Validity of a Single-Factor Model Underlying the Metabolic Syndrome in Young Adults: Confirmatory Factor Analysis

Montserrat Solera-Martínez, a,* Sara López-Martínez, b Mairena Sánchez-López, a,c Pablo Moya-Martínez,a Blanca Notario-Pacheco, a Natalia Arias-Palencia, a Pablo Franquelito-Morales, d and Vicente Martínez-Vizcaíno, a, Estudio de Cuenca Adultos

a Centro de Estudios Sociosanitarios, Escuela Universitaria de Enfermería, Universidad de Castilla-La Mancha, Cuenca, Spain
b Servicio de Urgencias, Hospital Virgen de la Luz, Cuenca, Spain
c Facultad de Educación, Universidad de Castilla-La Mancha, Ciudad Real, Spain
d Laboratorio, Hospital Virgen de la Luz, Cuenca, Spain

ABSTRACT

Introduction and objectives: To determine by confirmatory factor analysis whether a model of the metabolic syndrome including waist circumference-to-height ratio, as a measure of adiposity, has better goodness of fit than that based on waist circumference alone and, on the basis of the data of the best-fit model, to develop an index of global cardiometabolic risk in young adults.

Methods: Cross-sectional observational study involving 683 university students aged 18 to 30 years, in their first year at the University of Castilla-La Mancha in Spain, during the 2009-10 academic year. We compared the best fit of 2 models of the metabolic syndrome, both of which included the triglyceride-to-high-density lipoprotein cholesterol ratio, HOMA-IR index, and mean arterial blood pressure, but differed in that one of them used waist circumference, whereas the other used the waist circumference-to-height ratio. A metabolic syndrome index (MSI) was constructed and its association with aerobic capacity, daily physical activity and muscle strength was estimated.

Results: The single-factor model that included waist circumference was a better indicator of goodness of fit. The MSI was inversely associated with aerobic capacity and muscle strength.

Conclusions: This study confirms that a single factor underlies the concept of metabolic syndrome; including the waist circumference-to-height ratio does not result in improvements over the model in which waist circumference alone is considered, and the development of a quantitative MSI may be useful for the quantification of cardiometabolic risk in clinical practice.

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Palabras clave:
Análisis factorial confirmatorio
Síndrome metabólico
Adulto joven
Actividad física
Capacidad aeróbica
Fuerza muscular

RESUMEN

Introducción y objetivos: Comparar mediante análisis factorial confirmatorio si un modelo de síndrome metabólico que como medida de adiposidad incluye la razón perímetro de cintura/estatura tiene mejor bondad de ajuste que el que incluye el perímetro de cintura y, a partir de los datos del modelo de mejor ajuste, desarrollar un índice de riesgo cardiometabólico global en adultos jóvenes.

Métodos: Estudio observacional transversal en el que participaron 683 estudiantes universitarios de 18 a 30 años de primer curso de la Universidad de Castilla-La Mancha durante el curso 2009/2010. Se comparó el mejor ajuste de dos modelos de síndrome metabólico; ambos incluían la razón triglicéridos/colesterol unido a lipoproteínas de alta densidad, índice HOMA-IR, presión arterial media y uno de ellos incluyó el perímetro de cintura y otro, la razón perímetro cintura/estatura. Se construyó un índice de síndrome metabólico (ISM) y se estimó su asociación con la capacidad aeróbica, con la actividad física diaria y con la fuerza muscular.

Resultados: El modelo unifactorial que incluía el perímetro de cintura mostró mejores indicadores de bondad de ajuste. El ISM se asoció inversamente con la capacidad aeróbica y la fuerza muscular.

Conclusiones: Nuestro estudio corrobora que un solo factor subyace al concepto síndrome metabólico; la razón perímetro de cintura/estatura no aporta mejoras sobre considerar el perímetro de cintura.
INTRODUCTION

