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Original/*Síndrome metabólico*

Soluble and insoluble dietary fibre intake and risk factors for metabolic syndrome and cardiovascular disease in middle-aged adults: the AWHS cohort

Belén Moreno Franco[1,2], Montserrat León Latre[1], Eva María Andrés Esteban[3], José María Ordovás[4,5], José Antonio Casasnovas[1,2] and José Luis Peñalvo[4]

[1]Cardiovascular Prevention Unit, Instituto Aragonés de Ciencias de la Salud (I+CS), Zaragoza, Spain. [2]Department of Medicine, Psychiatry and Dermatology, University of Zaragoza, Zaragoza, Spain. [3]CIBER-ESP, Madrid, Spain. [4]Department of Epidemiology, Atherothrombosis and Cardiovascular Imaging, Centro Nacional de Investigaciones Cardiovasculares (CNIC), Madrid, Spain. [5]Jean Mayer USDA Human Nutrition Research Center on Aging, Tufts University, Boston, USA.

Abstract

Introduction: **The Westernization of the Mediterranean lifestyle has led to a modification of certain dietary habits such as a decrease in the consumption of dietary fibre-rich foods. The impact of these changes on cardiovascular diseases (CVD) has been studied over the last few years and the effect of the different sources of fibre on cardiovascular risk parameters and coronary heart disease (CHD) continues to create controversy.**

Objective: **To evaluate the association between the source of dietary fibre and the prevalence of metabolic syndrome (MetS) and other cardiovascular risk factors in a Spanish working population.**

Subjects and methods: **The study was carried out in a sample of 1592 Spanish workers free of CVD (40-55 years old) within the Aragon Workers' Health Study (AWHS) cohort. Sociodemographic, anthropometric, clinical and biochemical data were collected. Fibre intake was assessed by means of a validated 136-items semiquantitative food-frequency questionnaire. MetS was defined by using the modified National Cholesterol Education Programme - Adult Treatment Panel III (NCEP- ATP III) definition.**

Results: **After adjusting for possible confounding factors, we found an inverse association between insoluble fibre intake and systolic and diastolic blood pressure, total cholesterol, triglycerides, apolipoprotein B100 and ratio TG/HDL. Soluble fibre was inversely associated with triglycerides and apolipoprotein B100. Furthermore, prevalence of MetS was found to be lower (OR 0.62, 95% CI: 0.40-0.96) in those participants in the highest quartile of insoluble fibre intake.**

Correspondence: Belén Moreno-Franco.
Unidad de Prevención Cardiovascular.
Instituto Aragonés de Ciencias de la Salud (IACS).
Hospital Universitario Miguel Servet. C/Isabel La Católica 1-3.
50009 Zaragoza, España.
E-mail: bmorenof.iacs@aragon.es

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INGESTA DE FIBRA SOLUBLE E INSOLUBLE Y FACTORES DE RIESGO DE SÍNDROME METABÓLICO Y ENFERMEDAD CARDIOVASCULAR EN ADULTOS DE MEDIANA EDAD: LA COHORTE AWHS

Resumen

Introducción: **La occidentalización del estilo de vida mediterráneo ha dado lugar a una modificación de ciertos hábitos dietéticos, tales como una disminución en el consumo de alimentos ricos en fibra dietética. El impacto de estos cambios sobre las enfermedades cardiovasculares (ECV) se ha estudiado en los últimos años y el efecto de las diferentes fuentes de fibra en los parámetros de riesgo cardiovascular y en la enfermedad coronaria sigue creando controversia.**

Objetivo: **Evaluar la asociación entre la fuente de fibra dietética y la prevalencia de síndrome metabólico (SM) y otros factores de riesgo cardiovascular en una población laboral española.**

Sujetos y métodos: **El estudio se llevó a cabo en una muestra de 1592 trabajadores españoles libres de ECV (40-55 años) pertenecientes a la cohorte del Estudio de la Salud de los Trabajadores de Aragón (AWHS). Se recogieron datos sociodemográficos, antropométricos, clínicos y bioquímicos. La ingesta de fibra se evaluó por medio de un cuestionario semicuantitativo de frecuencia de consumo de alimentos de 136-items previamente validado. Para la definición de SM se siguieron los criterios del Programa Nacional de Educación del Colesterol en el marco del III Panel de Tratamiento de Adultos (NCEP-ATP III).**

Resultados: **Se encontró una asociación inversa entre el consumo de fibra insoluble y la presión arterial sistólica y diastólica, colesterol total, triglicéridos, apolipoproteína B100 y la relación TG/HDL, tras ajustar por posibles factores de confusión. Así mismo, la fibra soluble se asoció inversamente con triglicéridos y apolipoproteína B100. Además, se encontró una menor prevalencia de SM (OR 0.62, IC del 95%: 0.40 a 0.96) en aquellos participantes en el cuartil más alto de consumo de fibra insoluble.**

Conclusion: **A higher intake of insoluble fibre could play an important role in the control and management of hypertension, lipid profile and MetS.**

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Key words: *Dietary fibre*. *Metabolic syndrome*. *Cardiovascular disease*.

