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New non-invasive method for early detection of metabolic syndrome in the working population

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Abstract

Background: We propose a new method for the early detection of metabolic syndrome in the working population, which was free of biomarkers (non-invasive) and based on anthropometric variables, and to validate it in a new working population.
Methods: Prevalence studies and diagnostic test accuracy to determine the anthropometric variables associated with metabolic syndrome, as well as the screening validity of the new method proposed, were carried out between 2013 and 2015 on 636 and 550 workers, respectively. The anthropometric variables analysed were: blood pressure, body mass index, waist circumference, waist–height ratio, body fat percentage and waist–hip ratio. We performed a multivariate logistic regression analysis and obtained receiver operating curves to determine the predictive ability of the variables. The new method for the early detection of metabolic syndrome we present is based on a decision tree using chi-squared automatic interaction detection methodology.
Results: The overall prevalence of metabolic syndrome was 14.9%. The area under the curve for waist–hip ratio and waist circumference was 0.91 and 0.90, respectively. The anthropometric variables associated with metabolic syndrome in the adjusted model were waist–hip ratio, body mass index, blood pressure and body fat percentage. The decision tree was configured from the waist–hip ratio (⩾0.55) and hypertension (blood pressure ⩾128/85 mmHg), with a sensitivity of 91.6% and a specificity of 95.7% obtained.
Conclusions: The early detection of metabolic syndrome in a healthy population is possible through non-invasive methods, based on anthropometric indicators such as waist–hip ratio and blood pressure. This method has a high degree of predictive validity and its use can be recommended in any healthcare context.

Keywords

Metabolic syndrome, early detection, occupational health nursing, anthropometry, working population

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Introduction

Metabolic syndrome (MetS) is defined as a group of metabolic risk factors, characterised by central obesity, high arterial blood pressure (BP) and an impaired glucose (hyperglycaemia) and lipid (hypertriglyceridaemia and low high-density lipoprotein (HDL)-cholesterol) metabolism.[1]

MetS is closely linked to type 2 diabetes mellitus (DM), cardiovascular disease (CVD) and other cardiovascular risk factors that increase morbidity and mortality.[2,3] The general increase in the prevalence of MetS over the past few decades has made it an urgent priority for public health services in all countries.[4]

With the aim of the early detection of MetS, a large amount of research has been carried out recently aimed at

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identifying predictors based on biomarkers of metabolic risk, such as systemic inflammation markers (C-reactive protein, leukocyte rate and subtypes), adipocytokines (leptin, adiponectin, tumour necrosis factor α), uric acid and bilirubin, etc.[5–9]

In addition, the identification of abdominal obesity and, more specifically, the accumulation of visceral fat as a key factor in the pathogenesis of insulin resistance and the onset of MetS has led to a body of research aiming to link MetS to anthropometric measurements of obesity such as body mass index (BMI), waist circumference (WC), waist–hip index, waist–height index, etc.[10–12] However, the heterogeneity of the populations studied has meant that consensus and agreement in the results differ widely.

Occupational health nursing is actively involved in the promotion of health programmes at the workplace for the prevention of CVDs, focusing on the control of main risk factors: obesity, hypertension, hyperlipidaemia, smoking, balanced diet and physical activity.

The aim of this study is to propose a method for the early detection of MetS in a working population that is free of biomarkers (non-invasive) and based on anthropometric variables, and to validate it in a different population of workers.

Methods

Epidemiological design, population and sample

Two studies were carried out:

1. A cross-sectional study performed in 2013 on 636 workers, with the aim of showing the prevalence of MetS and providing a basis for univariate and multivariate logistic regression to determine which anthropometric variables are associated with MetS.
2. A diagnostic test accuracy study conducted in 2014–2015, on 550 workers, aimed at validating the new method of non-invasive screening against the benchmark of the National Cholesterol Education Program Adult Treatment Panel III (NCEP ATP III) guide, which defines MetS by the presence of at least three of the following criteria: WC $\geqslant$88 cm in women and $\geqslant$102 cm in men; BP $\geqslant$130/85 mmHg or undergoing treatment for high BP; triglycerides $\geqslant$150 mg/dl or HDL-cholesterol $\leqslant$50 mg/dl for women and $\leqslant$40 mg/dl for men; or undergoing dyslipidaemic therapy; fasting plasma glucose $\geqslant$100 mg/dl, undergoing hypoglycaemic treatment or diagnosis of DM.

The reference population consisted of workers from a local government office in Córdoba (Spain) during the period 2013–2015, which employed an average of 1968 workers per year. The samples were selected by a random procedure and classified by age and gender. The subjects chosen were mutually exclusive for both samples.

To determine the sample size, EPIDAT (version 4.0) was used. For the cross-sectional study, the calculation of the sample size was made on the basis of 14% expected prevalence, 2.5% absolute precision and 95% accuracy, with a sample size of 539 workers. In the diagnostic test accuracy study, 90% expected sensitivity, 14% expected prevalence, 80% power and 95% confidence level were established, resulting in a sample size of 541 subjects.

All the workers were recruited using occupational health examinations performed in the workplace, were informed verbally and in writing about the objectives of the occupational health examination, and their informed consent was obtained, in accordance with the regulations. The study protocol complied with the Declaration of Helsinki for conducting medical research involving human subjects.

Study variables and measurement

The explanatory variables analysed were classified into the following categories:

a) Personal lifestyle variables: gender, age, education level, smoking, alcohol consumption and physical activity.
b) Anthropometric variables: WC in centimetres, BMI in kg/m^2, body fat percentage (BFP) calculated according to the Deurenberg equation, waist–height ratio (WtHR) calculated by the quotient between WC and height in centimetres, waist–hip ratio (WHR) calculated by the ratio of the circumference of the waist and hip in centimetres, systolic blood pressure (SBP) and diastolic blood pressure (DBP) expressed in mmHg.
c) Analytical variables: HDL-cholesterol (mg/dl), fasting plasma glucose (mg/dl) and triglycerides (mg/dl).

