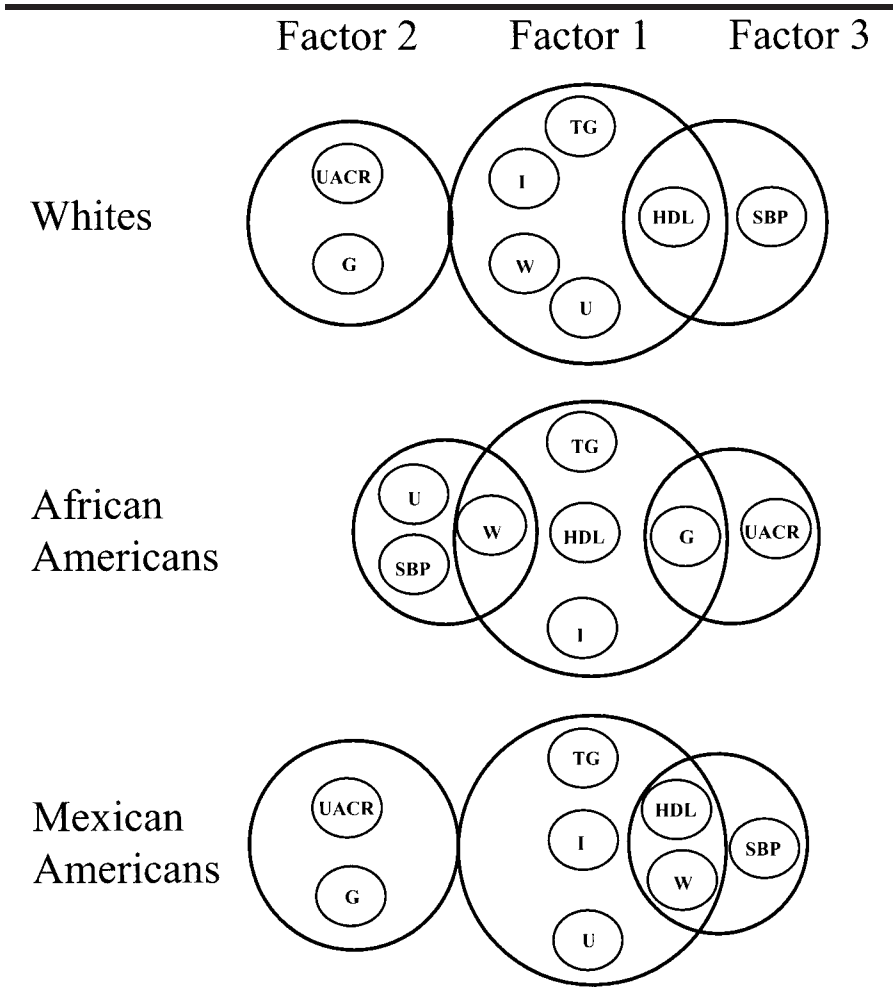

Fig 1. Venn diagram illustrating the results of factor analysis among men. The area of the factor circles has been scaled to the amount of variance explained by each factor. Variables in the areas of overlapping circles are thought to link factors. G=glucose; HDL=high-density lipoprotein cholesterol; I=insulin; SBP=systolic blood pressure; TG=triglycerides; U=uric acid; UACR=urinary albumin-creatinine ratio; W=waist

results from this analysis provide limited support for both definitions. Both definitions use measures of central adiposity and dyslipidemia, a part of the first component identified in this analysis. However, blood pressure and glucose concentrations which are part of both the WHO and ATP III definition, and urinary ACR, which is specific to the WHO definition, did not load together with the other variables on a single component. Nor were the separate factors consistently linked by a common variable such as central adiposity or fasting insulin concentration.

The WHO has proposed the use of the microalbuminuria as one criteria for the metabolic syndrome. Urinary ACR, as shown in this analysis, tended to load on a separate factor usually with fasting glucose, systolic blood pressure, or both. Only one other study included a measure of microalbuminuria finding that the urinary ACR loaded on a factor with age, systolic blood pressure, and left ventricular hypertrophy in both men and women.[12] Prolonged exposure to hyperglycemia and hypertension may damage the kidneys, resulting in microalbuminuria; therefore, this raises the possibility that microalbuminuria may be a consequence rather than a fundamental abnormality of the metabolic syndrome.