Abbreviations

CVD: Cardiovascular disease.
CHD: Coronary heart disease.
MetS: Metabolic syndrome.
AWHS: Aragon Workers´ Health Study.
SFFQ: Semiquantitative food-frequency questionnaire.
CRP: C reactive protein.
HbA1c: Glycated hemoglobin.
MET: Metabolic equivalent.
NCEP-ATP III: National Cholesterol Education Programme - Adult Treatment Panel III.
IQR: Interquartile Range.

Introduction

The Westernization of the Mediterranean countries, has led to a decrease in the consumption of traditional Mediterranean foods concurrent with an increase in the prevalence of some chronic disorders such as cancer, obesity and cardiovascular diseases (CVD)[1]. Defined as a plant-derived material that is resistant to digestion by human alimentary enzymes[2], dietary fibre consists mainly of polysaccharides and lignin, but also includes other vegetable substances such as waxes and cutin. Based on their physical properties of solubility, dietary fibre can be classified in two major groups: insoluble fibre, mainly present in wheat bran and whole bread and grains, and soluble fibre that is abundant in cereals such as oats and barley, legumes and most fruits and vegetables.

The role of dietary fibre-rich diets and the different dietary fibre sources in the prevention of CVD has been under investigation over the last few decades[3]. Dietary fibre seems to be related to a hypocholesterolemic effect and possibly also to the modulation of metabolic routes related to blood pressure[4], blood glucose levels[4], platelet aggregation[5], endothelial damage[5] or inflammation[6]. An insufficient intake of dietary fibre is also a known risk factor for the development of coronary heart disease (CHD)[7] and the source of dietary fibre is an important factor in the modulation of this risk. Observational studies have found stronger associations for cereal fibre (mostly insoluble fibre) than for fibre deriving from fruits or vegetables in terms of lower incidence of CHD[8,9].

This study aims to investigate the association between the intake of different types of dietary fibre and the prevalence of metabolic syndrome (MetS) and other metabolic-related conditions as intermediate markers of CVD in a cohort of Spanish workers.

Conclusión: **Una mayor ingesta de fibra insoluble puede desempeñar un papel importante en el control y manejo de la hipertensión, el perfil lipídico y el SM.**

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Palabras clave: *Fibra dietética*. *Síndrome metabólico*. *Enfermedad cardiovascular.*

Subjects and methods

Study participants

The Aragon Workers' Health Study (AWHS) is a longitudinal prospective cohort study based on the annual health exams of voluntary workers of the General Motors Spain automobile assembly plant located in Figueruelas (Zaragoza, Spain) with the aim to characterize the factors associated with metabolic abnormalities and subclinical atherosclerosis in a middle aged population free of clinical CVD. A detailed description of the cohort assembly procedures, and variables and outcomes studied has been reported previously[10].

Each year, one random third of study participants 40 – 55 years of age at baseline are randomly selected for subclinical atherosclerosis imaging and for additional questionnaires of cardiovascular and lifestyle factors. The present cross-sectional analysis was carried out on a subsample of the first 1592 volunteers who complete the semiquantitave food frequency questionnaire (SFFQ). The AWHS was approved by the Central Institutional Review Board of Aragón, and all study participants provided written informed consent.

Anthropometric, clinical and biological data

Study participants provided a clinical history, including clinical events and hospitalizations over the past year, indicating the presence of personal or family history of early CVD, diagnosis of hypertension, diabetes or dyslipidemia, current medication use and smoking status (current, never and former), and undergo a physical exam, including anthropometry (height, weight, and waist circumference), blood pressure measurements and heart rate.