The anthropometric measurements (height, weight, waist and hip circumferences) were measured following the recommendations in the reference manual for anthropometric standardization,[13] and were performed by experienced technicians to minimise coefficients of variation. Each measurement was made three times and the average value was calculated. Weight and height were determined according to recommended techniques mentioned above. Body weight was measured to the nearest 0.1 kg using an analogue scale. Height was measured to the nearest 0.1 cm using a stadiometer. Waist and hip circumferences were measured using a flexible steel tape. The plane of the tape was perpendicular to the long axis of the body and parallel to the floor. WC was measured half way between the lower costal border and the iliac crest. The measurement was

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made at the end of a normal expiration while the subject stood upright, with feet together and arms hanging freely at the sides. Hip circumference was measured over non-restrictive underwear, or light-weight shorts, at the level of the maximum extension of the buttocks posteriorly in a horizontal plane, without compressing the skin.

To measure BP, the recommendations in the *Manual of Hypertension of the Spanish Society of Family Medicine*[14] were followed. BP was determined after a resting period of 10 minutes in the supine position using an automatic and calibrated sphygmomanometer (OMRON M3, OMRON Healthcare Europe, Spain). As indicated for the anthropometrical measures, BP was measured three times with a 1-minute gap between each measurement and an average value was calculated.

Statistical analysis

We used the statistical and epidemiological packages G-STAT (version 2.0), SPSS (version 15.0) and EPIDAT (version 4.0).

The quantitative variables are presented with their mean and standard deviations, except for triglycerides, for which the median and interquartile ranges are shown. The qualitative variables are shown as percentages. We carried out analysis of the type of distribution and normality test for each variable using the Kolmogorov–Smirnov test. For bivariate analysis Student's *t*-test for means in normal distribution variables (using the Levene test for variance equality) and non-parametric tests such as the U Mann–Whitney test (independent samples) for variables showing non-normal distribution were used. For categorical variables the chi-squared test and Fisher's exact test whenever necessary for each contingency table were used. We also computed correlation and regression measures when necessary for continuous variables. In addition, analysis of variance tests with the post hoc Bonferroni contrast method were carried out.

The prevalence of MetS was determined for each independent variable. Multivariate analysis was performed by logistic regression. The crude and adjusted odds ratios (ORs) were calculated. Goodness of fit tests for the model (–2 log likelihood, goodness of fit statistic, Cox and Snell R^2, Nagelkerke R^2 and Hosmer–Lemeshow tests) were calculated to assess the global adjustment of the model. Exponentiation was used for the b-coefficients in the regression models to estimate the OR, and the standard error of the b-coefficients was used to calculate the 95% confidence intervals (CIs). Receiver operator characteristic (ROC) curves were carried out and the area under the curve (AUC) was calculated to determine which explanatory variables best predict the onset of MetS.

To perform the diagnostic test accuracy study, sensitivity, specificity, predictive values, likelihood ratios, Youden and prediction indices were analysed.

The new model of the early detection of MetS was obtained from a clinical decision tree (classification) using the chi-squared automatic interaction detection (CHAID) technique as a growth method. The statistical significance level for splitting nodes and merging categories was $P<0.05$, significance values were corrected by the Bonferroni method and the maximum number of iterations was 100.

The level of statistical significance was fixed in all the contrasts for an alpha error below 5%, and the confidence intervals were calculated with 95% level of confidence.

Results

Prevalence of MetS and anthropometric predictor variables

Of the 636 workers, 432 were men (67.9%). The overall mean age was 45.1 ± 8.8 years (95% CI 44.4–45.9 years). A total of 95 workers had MetS, with an overall prevalence of 14.9% (95% CI 12.3–17.9). The prevalence obtained in men was 19.4% and in women it was 5.4% (OR 4.2; $P<0.001$).

Table 1 shows the characteristics of the study sample, the results according to the independent variables (prevalence and means) for the groups with and without MetS and finally a crude and adjusted logistic regression analysis.

The variables of personal details and health habits, such as age (higher average age), gender (male), level of education (primary education) and physical activity (sedentary/light), produced a higher prevalence of MetS ($P<0.001$).

With regard to the anthropometric variables, in the univariate logistic regression analysis they all showed an association with MetS ($P<0.001$).

Nevertheless, when the relationship of these variables with MetS was studied after adjusting for age, gender, level of education and physical activity, only WtHR, BFP, BMI and DBP showed a link with MetS (see Table 1).

Figure 1 shows the ROC curves, AUC, cutoff points, sensitivity, specificity and Youden index for each anthropometric variable. WtHR achieved an AUC of 91%, and with a cutoff value of 0.55, sensitivity and specificity were 90.4% and 81.5%, respectively. WC produced an AUC of 90%, a cutoff point of 94.75 cm, 84.2% sensitivity and 79.8% specificity.

Designing the decision tree to detect MetS based on anthropometric variables (non-invasive method)

Based on the significant anthropometric variables from the crude and adjusted multiple logistic regression (Table 1), three predictive models of MetS have been compared:

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Table 1. Characteristics of the sample by MetS and (crude and adjusted) logistic regression.