The metabolic syndrome is a group of cardiometabolic disorders that is considered to be a predictor of cardiovascular disease, type 2 diabetes mellitus, and overall mortality. The definition of the metabolic syndrome is a subject of controversy, although all the currently accepted definitions include insulin resistance or glucose intolerance, hypertension, dyslipidemia, and central obesity. Exploratory factor analysis techniques can be used to analyze the interrelationship among a set of variables determined in a group of individuals and to establish a small group of latent variables that we refer to as factors. A number of studies have examined the relationship between the different phenotypic factors or traits that constitute the metabolic syndrome using factor analysis techniques, mainly principal component analysis. Most of the analyses included several measures of adiposity, arterial blood pressure, and fasting plasma concentrations of triglycerides, high-density lipoprotein cholesterol (HDLc), glucose and insulin. To date, however, there is no consensus as to the number of factors underlying the concept of the metabolic syndrome that includes waist circumference as a measure of adiposity with another that includes the waist circumference-to-height ratio; on the basis of the best fit model, to develop an index of global cardiometabolic risk, as has been established for Spanish children; and to estimate the relationship between this index and aerobic capacity, muscle strength, and physical activity.

METHODS

Subjects and Experimental Design

We describe a cross-sectional observational study in which all the first-year university students on the Cuenca Campus of the Universidad de Castilla-La Mancha in Spain were invited to participate. Of the 770 students invited, 683 (88.7%) accepted. The study protocol was approved by the Clinical Research Ethics Committee of Hospital Virgen de la Luz in Cuenca and, once they had been informed orally and in writing, all the subjects were asked for their signed consent as a condition to participate in the study.

Anthropometric Variables

During the 2009-2010 academic year, in addition to sociodemographic variables (age, sex, type of studies undertaken, etc.), for all subjects we collected the following data:

- Body weight: the mean of 2 measurements using an approved, easily calibrated Seca-770 scale, with the subject barefoot and wearing light clothing.
- Height: the mean of 2 measurements using a Seca-222 wall-mounted stadiometer, with the subject barefoot and standing erect, with his or her sagittal midline at the midline of the stadiometer.
- Body mass index: calculated as weight (in kg) / square of height (in m).
- Waist circumference: the mean of 2 measurements of the waist using a flexible tape measure (midway between the last rib and the iliac crest).
- Systolic and diastolic arterial blood pressure: the mean of 2 measurements separated by an interval of 5 min, following a rest period of at least 5 min prior to the first determination. The subject was seated, in a calm, quiet atmosphere. Arterial blood pressure was obtained by an automated procedure using the OMRON M5-I monitor.

The anthropometric measurements and arterial blood pressure readings were taken by nurses who had attended a series of training sessions.

Lipid and Metabolic Variables

Blood samples were collected via cubital vein puncture under standard conditions between 8:15 and 9:00 AM after at least 12 h...
of fasting. The samples were processed in a COBAS C711 system from Roche Diagnostics, and the following biochemical parameters were determined: total cholesterol (CHOD-PAP enzymatic method), triglycerides (GPO-PAP enzymatic method), glucose (hexokinase method) and direct HDLc plus (second generation method without deproteinization). The blood insulin concentration was determined by 1-step chemiluminescent microparticle immunoassay and processing on a platform composed of 2 ARCHITECT i2000SR systems from Abbott Laboratories. Insulin sensitivity was determined on the basis of the HOMA-IR index\(^ {18}\) using the formula: baseline glucose (mmol/L) \times\) baseline plasma insulin (mU/mL) / 22.5.

**Physical Activity and Fitness Variables**

Given that an association has been reported between physical activity, muscle strength, and aerobic capacity, independent of the incidence of the metabolic syndrome,\(^ {19,20}\) for the purpose of examining the relationship between the cardiometabolic risk index and these variables, we determined the following variables:

**Aerobic Capacity**

Maximum oxygen consumption (\(VO_{2\text{max}}\)) was determined by a submaximal exercise test on a cycle ergometer (Ergoline Variobike 550; Ergometrix, Barcelona, Spain) according to a protocol established by the FitMate device.\(^ {21}\) The oxygen concentration was measured directly using the FitMate Pro gas analyzer (COSMED, Rome, Italy).

**Muscle Strength**

This aspect was evaluated by means of 2 tests: standing long jump with feet shoulder width apart and handgrip dynamometry using a Takei TKK 5101 digital dynamometer (range, 5-100 kg; accuracy, 0.1 kg). These tests are validated and standardized and are part of the EUROFIT battery.\(^ {22}\) We calculated a synthetic muscle strength index composed of the sum of the standardized \(z\) scores for the dynamometric test-to-weight ratio and the long jump test.