Each participant also provided a sample of blood after overnight fasting (>8 h) for laboratory analyses and biobanking. A battery of laboratory tests was performed annually in all workers at the laboratory of the Medical Services of General Motors Spain. Fasting serum glucose, triglycerides, total cholesterol and HDL cholesterol were measured by spectrophotometry (Chemical Analyzer ILAB 650, Instrumentation Laboratory), serum apolipoproteins A1 and B100, lipoprotein (a) and C-reactive protein (CRP) by kinetic nephelometry (Immunochemistry Analyzer IMMAGE 800, Beckman Coulter), and fasting serum insulin by immunoenzymatic chemiluminiscence (Access Immunoassay System,

Beckman Coulter). Whole blood glycated hemoglobin (HbA1c) was measured by reverse-phase cationic exchange chromatography and quantification by double wave-length colorimetry quantification (Analyzer ADAMS A1c HA-810, Arkray Factory). LDL cholesterol levels were calculated using the Friedewald equation when triglycerides levels were lower than 400 mg/dl.

Dietary assessment

Dietary habits were assessed by means of a semi-quantitative food-frequency questionnaire previously validated in Spain[11], capturing long-term intake during the preceding year, taking into account seasonal variations and differences between weekday and weekend patterns. The questionnaire is based on 136 food items, including questions about consumption of supplements and special diets tracking. For each food included in the questionnaire serving size is specified and offer the choice between nine frequencies of consumption, from "never or almost never" to "more than six times a day". Data derived from the questionnaire were subsequently converted into energy and nutrients according to two Spanish food composition tables[12,13].

Physical activity assessment

For physical activity assessment we used the Spanish validated version of the Nurses' Health Study and Health Professionals' Follow-up physical activity questionnaires[14]. Participants were asked about the time devoted to the practice of 17 different sports during the year preceding the date of the interview. It consists of 10 categories, from "never" to "more than 11 hours a week". Participants were also asked about the months a year in which each activity was performed. To compute the volume of activity performed for each participant, metabolic equivalents (METs) were assigned for each activity[15] and multiplied by the time the participant reported practicing each activity. From the sum of all activities we obtained a value of overall weekly METs-h.

Additional variables

Participants completed an additional questionnaire on sociodemographic characteristics including: date of birth, gender, education level, years in company, shift and type of work performed, marital status, number of children and number of people that integrate their family unit.

Metabolic syndrome definition

MetS was diagnosed when subjects meet at least 3 of the 5 following criteria: elevated waist circumference (waist circumference ≥ 102 cm for men and ≥ 88 for women), elevated triglycerides (≥ 150 mg/dl or being on drug treatment for increased triglycerides), reduced HDL cholesterol (< 40 mg/dl for men and < 50 mg/dl for women), elevated blood pressure (systolic blood pressure ≥ 130 mmHg and/or diastolic blood pressure ≥ 85 mmHg or being on antihypertensive drug treatment in a patient with a history of hypertension), and elevated fasting glucose (≥ 100 mg/dl or being on drug treatment for elevated glucose), according to the modified National Cholesterol Education Programme - Adult Treatment Panel III (NCEP-ATP III) definition[16].

Statistical methods

Median and Interquartile Range (IQR) were used to describe participant's characteristics. Differences in fibre consumption between groups were analysed by the nonparametric Mann Whitney U-test for gender and type of work and by Kruskal-Wallis H-test for age, level of studies completed, shift work, smoking status and physical activity. Multivariate analysis was performed using multivariate linear models. Dependent variables were each of the clinical variables described, and independent variables were intakes of both insoluble and soluble fibre. Results are presented as crude and adjusted models using age, gender, energy intake (kcal/day), physical activity (METs-h/week), smoking status, alcohol (g/week), and treatment for hypertension, hypercholesterolemia, and diabetes diagnosis as covariates. Logistic regression models were used for the analysis of the association between the intake of insoluble and soluble fibre and the prevalence of MetS and its components. The discriminatory power was assessed using the area under the ROC curve (receiver-operator characteristics) obtained by analysing the probability of the value predicted by the multivariate model. The results of the multivariable model were adjusted by age, gender, level of studies completed and type of work performed (Model A) and additionally adjusted for energy intake (kcal/day), physical activity (METs-h/week), smoking status and alcohol consumption (g/week) (Model B). All statistical analyses were conducted using STATA 9.0/SE (Stata Corp, College Station, Tex) and $p<0.05$ was considered statistically significant for all analysis.

Results

Total mean dietary fibre intake was 25.7 ± 8.1 g/day corresponding mainly (70.4%) to insoluble fibre. The most important food sources of insoluble fibre intake were dried fruits (30%), whole grain breakfast cereals (11%), white beans (9.2%), nuts (7.8%), whole-wheat bread (6.8%) and green peas (6.1%), whereas soluble fibre intake was determined by the consumption of mostly dried fruits (8.5%), walnuts (4.5%) and nuts (2.0%).