Variable		Total (*N*=636)	Presence of MetS (*N*=95)	Absence of MetS (*N*=541)	OR crude CI (95%)	*P* value	OR adjusted[a] CI (95%)	*P* value
Age (years)		45.1 ± 8.8	51.9 ± 7.9	43.9 ± 8.4	1.13 (1.1–1.16)	<0.001		
Gender								
Female		204 (32.1%)	11 (5.4%)	193 (94.6%)	1			
Male		432 (67.9%)	84 (19.4%)	348 (80.6%)	4.2 (2.2–8.5)	<0.001		
Education level								
Primary		120 (18.9%)	39 (32.5%)	81 (67.5%)	1			
Secondary		285 (44.8%)	34 (11.9%)	251 (88.1%)	0.3 (0.2–0.5)	<0.001		
University		231 (36.3%)	22 (9.5%)	209 (90.5%)	0.2 (0.1–0.4)	<0.001		
Smoking								
Non-smoker		454 (71.4%)	65 (14.3%)	389 (85.7%)	1			
Smoker		182 (28.6%)	30 (16.5%)	152 (83.5%)	1.2 (0.7 – 1.9)	NS		
Alcohol consumption								
Low		282 (44.4%)	35 (12.4%)	247 (87.6%)	1			
Medium–high		354 (55.6%)	60 (16.9%)	294 (83.1%)	1.4 (0.9–2.3)	NS		
Physical activity								
Sedentary/light		198 (31.1%)	42 (21.2%)	156 (78.8%)	1			
Moderate/high		438 (68.9%)	53 (12.1%)	385 (90.3%)	0.5 (0.3–0.8)	<0.05		
Anthropometric variables	**WC (cm)**	87.8 ± 12.2	102.7 ± 10	85.1 ± 10.6	1.2 (1.1–1.24)	<0.001		
	WHR (cm)[b]	0.88 ± 0.09	0.96 ± 0.07	0.86 ± 0.08	18.3 (9.5–35.2)	<0.001		
	WtHR[b]	0.52 ± 0.07	0.61 ± 0.06	0.5 ± 0.06	23.3 (12.6–43.2)	<0.001	7.9 (2.7–23.1)	<0.001
	BFP (%)	29.1 ± 6.5	34.9 ± 5.6	28.1 ± 6.2	1.2 (1.1–1.24)	<0.001	1.4 (1.1–1.7)	<0.01
	BMI (kg/m²)	26.5 ± 4.1	31.5 ± 4.1	25.6 ± 3.5	1.5 (1.4–1.6)	<0.001	0.7 (0.6–0.9)	<0.01
	SBP (mmHg)	118.7 ± 15.1	132.7 ± 12.9	116.2 ± 14.2	1.08 (1.06–1.1)	<0.001		
	DBP (mmHg)	76.1 ± 9.1	85.7 ± 8.3	74.4 ± 9	1.15 (1.1–1.2)	<0.001	1.1 (1–1.14)	<0.001
Glucose mg/dl		96.7 ± 19.4	116.2 ± 29.8	93.3 ± 14.4	1.1 (1.07–1.13)	<0.001		
Cholesterol-HDL mg/dl		56.6 ± 14.6	48.1 ± 12.3	58.1 ± 14.5	0.93 (0.91–0.96)	<0.001		
Triglycerides[c]		99 (66)	174 (106)	92.5 (54)	1.01 (1.01–1.02)	<0.001		

MetS: metabolic syndrome; CI: confidence interval; WC: waist circumference; WHR: waist–hip ratio; WtHR: waist–height ratio; BFP: body fat percentage (Deurenberg formula); BMI: body mass index; SBP: systolic blood pressure; DBP: diastolic blood pressure; HDL: high-density lipoprotein.
[a]Multiple logistic regression for anthropometric variables, adjusted for age, gender, level of education and physical activity.
[b]WtHR and WHR: transformed as naperian logarithm only for logistic regression analysis.
[c]Median and interquartile range.

- Model 1. Produced with significant anthropometric variables and expressed quantitatively (in intervals): WtHR, BFP, BMI and DBP.
- Model 2. Produced with the same variables, but expressed in a qualitative dichotomous way (recoded according to whether its value is higher or lower than the cutoff point mentioned in Figure 1): WtHR (0.55), BFP (30.5%), BMI (28.5 kg/m^2), hypertension (⩾128/85 mmHg).
- Model 3. Based on the same variables, expressed in a qualitative dichotomous way, too; but recoded according to whether its value is higher or lower than the next cutoff values: WtHR (0.50), BMI (30 kg/m2), hypertension (⩾140/90 mmHg).

After studying the models with the logistic regression analysis, we found that significant variables that retain their predictive value in model 1 are BMI, BFP, WtHR and DBP; while for model 2, they are BFP, WtHR and hypertension; while for model 3, they were WtHR, hypertension and BMI (Table 2).

Table 3 shows the results of the indicators (sensitivity, specificity and validity index) for each model. Models 1, 2 and 3 show a sensitivity of 58.9%, 59.6% and 35.8%, respectively. There are not significant differences between model 1 and model 2. However, we could find them between models 2 and 3.

Next, a clinical decision tree for the early detection of MetS was developed. As no significant differences between models 1 and 2 were found, model 2 was chosen (use of qualitative variables) for its greater simplicity and versatility for clinical management in medical and nursing consultation. Various decision trees were produced with different modifications in the growth criteria (minimum number of subjects for parental and child nodes), as well as positioning each of the independent variables as first input. Of all the trees obtained, the one that showed the best predictive capacity met the following criteria: no independent variable positioned first, minimum number of subjects in parent node (100) and minimum number of subjects in child node (50).