**Physical Activity**

A subsample of 273 subjects wore on their right hips, for 7 consecutive days, a MTI/CSA 7164 accelerometer (Actigraph, Shalimar, Florida, United States) programmed to record minute-by-minute movement. The intensity of weekly physical activity was evaluated as the average counts/min for the duration of the activity.

**Statistical Analysis**

We tested two models of clustering of metabolic syndrome variables under a factor: that proposed by Pladevall et al.,\(^ {13}\) which includes waist circumference, the triglyceride-to-HDLc ratio, HOMA-IR, and MAP (diastolic arterial pressure + 1/3 [systolic arterial pressure − diastolic arterial pressure]), and another model in which the waist circumference variable is replaced by the waist circumference-to-height ratio.

The HOMA-IR index and the triglyceride-to-HDLc ratio were logarithmically transformed to fit them to a normal distribution, and all the variables of the model were standardized (mean = 0 and standard deviation = 1) according to age and sex. The factor weights (\(\lambda\)) corresponding to each of the variables measured indicate the strength of the association between the variables and the concept of the metabolic syndrome. We used a cut-off point of ±0.3 as the minimum level of practical significance of a \(\lambda\) coefficient.

The estimates of the parameters were obtained using maximum likelihood methods.

The fit of the models was analyzed in several ways. The \(\chi^2\) test was utilized to assess the fit of the hypothetical models to the sample data. As the size of the sample was relatively large (\(n = 683\)), goodness of fit was analyzed using the criteria of Hu et al.,\(^ {23}\) which include the comparative fit index (CFI) and the standardized root mean square residual (SRMR). A model was considered to have good fit if the CFI value was greater than 0.96 and the SRMR value was less than 0.08.

Multiple group analysis was carried out to examine sex-related differences. We determined whether the differences in the factor weights were statistically significant using the \(\chi^2\) difference test.

We calculated a new metabolic syndrome index (MSI) comprised of the sum of the standardized scores for the 4 variables that make up the model, multiplied by their factor weights. A web application has been developed for the automated calculation of the MSI on the basis of individual gross values (available at: http://www.cess.uclm.es/sm). The means of the MSI according to sex were compared using Student’s \(t\) test.

Receiver operating characteristic (ROC) curves were generated to obtain the optimal cut-off point for the MSI, taking into account the Youden index\(^ {24}\) for the prediction of risk of the metabolic syndrome in adult university students. As diagnostic criteria, we used that of the International Diabetes Federation,\(^ {25}\) which, in addition to the presence of central obesity (waist circumference greater or equal to 94 cm in men and 80 cm in women), requires the presence of at least two of the following factors: triglycerides \(\geq 150\) mg/dL, HDLc < 40 mg/dL in men and <50 mg/dL in women, glucose \(\geq 100\) mg/dL and elevated arterial blood pressure (systolic \(\geq 130\) mmHg and/or diastolic \(\geq 85\) mmHg).

Using covariance analysis adjusted for age and sex, we evaluated the differences in the average MSI according to categories of aerobic capacity, physical activity (counts/min) and a synthetic muscle strength index. These variables were recorded on the basis of the quartiles in 3 groups (Q1, Q2-Q3, and Q4), and linear trend analysis was performed using polynomial contrast. The \(P\) value of the post \(hoc\) contrast hypothesis was determined with the Bonferroni correction for multiple comparisons. The criteria for statistical significance of 2-sided testing was a \(P\) value less than or equal to .05. All the statistical analyses were performed with the SPSS 17.0 software package, except for the CFA, which was carried out with the AMOS 17.0 software package (SPSS Inc).\(^ {26}\)

**RESULTS**

The final sample included 683 first-year university students, with ages between 18 and 30 years (mean, 20.19 \(\pm\) 4.36 years). Of these, 505 (73.9%) were women. The prevalence of the metabolic syndrome, according to the criteria of the International Diabetes Federation, was 2.2%.