The present analysis supports the use of either waist circumference or

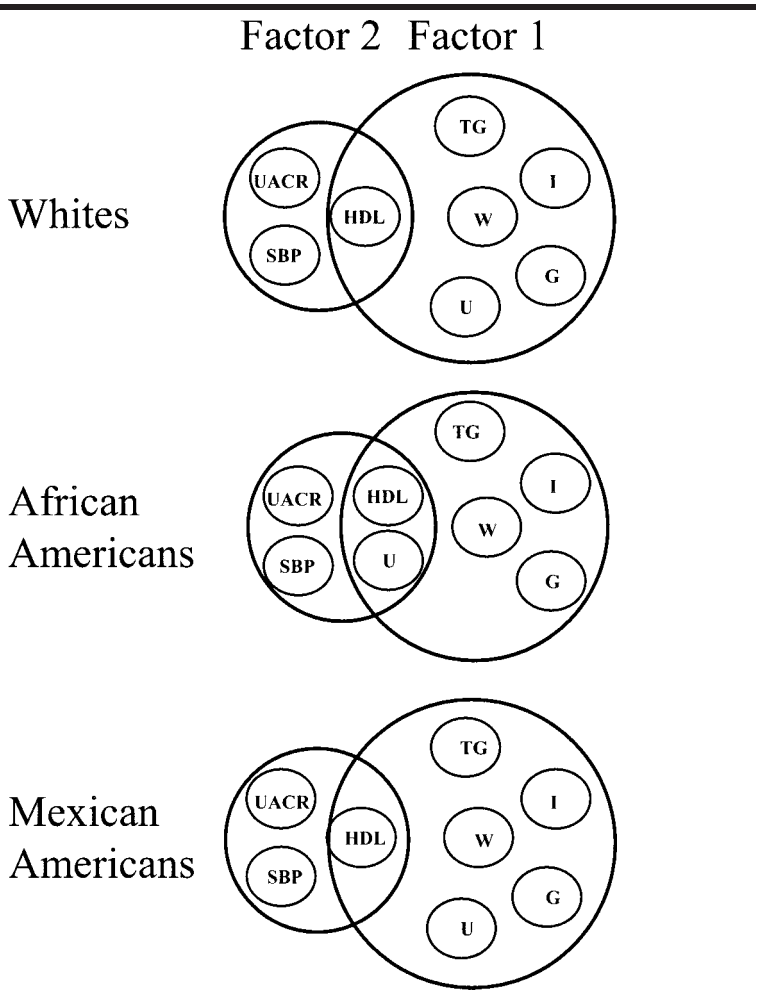

Fig 2. Venn diagram illustrating the results of factor analysis among women. The area of the factor circles has been scaled to the amount of variance explained by each factor. Variables in the areas of overlapping circles are thought to link factors. G=glucose; HDL=high-density lipoprotein cholesterol; I=insulin; SBP=systolic blood pressure; TG=triglycerides; U=uric acid; UACR=urinary albumin-creatinine ratio; W=waist

body mass index to measure central adiposity. Both epidemiologic studies and clinical settings may find this analysis useful.

The failure of systolic blood pressure to load with several of the other components on the first factor is consistent with reports from several other factor analysis studies. These studies also found that some measure of blood pressure often loads on a separate component[7,10–12,14,16–18] or does not load on any of the factors.[5] Many researchers believe insulin resistance is an underlying or unifying feature of the metabolic syndrome.[2,24] Because an inverse relation exists between insulin concentrations, which may be considered a marker for insulin resistance and blood pressure,[25] some measure of blood pressure is usually part of the definition of the metabolic syndrome. Nevertheless, the strength of the relation between insulin resistance and blood pressure may be insufficient to link them with other metabolic abnormalities associated with insulin resistance.

Few studies have presented results from factor analysis from African Americans. Donahue and colleagues studied 50 participants, of whom 23 were African American.[8] Although the authors concluded that results did not appear to differ by race or ethnicity, they also acknowledged having limited statistical power to address this issue. In an analysis of data from the Bogalusa Heart Study, Chen and colleagues provided separate results for Whites and African Americans and found identical factor patterns in the 2 groups aged 18–38 years.[13] Approximately 36.3% of the entire study sample aged 5–38 years were African American. None of the previous 15 studies that used factor analysis appear to have reported separate results for Hispanic populations, although clustering of metabolic abnormalities has been demonstrated among Mexican Americans.[26] In comparison, the results from this analysis of NHANES III data show that White men, African-American men, and Mexican-American men had identical factor loading patterns for the first factor. Furthermore, White men and Mexican-American men had an identical third factor, which was identical to the second factor for African-American men. Among women, 2 factors explained much of the variance in all 3 race or ethnic groups. Furthermore, the factor loading patterns were essentially identical among the 3 groups. Because of limited sample size in subgroup analyses, the results from these analyses should be interpreted with some degree of caution. Although the existence of a metabolic syndrome among African Americans had been questioned,[27] the results from this study and results from the Atherosclerosis Risk in Communities Study[28] suggest that a number of metabolic or physiologic abnormalities cluster in both Whites and African Americans.