Figure 2 shows the decision tree (classification algorithm) with the best predictive capacity: sensitivity (77.9%),

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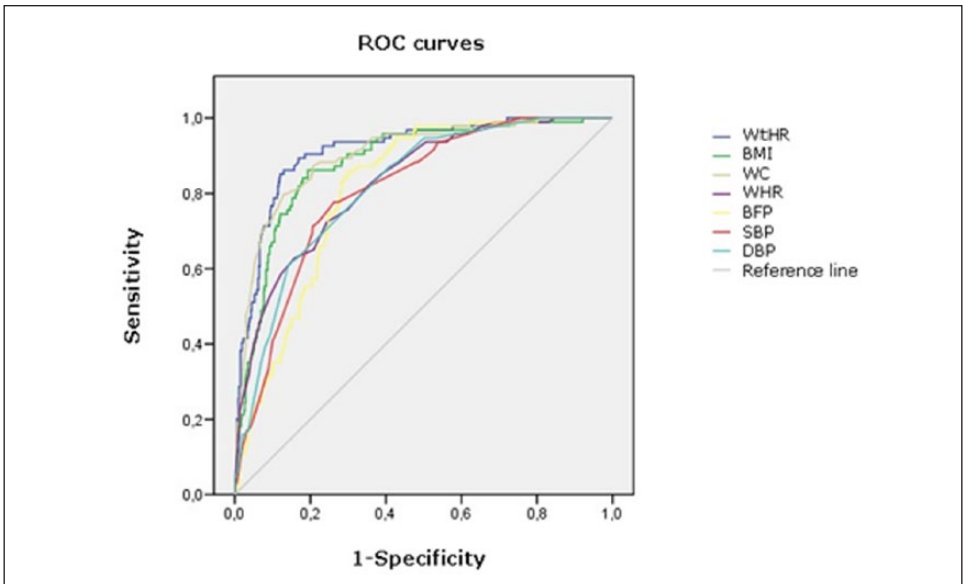

Variable	AUC	p	95% CI	Cut-off point	S	SP	J
WtHR	0.91	<0.001	0.88–0.94	0.55	90.4%	81.5%	0.72
BMI	0.88	<0.001	0.85 - 0.92	28.5 Kg/m²	83.2%	82.3%	0.66
WC	0.90	<0.001	0.8 –0.94	94.75 cm	84.2%	79.8%	0.64
WHR	0.83	<0.001	0.79–0.87	0.9	81.9%	64.5%	0.46
BFP	0.81	<0.001	0.78–0.85	30.5%	81.9%	71.7%	0.54
SBP	0,81	<0,001	0,77–0,85	128 mm Hg	72,6%	77,8%	0,50
DBP	0,82	<0,001	0,78-0,86	85 mm Hg	63,2%	86%	0,48

S: Sensitivity SP: Specificity J: Youden index

Figure 1. ROC curves, AUC and cutoff points for the anthropometric variables predicting MetS (*N*=636).
ROC: receiver operator characteristic; AUC: area under the curve; MetS: metabolic syndrome; WtHR: waist–height ratio; BMI: body mass index; WC: waist circumference: WHR: waist–hip ratio; BFP; body fat percentage; SBP: systolic blood pressure; DBP: diastolic blood pressure.

specificity (91.5%) and index validity of the model (89.5%). The variable with the greatest association with MetS was WtHR ($\chi^2 = 197.4$), which was used by the model to generate the first two parent nodes. Each of these branched into two child nodes from the hypertension variable with a chi-squared value of 25.4 and 34 for each node, respectively.

According to this model for the early prediction of MetS, workers with WtHR ⩾0.55 (regardless of gender) and BP ⩾128/85 mmHg had a 61.7% probability of developing MetS.

Validation of the new method of early detection of MetS: diagnostic test accuracy study

To check the validity and safety of the proposed model, a diagnostic test accuracy study was carried out, and the method was used with a new sample of workers. These were selected randomly and stratified by age and gender, with a total of 550 new workers, with a mean age of 44.8 ± 8.3 years, of which 358 were men (65.1%), without significant differences found between both work populations. As a reference standard test for the diagnostic contrast, the NCEP ATP III definition guide was used.

Table 4 shows the diagnostic criteria and the probabilities of developing MetS of the new method being validated. It can be seen that, according to the two variables in the method (WtHR–hypertension), four different situations can arise with a different probability of suffering from MetS. This method of screening considers it to be a 'case' of MetS when workers meet both positive criteria, that is, WtHR ⩾0.55 (WtHR=1) and BP ⩾128/85 mmHg (hypertension=1); and they therefore have a probability of developing MetS of over 60%.

With regard to the validation of the method for the early detection of MetS, 83 out of the 550 workers were diagnosed as having MetS according to the NCEP ATP III. The proposed new method identified 76 of the 83 subjects with MetS and 447 of the 467 subjects without MetS, thus

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Table 2. Multivariate analysis and adjusted logistic regression for models 1, 2 and 3.

	Model 1 quantitative variables			Model 2 qualitative variables			Model 3 qualitative variables		
Variable	Coeff.	OR CI (95%)	*P* value	Coeff.	OR CI (95%)	*P* value	Coeff.	OR CI (95%)	*P* value
BMI	−0.3	0.7 (0.6–0.9)	<0.05	–	–	NS	2.04	7.7 (4.4–13.3)	<0.001
BFP	0.34	1.4 (1.1–1.7)	<0.05	1.9	7 (3.4–14.6)	<0.001	–	–	–
DBP	0.09	1.1 (1–1.14)	<0.001	–	–	–	–	–	–
WtHR[a]	2.06	7.9 (2.7–23.1)	<0.001	2	7.4 (3.4–16.4)	<0.001	2.4	10.6 (3.2–35.4)	<0.001
Hypertension	_	_	_	2.2	9.1 (4.4–18.7)	<0.001	0.92	2.5 (1.4–4.4)	<0.05

BMI: body mass index; BFP: body fat percentage (Deurenberg formula); DBP: diastolic blood pressure; WtHR: waist–height ratio; OR: odds ratio; CI: confidence interval.
Hypertension (if blood pressure ⩾128/85 mmHg).
[a]WtHR: values are transformed as naperian logarithm in model 1.