Table I
Intake (g/day) of insoluble and soluble dietary fibre according to participants' characteristics

		Total fibre		*Insoluble fibre*		*Soluble fibre*	
	N (%)	*Median (IQR)*	*P-value*	*Median (IQR)*	*P-value*	*Median (IQR)*	*P-value*
Age (years)[a]			0.545		0.432		0.627
40-45	211 (13.3)	24.5 (19.9-28.7)		16.9 (14.0-20.2)		7.4 (5.9-8.9)	
46-50	286 (18.0)	24.7 (19.9-30.2)		17.0 (13.6-21.0)		7.6 (6.0-9.3)	
51-55	1095 (68.7)	24.8 (20.4-29.9)		17.2 (14.4-21.0)		7.5 (6.1-9.0)	
Gender (%)[b]			0.649		0.933		0.103
Man	1514 (95.1)	24.8 (20.3-29.7)		17.1 (14.2-20.8)		7.5 (6.1-9.0)	
Woman	78 (4.9)	24.2 (19.9-31.1)		17.4 (14.0-21.8)		6.8 (5.8-9.1)	
Level of studies completed (%)[a]			0.495		0.502		0.192
Primary studies	795 (50.3)	24.6 (20.2-29.6)		17.1 (14.1-20.8)		7.4 (6.0-9.1)	
Secondary studies	182 (11.5)	24.7 (20.4-30.3)		17.1 (14.5-21.4)		7.6 (6.0-9.1)	
Professional training	513 (32.6)	25.1 (20.9-29.8)		17.4 (14.6-20.8)		7.5 (6.2-9.0)	
University studies	89 (5.6)	23.4 (18.6-28.6)		16.8 (12.8-20.8)		6.8 (5.4-8.4)	
Type of work (%)[b]			0.016		0.053		0.001
Hand worker	1355 (85.2)	24.9 (20.4-30.1)		17.2 (14.3-21.0)		7.6 (6.1-9.1)	
Office worker	235 (14.8)	23.7 (19.4-28.0)		16.9 (13.5-20.3)		6.9 (5.6-8.5)	
Shift work (%)[a]			0.035		0.162		<0001
Rotary Morning-Afternoon	979 (61.6)	24.8 (20.3-30.0)		17.1 (14.2-21.0)		7.6 (6.1-9.2)	
Rotary Morning-Afternoon-Night	317 (19.9)	25.2 (21.0-30.1)		17.6 (14.5-21.1)		7.7 (6.4-9.0)	
Day shift	167 (10.5)	23.3 (19.0-28.3)		16.8 (13.2-20.3)		6.8 (5.3-8.2)	
Night shift	127 (8.0)	24.2 (20.7-29.4)		17.2 (14.7-20.4)		7.2 (6.3-9.0)	
Physical activity (METs)[a]			0.003		0.014		<0.001
Light (<3 METs)	503 (31.6)	24.4 (20.1-29.2)		16.9 (14.1-20.6)		7.3 (6.0-8.8)	
Moderate (3-6 METs)	589 (37.0)	24.3 (19.8-29.4)		17.0 (14.0-20.6)		7.3 (5.8-8.9)	
Vigorous (>6METs)	500 (31.4)	25.6 (21.2-30.8)		17.7 (14.7-21.7)		7.8 (6.4-9.3)	
Smoking status[a]			0.108		0.102		0.205
Never	486 (32.9)	25.1 (20.6-30.3)		17.6 (14.3-21.4)		7.6 (6.1-9.1)	
Former	498 (33.8)	25.2 (20.8-29.7)		17.4 (14.6-21.0)		7.5 (6.3-9.0)	
Current	491 (33.3)	24.3 (19.8-29.5)		16.9 (13.9-20.4)		7.3 (5.9-8.9)	

[a]Kruskal-Wallis *H* test. [b]Mann-Whitney *U* test.