Only 2 other studies have included leptin concentrations in their factor analyses.[9,18] Leptin is produced by adipocytes and, not surprisingly, loaded on the same factor that included waist circumference. In a study of 74 men, leptin loaded on 2 factors: one that includ-

Table 7. Factor loadings by sex, National Health and Nutrition Examination Survey III, 1988–1994

	Men (*N*=2229)			Women (*N*=2412)		
	Factor 1	**Factor 2**	**Factor 3**	**Factor 1**	**Factor 2**	**Factor 3**
High-density lipoprotein cholesterol (mmol/L)	−0.36	−0.12	**0.73**	−0.16	**−0.73**	0.32
Triglycerides (mmol/L)	**0.46**	0.34	**−0.42**	0.13	**0.76**	0.21
Glucose (mmol/L)	0.13	**0.81**	−0.07	0.20	**0.52**	0.29
Insulin (pmol/L)	**0.68**	0.14	−0.23	**0.72**	0.28	−0.09
Systolic blood pressure (mm Hg)	**0.40**	0.26	**0.63**	0.24	0.07	**0.75**
Waist circumference (cm)	**0.84**	0.13	−0.04	**0.83**	0.24	0.13
Uric acid (μmol/L)	**0.55**	−0.16	−0.04	**0.52**	0.15	0.31
Urinary albumin : cratinine ratio (mg/g)	−0.08	**0.79**	0.06	−0.09	0.04	**0.58**
Leptin	**0.81**	0.06	0.04	**0.89**	0.01	−0.03
% Total variance	0.3251	0.1499	0.1189	0.3351	0.1305	0.1167
% Cumulative variance	0.3251	0.4750	0.5939	0.3351	0.4656	0.5823

Note: Values with a factor loading ≥0.40 are shown in bold type.

ed insulin sensitivity, IVGTT insulin, fasting glucose, and fasting insulin and a second factor that included measures of central obesity, IVGTT glucose, uric acid, systolic blood pressure.[9] However, in models that included body mass index-adjusted leptin, this variable loaded only on the first factor. In a study conducted in Mauritius of 1414 men and 1654 women, leptin loaded with measures of central obesity, triglycerides, high-density lipoprotein cholesterol, uric acid, fasting insulin, and 2-hour insulin in women.[18] Results in men were similar to those in women, except that the loading factor for uric acid was 0.33. The results from this study are reasonably consistent with those of Hodge and colleagues.[17] Hodge and colleagues suggested that leptin may not be a unifying feature of the metabolic syndrome because it did not load on other factors that included variables thought to be part of the metabolic syndrome.

Waist circumference, fasting insulin, triglycerides, and high-density lipoprotein cholesterol loaded together with or without additional variables on the component that explained the largest portion of the variance.

In summary, using principal components analysis to analyze a set of metabolic or physiologic variables that are thought to be part of the metabolic syndrome or closely related to it, the author found that 2 or 3 components explained up to about 60% of the underlying variance. Some heterogeneity in results was observed among the different age groups and between men and women. When stratified by sex, results were reasonably homogeneous among Whites, African Americans, and Mexican Americans, especially among women. Waist circumference, fasting insulin, triglycerides, and high-density lipoprotein cholesterol loaded together with or without additional variables on the component that explained the largest portion of the variance. Because studies have failed to consistently show that one factor links a number of variables that are thought to be part of or closely associated with the metabolic syndrome or that one variable links separate factors, the possibility that more than one metabolic syndrome exists deserves consideration. As more is learned about the metabolic syndrome, current conceptualizations of the metabolic syndrome will surely evolve.

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Design and concept of study: Ford
Acquisition of data: Ford
Data analysis and interpretation: Ford
Manuscript draft: Ford
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Supervision: Ford