Table 3. Sensitivity, specificity and validity index for predictive models of MetS.

Indicator	Model 1 quantitative variables	Model 2 qualitative variables	Model 3 qualitative variables	*P* value[a]	*P* value[b]
Sensitivity	58.9%	59.6%	35.8%	NS	<0.05
Specificity	97.6%	95.5%	97%	NS	NS
Validity index	91.8%	90.2%	87.9%	NS	NS
R^2 Nagelkerke	0.55	0.58	0.43	NS	<0.05
R^2 Cox–Snell	0.32	0.33	0.24	NS	<0.05
Hosmer–Lemeshow (*P* value)	0.91	0.9	0.7	NS	<0.05

[a]Statistical significance between models 1 and 2.
[b]Statistical significance between models 2 and 3.
MetS: metabolic syndrome.

achieving a sensitivity of 91.6% and a specificity of 95.7%, with a validity index of 94.2%, kappa clinical concordance index of 0.82 and Youden's index of 0,87 (see Table 5).[15,16]

Discussion

We have proposed and validated a method for the early detection of MetS in the working population, based on a purely anthropometric metabolic phenotype, and defined by WtHR and hypertension.

The overall prevalence of MetS was 14.9%, similar to that found in other studies in a Spanish working population. Thus, the MESYAS register (n=7256 employees) produced a prevalence of 10.2%;[17] León obtained a prevalence of 12% in a sample of 18,774 workers;[18] and finally, Tauler et al. obtained a prevalence of 12.4% from a study of 43,255 workers.[19] On the other hand, other European working populations have shown similar prevalence rates. Torres Felipe-de-Melo et al.[20] reported a prevalence of 15% in 1387 administrative workers from the oil industry in Portugal; Schaller et al.[21] found a prevalence of 11.7% in a sample of 27,359 workers from the automobile industry of Germany; and Thabit et al.[22] found a prevalence of 21% in 986 Irish construction workers.

With regard to the predictor variables, the univariate analysis showed a strong association between all the anthropometric indices and MetS. Of these, those that had a greater predictive ability (measured by the AUC in ROC curves) were: WtHR (0.91), WC (0.9) and BMI (0.88). These results have produced higher values than those reported by Bellido et al.[23] in a population of 3316 Spanish patients, who obtained an AUC value for WtHR of 0.729, WC (0.724) and BMI (0.68).

The cutoff values for the anthropometric indicators are specific to a population group (ethnicity, age and gender stratification, and so on).[10–14,19,24,25] In our study, the WtHR obtained 90.4% sensitivity in predicting MetS for a cutoff value of 0.55; WC obtained 84.2% sensitivity with a cutoff value of 94.75 cm; and finally, BMI, with a cutoff value of 28.5 kg/m^2, obtained a sensitivity of 83.2%. Bennasar-Veny et al., in a sample of 50,254 Spanish workers, obtained a BMI value of 27.16 kg/m^2 and 78% sensitivity.[26]

Three predictive models were compared to choose which one could be used in a clinical decision tree. Model 3 was ruled out because it showed lower sensitivity and coefficients of determination (Nagelkerke and Cox–Snell). As no significant differences between models 1 and 2 were found, the qualitative model was preferred, because it proved to be easier to apply and more versatile in clinical

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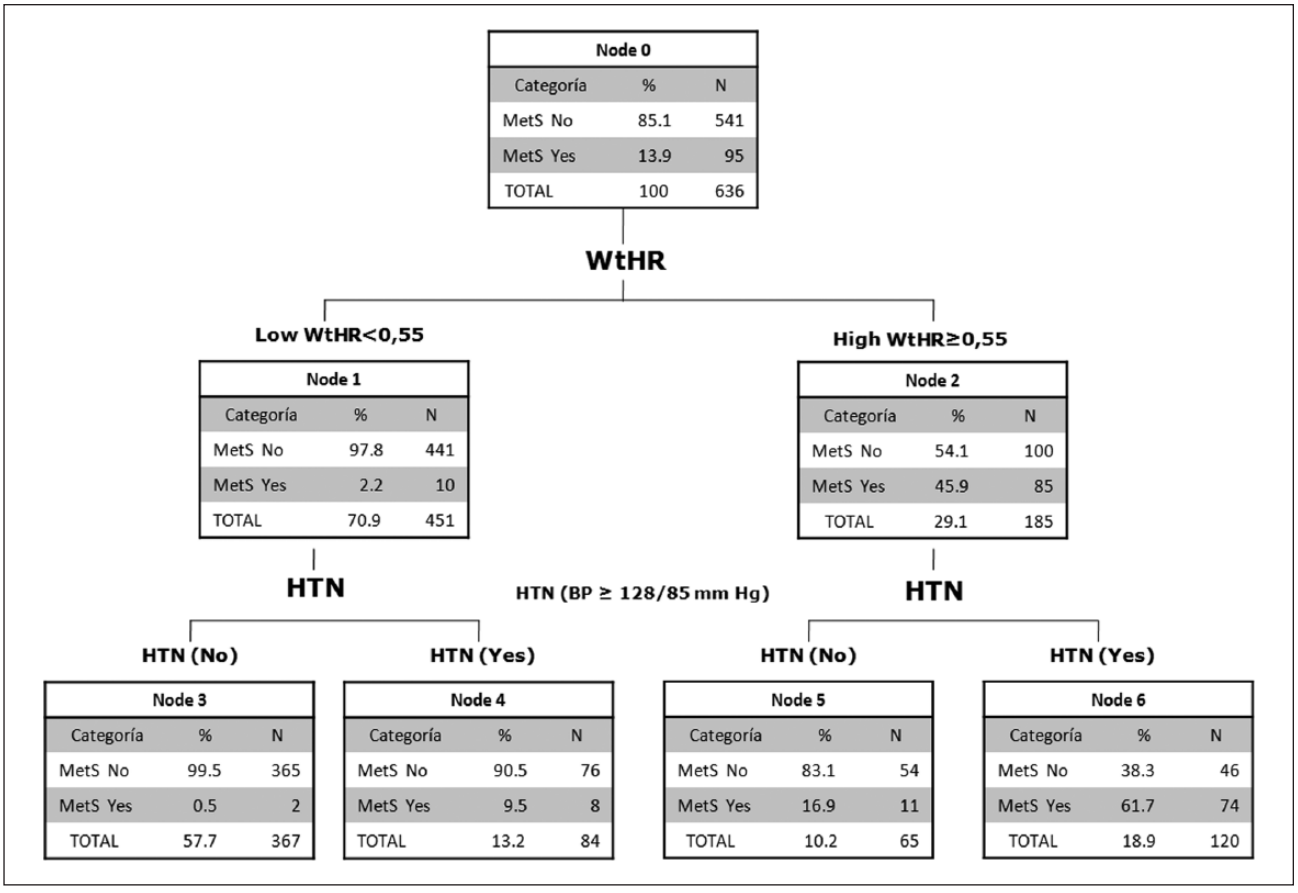