Figure 1 shows both models of a factor proposed to analyze the factor structure of the metabolic syndrome. Both the fit of the model proposed by Pladevall et al.\(^ {13}\) (Fig. 1A) (\(\chi^2 = 2.27; df = 2; P = .321; CFI = 0.99; SRMR = 0.016\)) and that of the same model substituting waist circumference for the waist circumference-to-height ratio (Fig. 1B) (\(\chi^2 = 2.76; df = 2; P = .251; CFI = 0.99; SRMR = 0.018\)) were quite good. However, for the latter, the factor weight for the waist-to-height ratio variable (\(\lambda=0.56\)) was somewhat lower than that of the waist circumference variable...
measurements were similar in both men and women (Fig. 2), and found that includes waist circumference, HOMA-IR, triglyceride-to-HDL cholesterol, and MAP, checking for sex-related differences. This model provides better fit than one in which this variable is replaced by the waist circumference-to-height ratio. However, in our population, both the factor weights and the indicators of goodness of fit of the model are somewhat better when we use waist circumference. This circumstance could be due to the fact that the variables that represent each component of our model are adjusted for age and sex and, thus, could be indirectly be adjusted for height due to its close relationship with those variables.

**DISCUSSION**

Our data confirm by means of CFA that, in young adults, there is a single factor behind the concept of the metabolic syndrome. Moreover, in our population, the model that includes waist circumference as a measure of adiposity is associated with better indicators of goodness of fit than that including the waist circumference-to-height ratio. Finally, we have developed an index to quantify the risk of the metabolic syndrome in which the average values improve as the aerobic capacity and muscle strength increase.

A number of studies have employed CFA to evaluate models of the metabolic syndrome in children, adolescents, and adults. There is no consensus in the literature as to the number of factors that comprise the concept of the metabolic syndrome. Pladevall et al. demonstrated the goodness of fit of a single-factor model that included only 1 variable as a representative measure of each of the 4 components that are included in the different definitions of the metabolic syndrome. This model involving a single factor, but having different variables, has also been tested in children and adolescents and our study confirms that the model proposed by Pladevall et al. also shows a satisfactory fit in young adults in Castilla-La Mancha, Spain.

The waist circumference-to-height ratio has been reported to be more strongly associated with cardiovascular and metabolic risk than other anthropometric indices, both in adults and children. Thus, it seems logical to think that a conceptual model of the metabolic syndrome that includes the waist circumference-to-height ratio as a measure of adiposity should provide better fit than one in which this variable is replaced by waist circumference. However, in our population, both the factor weights and the indicators of goodness of fit of the model are somewhat better when we use waist circumference. This circumstance could be due to the fact that the variables that represent each component of our model are adjusted for age and sex and, thus, could indirectly be adjusted for height due to its close relationship with those variables.
In clinical practice, it is very useful to establish two diagnostic categories; however, given the relatively low prevalence in young adults, it is difficult to find enough power to establish associations between this syndrome and a number of lifestyle-related factors. For this reason, numerous studies aimed at relating cardiometabolic risk to different lifestyle-related factors have utilized summative indices on the basis of variables representing each component of the metabolic syndrome. The European Association for the Study of Diabetes and the American Diabetes Association have even recommended the development of studies with similar results. However, the results of the studies dealing with the relationship between physical activity and cardiometabolic risk are contradictory. The values of the MSI that we developed on the basis of factor analysis data improve as the aerobic capacity and muscle strength increase. The muscle strength index was calculated as the sum of the standardized z scores for the dynamometry-to-weight ratio and the long jump test. The error bars represent the standard error of the mean.

FIGURE 3. Difference in the average metabolic syndrome index in each of the categories of aerobic capacity and muscle strength according to sex. Q1: first quartile; Q2-Q3: second-third quartiles; Q4: fourth quartile; VO\(_{2\max}\): maximal oxygen consumption (aerobic capacity). The muscle strength index was calculated as the sum of the standardized z scores for the dynamometry-to-weight ratio and the long jump test. The error bars represent the standard error of the mean.

CONCLUSIONS

Our study corroborates the affirmation that a single factor underlies the concept of the metabolic syndrome and the fact that inclusion of the waist circumference-to-height ratio does not improve the goodness of fit of the model and makes it less parsimonious. Moreover, this report provides a new index for the quantification of cardiometabolic risk and the development of a web site for its calculation.

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CONFLICTS OF INTEREST

None declared.
APPENDIX 1

Researchers Participating in The Estudio de Cuenga Adultos
Principal investigator: V. Martínez Vizcaíno. Universidad Castilla-La Mancha.
Bilbao: Gonzalo Grandes, Unidad de Investigación de Atención Primaria (Primary Care Research Unit). Osakidetza.

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