Figure 2. Clinical decision tree for early detection of MetS (non-invasive method). Qualitative anthropometric variables (WtHR/HTN). MetS criteria according to NCEP ATP III.
MetS: metabolic syndrome; WtHR: waist–height ratio; HTN: hypertension; BP: blood pressure; NCEP ATP III; National Cholesterol Education Program Adult Treatment Panel III.

Table 4. MetS classification criteria for the new method of early detection. Probability of developing MetS according to decision tree.

WtHR	Hypertension	*P* value (MetS +)	Classification by the model MetS (Yes/No)
0	0	0.5%	No
0	1	9.5%	No
1	0	16.9%	No
1	**1**	**61.7%**	**Yes**

WtHR = 0 if WtHR <0.55 WtHR = 1 if WtHR ⩾0.55.
Hypertension = 0 if BP <128/85 mmHg hypertension = 1 if BP ⩾128/85 mmHg.
MetS: metabolic syndrome; WtHR: waist–height ratio; BP: blood pressure.

settings. The clinical decision tree configured through the CHAID methodology selected WtHR and hypertension as the best predictors for the occurrence of MetS. With these two anthropometric variables, 77.9% of all cases of MetS existing in the study sample could be detected.

Table 5. Main indicators in model for early detection of MetS in the diagnostic test accuracy study.

Indicator	CI value (95%)
Prevalence	15.1% (12.2–18.2)
Sensitivity	91.6% (93.8–97.7)
Specificity	95.7% (93.2–97)
PPV	79.2% (70.5–87.8)
NPV	98.5% (97.2–99.7)
LH+	21.4 (13.9–33)
LH–	0.09 (0.04–0.18)
Validity index	94.2% (89.9–98.5)
Youden`s index	0.87 (0.8–0.94)
Kappa index	0.82 (0.75–0.88)

MetS: metabolic syndrome; PPV: positive predictive value; NPV: negative predictive value; LH+: likelihood ratio positive; LH–: likelihood ratio negative.
Youden's index (significance).[15] Range 0 to 1. For a test with poor diagnostic accuracy, Youden's index equals 0, and in a perfect test Youden's index equals 1.
Kappa index (significance and magnitude):[16] values <0 as indicating no agreement and 0–0.20 as slight, 0.21–0.40 as fair, 0.41–0.60 as moderate, 0.61–0.80 as substantial and 0.81–1 as almost perfect agreement.

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The study reveals that WtHR was the variable with the greatest predictive ability for univariate and multivariate analysis. With a cutoff value of 0.55, it is able to predict 49.5% of cases of MetS, which is much higher than the rate reported by Bellido et al. (20%).[23] Ashwell et al., in a systematic review of 31 studies (26 cross-sectional and five longitudinal), concluded that WtHR was the best anthropometric indicator for the prediction of MetS.[27]

With regard to the gender analysis, it is important to indicate two facts. Firstly, the baseline is a masculine working population (67.9% men vs. 32.1% women). Secondly, most of the referenced studies[17–22] have shown evidence of a lower prevalence of MetS in women than in men. Both aspects are a serious drawback for stratified or multivariate statistical analysis, because of the 96 cases of MetS, only 11 cases were women (prevalence of 5.4%).

However, the results obtained in the whole sample, both for the area under the ROC curve of the variable WtHR (0.91) and for the clinical decision tree (high sensitivity and specificity) were very satisfactory. This could be because WtHR corrects by gender, so in our general and working population, the height of men is higher than women, and this implies that WC should be higher in men than women to obtain the same cutoff values.

This does not preclude future investigations in which we should increase the sample size in order to achieve a greater number of working women, who would allow us to obtain specific cutoff points according to gender.

If the worker has a low WtHR (<0.55) and no hypertension (BP <128/85 mmHg), the probability of suffering from MetS is very low (0.5%), and therefore it would not be advisable to carry out a blood test to diagnose MetS.

In addition, if the worker only has hypertension (BP ⩾128/85 mmHg), the probability of developing MetS is also very low (<10%), and so, again, it would not be advisable to carry out a blood test to confirm or rule out a diagnosis of MetS.

However, when only high WtHR (⩾0.55) occurs, the likelihood of MetS is moderate (16.9%) and the coexistence of other cardiovascular risk factors should be assessed, which justifies carrying out blood tests.

Finally, the occurrence of both predictors together (high WtHR and hypertension) indicates a high probability of having MetS (61.7%). In these cases, blood tests are needed to confirm the diagnosis of MetS and to check the metabolic status of the workers.

Different research has put forward MetS prediction models based on non-invasive methods. De Kroon et al. proposed a decision tree using three anthropometric variables (BMI, WC and BP) to identify MetS in young adults.[28] The risk of having MetS was high when WC was high and hypertension was 64.3% and 66.7% for obese and non-obese subjects, respectively. Miller et al. also used a decision tree to detect MetS in a young adult population, but they included, simultaneously, anthropometric and analytical variables (WC, triglycerides, HDL, glucose).[29] In addition, other studies have relied on creating artificial neural networks and Markov models to obtain predictive mathematical patterns of MetS in which both anthropometric and analytical variables are included.[30,31]

Finally, the new method was validated in a new population of workers using the NCEP ATP III criteria as a reference test. The indicators obtained show a high predictive capacity and screening validity for detecting MetS in a working population (aged 18–65 years), making it an effective tool in the prevention of type 2 DM and CVD in a (healthy) working population. The validity of the proposed method produced a Youden index of 0.87 (sensitivity 91.6% and specificity 95.7%) and a validity index or diagnostic capacity of 94.2%. With regard to the reliability of the method, the positive predictive values and negative predictive values were 79.2% and 98.5%, respectively.

Conclusions

The new method proposed for the early detection of MetS has several advantages over other methods of screening and diagnosis of MetS:

1. The method employs only two anthropometric variables (WtHR/hypertension), which are easily measurable in any context – health (primary care, hospital care, occupational health, etc.) or otherwise (education, military facilities, prisons, nursing homes, etc.).
2. The proposed method reduces the frequency of the use of blood tests only for those cases requiring confirmation.
3. It is economic and versatile, and easy to interpret very clearly using a decision tree.
4. It introduces WtHR as a component of MetS, which is not included in any other proposal for MetS diagnosis either with analytical or non-analytical methods, but which is related to abdominal obesity and best predicts the onset of MetS.
5. The method provides pathways with different probabilities of the occurrence of MetS, because it assigns each covariate a different 'specific weight' to aid discrimination. This aspect is not included in other methods (NCEP ATP III, International Diabetes Federation, World Health Organization, etc.).
6. The indicators of validity, safety and the clinical concordance of this method with the NCEP ATP III criteria make it ideal for use as a MetS screening test in a healthy population.

Research limitations

The low prevalence of MetS in women means that there is a low incidence of MetS in this group, which results in less statistical power in the logistic regression models. It would therefore be advisable to increase the number of working

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women in the sample, thus increasing the number of cases of MetS, in order to investigate whether there are differences in cutoffs according to gender.

The CHAID methodology used to make the decision tree recommends that sample sizes are large in order to optimise statistical significance. In the sample used in this study (n=636), the criteria for forming the parent and child nodes were moderate (100 and 50, respectively).

In the light of these two limitations, future research should use considerably larger samples in order to contrast the proposed method of early detection with greater reliability.

Implications for practice

- We have developed a new method for the screening of MetS using non-invasive techniques and based on just two anthropometric variables: WtHR (⩾0.55) and BP (⩾128/85 mmHg). This method reduces the use of blood tests for those cases in which confirmation is required.
- The new method has been proposed as a clinical decision tree composed of these two predictors (WtHR and BP). It is a versatile, economic and easily measurable method in any healthcare setting.
- This new method has shown an elevated diagnostic accuracy, with high sensitivity, specificity and clinic concordance with the reference test (NCEP ATP III).

Conflict of interest

None declared.

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References

1. Zimmet P, Alberti G and Shaw JE. Editorial: Mainstreaming the metabolic syndrome: a definitive definition. *Med J Aust* 2005; 183: 175–176.
2. Salminen M, Kuoppameaki M, Vahlberg T, et al. Metabolic syndrome defined by modified International Diabetes Federation criteria and type 2 diabetes mellitus risk: a 9-year follow-up among the aged in Finland. *Diab Vasc Dis Res* 2013; 10: 11–16. doi: 10.1177/1479164112442077
3. O'Donnell DJ and Elosua R. Factores de riesgo cardiovascular. Perspectivas derivadas del Framingham Heart Study. *Rev Esp Cardiol* 2008; 61: 299–310.
4. Isomaa B, Almgren P, Tuomi T, et al. Cardiovascular morbidity and mortality associated with the metabolic syndrome. *Diabetes Care* 2001; 24: 683–689.
5. Fernández-Berges D, Consuegra-Sánchez L, Peñafiel J, et al. Perfil metabólico-inflamatorio en la transición obesidad, síndrome metabólico y diabetes mellitus en población mediterránea. Estudio DARIOS Inflamatorio. *Rev Esp Cardiol* 2014; 67(8): 624–631.
6. Meng W, Zhang C, Zhang Q, et al. Association between Leukocyte and Metabolic Syndrome in Urban Han Chinese: a longitudinal cohort study. *PlosOne* 2012; 7: e49875.
7. González-Chávez A, Elizondo-Argueta S and Amancio-Chassin O. Relación entre síndrome metabólico e hiperuricemia en población aparentemente sana. *Rev Med Hosp Gen Méx* 2011; 74(3): 132–137.
8. Lee MJ, Jung CH, Kang YM, et al. Serum bilirubin as a predictor of incident metabolic syndrome: a 4-year retrospective longitudinal study of 6205 initially healthy Korean men. *Metab Diabetes* 2014; 40(4): 305–309. doi: 10.1016/j.diabet.2014.04.006
9. Olza J, Aguilera CM, Gil-Campos M, et al. A continuous metabolic syndrome score is associated with specific biomarkers of inflammation and CVD risk in prepubertal children. *Ann Nutr Metab* 2015; 66(2–3): 72–79. doi: 10.1159/000369981
10. Bener A, Yousafzai MT, Darwish S, et al. Obesity index that better predict metabolic syndrome: body mass index, waist circumference, waist hip ratio, or waist height ratio. *J Obes* 2013; 23: 1–9.
11. Sagun G, Oguz A, Karagoz E, et al. Application of alternative anthropometric measurements to predict metabolic syndrome. *Clinics* 2014; 69(5): 347–353.
12. Liu P, Ma F, Lou H, et al. The utility of fat mass index vs. body mass index and percentage of body fat in the screening of metabolic syndrome. *BMC Public Health* 2013; 13: 629.
13. Callaway CW, Chumlea WC, Bouchard C, et al. Circumferences. In: Lohman TG, Roche AF and Martorell R (eds) *Anthropometric Standardization Reference Manual*. Campaign: Human Kinetics Books, 1991, pp. 44–45.
14. González A. La medición correcta de la presión arterial. In: *Manual de hipertensión arterial en la práctica clínica de atención primaria*. Grupo de hipertensión arterial. Sociedad Andaluza de Medicina Familiar, 2006, pp. 35–41.
15. Feinstein AR. Clinical biostatistics. XXXI. On the sensitivity, specificity and discrimination of diagnostic tests. *Clin Pharmacol Ther* 1975; 17: 104–116.
16. Cohen J. A coefficient of agreement for nominal scales. *Educational and Psychological Measurement* 1960; 20: 37–46.
17. Alegría E, Cordero A, Laclaustra M, et al. Prevalencia del síndrome metabólico en población laboral española: registro MESYAS. *Rev Esp Cardiol* 2005; 58(7): 797–806.
18. León M. Síndrome metabólico en una muestra de población laboral española. Análisis transversal de prevalencia, forma de presentación y relación con la cardiopatía isquémica. Tesis doctoral. *Universidad de Zaragoza, Spain*, 2005.
19. Tauler P, Bennasar-Veny M, Morales-Asencio JM, et al. Prevalence of premorbid metabolic syndrome in Spanish adult workers using IDF and ATPIII diagnostic criteria: relationship with cardiovascular risk factors. *PlosOne* 2014; 9(2): e89281. doi:10.1371/journal.pone.0089281
20. Torres Felipe-de-Melo ER, da Silva RC, Assis AM, et al. Fatores associados à síndrome metabólica em trabalhadores administrativos de uma indústria de petróleo. *Ciência & Saúde Coletiva* 2011; 16(8): 3443–3452.

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21. Schaller N, Blume K, Hanssen H, et al. Prevalence of the metabolic syndrome and its risk factors: results of a large work-site health assessment. *Dtsch Med Wochenschr* 2014; 139(45): 2279–2284. doi: 10.1055/s-0034–1387352
22. Thabit H, Burns N, Shah S, et al. Prevalence and predictors of diabetes and cardiometabolic risk among construction workers in Ireland: the Construction Workers Health Trust screening study. *Diab Vasc Dis Res* 2013; 10(4): 337–345. doi: 10.1177/1479164113479808
23. Bellido D, López M, Carreira J, et al. Índices antropométricos estimadores de la distribución adiposa abdominal y capacidad discriminante para el síndrome metabólico en población española. *Clin Invest Arterioscl* 2013; 25(3): 105–109.
24. Rajput R, Rajput M, Bairwa M, et al. Waist height ratio: a universal screening tool for prediction of metabolic syndrome in urban and rural population of Haryana. *Ind J Endocrinol Metab* 2014; 18: 394–399.
25. Sonmez A, Bayram F, Barcin C, et al. Waist circumference cutoff points to predict obesity, metabolic syndrome, and cardiovascular risk in Turkish adults. *Intl J Endocrinol* 2013; 1–7. doi: org/10.1155/2013/767202
26. Bennasar-Veny M, Lopez-Gonzalez AA, Tauler P, et al. Body adiposity index and cardiovascular health risk factors in Caucasians: a comparison with the body mass index and others. *PlosOne* 2013; 8(5): e63999. doi: 10.1371/journal.pone.0063999
27. Ashwell M, Gunn P and Gibson S. Waist-to-height ratio is a better screening tool than waist circumference and BMI for adult cardiometabolic risk factors: systematic review and meta-analysis. *Obesity Rev* 2012; 13: 275–286.
28. De Kroon M, Renders C, Kuipers E, et al. Identifying metabolic syndrome without blood tests in young adults – the Terneuzen Birth Cohort. *Eur J Public Health* 2008; 18(6): 656–660.
29. Miller B, Fridline M, Liu PY, et al. Use of CHAID decision trees to formulate pathways for the early detection of metabolic syndrome in young adults. *Computat Mathemat Methods Med* 2014: 1–7. doi: org/10.1155/2014/242717
30. Lin CC, Bai YM, Chen JY, et al. Easy and low-cost identification of metabolic syndrome in patients treated with second-generation antipsychotics: artificial neural network and logistic regression models. *J Clin Psychiatry* 2010; 71(3): 225–234. doi: 10.4088/JCP.08m04628yel
31. Hwang L-C, Bai C-H, You S-L, et al. Description and prediction of the development of metabolic syndrome: a longitudinal analysis using a Markov model approach. *PlosOne* 2013; 8(6): e67436. doi: 10.1371/journal.pone.0067436

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