Table II

Crude and adjusted coefficients for anthropometric and biochemist variables of insoluble and soluble fibre intake, using linear regression models

	Insoluble fibre						*Soluble fibre*					
	Crude			*Adjusted*[a]			*Crude*			*Adjusted*[a]		
	β	*SE*	*P value*	β	*SE*	*P value*	β	*SE*	*P value*	β	*SE*	*P value*
Anthropometry and blood pressure												
BMI (Kg/m^2)	-0.038	0.015	0.012	-0.024	0.017	0.144	-0.092	0.041	0.023	-0.064	0.051	0.212
Waist circumference (cm)	-0.059	0.051	0.249	-0.029	0.056	0.605	-0.056	0.138	0.681	-0.052	0.170	0.757
Systolic blood pressure (mmHg)	-0.154	0.062	0.014	-0.150	0.070	0.032	-0.196	0.168	0.244	-0.227	0.211	0.282
Diastolic blood pressure (mmHg)	-0.092	0.041	0.026	-0.125	0.037	0.008	-0.050	0.111	0.653	-0.162	0.141	0.251
Plasma lipids												
Total cholesterol (mg/dl)	-0.284	0.149	0.058	-0.355	0.175	0.042	-0.624	0.399	0.118	-0.84S	0.527	0.108
HDL cholesterol (mg/dl)	0.048	0.049	0.323	0.086	0.055	0.118	0.052	0.131	0.693	0.214	0.167	0.199
LDL cholesterol (mg/dl)	-0.141	0.132	0.284	-0.180	0.153	0.239	-0.379	0.352	0.281	-0.459	0.461	0.320
Triglyceride (mg/dl)	-1.041	0.410	0.011	-1.578	0.467	0.001	-1.145	1.094	0.295	-2.876	1.409	0.041
Apolipoprotein Al (mg/dl)	0.061	0.082	0.455	-0.013	0.094	0.888	0.333	0.220	0.131	0.182	0.286	0.525
Apolipoprotein B100 (mg/dl)	-0.195	0.097	0.044	-0.223	0.113	0.049	-0.493	0.259	0.058	-0.684	0.344	0.047
Lipoprotein (a) (mg/dl)	0.102	0.162	0.527	0.267	0.189	0.157	-0.184	0.438	0.673	0.176	0.573	0.758
Glycaemia												
Fasting blood glucose (mg/dl)	-0.036	0.076	0.638	-0.060	0.079	0.447	-0.054	0.203	0.790	-0.176	0.240	0.463
HbA1c (mg/dl)	0.000	0.002	0.794	-0.001	0.002	0.523	0.000	0.006	0.948	-0.004	0.006	0.512
Insulim (uU/mL)	-0.040	0.025	0.119	-0.030	0.029	0.302	-0.097	0.068	0.153	-0.086	0.088	0.328
HOMA-IR	-0.010	0.007	0.174	-0.008	0.008	0.292	-0.021	0.020	0.283	-0.021	0.025	0.393
TG/HDL	-0.024	0.011	0.037	-0.037	0.013	0.004	-0.020	0.031	0.501	-0.062	0.039	0,116
Inflammation												
C-reactive protein (mg/dl)	-0.005	0.001	0.006	-0.002	0.002	0.236	-0.014	0.005	0.005	-0.005	0.006	0.387

Abbreviations: HbAlc, glycated hemoglobin; HOMA-IR, homeostatic model assessment-insulin resistance. [a]Adjusted for age, gender, energy intake (kcal/day), physical activity (METs-h/week), smoking status, alcohol (g/week), and treatment for hypertension, hypercholesterolemia and diabetes.

Total, insoluble and soluble fibre intake according to sociodemographic characteristics are presented in Table I. No significant differences were found by age, gender, level of studies completed or smoking status. Total, insoluble and soluble fibre intake were associated with increasing levels of physical activity, but only total and soluble fibre also seems to vary according to the type of work and shift of the participants.

Table II shows the crude and adjusted models for the association between insoluble and soluble fibre intake and each of the metabolic risk markers studied. We observed an association between both insoluble and soluble fibre and BMI in the crude model, although the association disappeared after controlling for other variables. Insoluble fibre was inversely associated with systolic blood pressure (β = -0.150; p = 0.032), and diastolic blood pressure (β = -0.125; p = 0.008) after adjusting for potential confounders. As for plasma lipids, insoluble fibre was again inversely associated with total cholesterol (β = -0.355; p = 0.042), triglycerides (β = -1.578; p = 0.001), and apolipoprotein B100 (β = -0.223; p = 0.049). Soluble fibre was inversely associated with triglycerides (β = -2.876; p = 0.041) and apolipoprotein B100 (β = -0.684; p = 0.047). This analysis indicates that increasing 1g/day of insoluble fibre is associated with a reduction of 0.037 mg/dl in the TG/HDL ratio, but no association was found for soluble fibre.

The association between fibre intake and MetS and its definition criteria is shown in table III and IV. Data is presented for types of fibre. In the crude model we observed significant differences for MetS diagnosis and blood pressure, waist circumference, HDL cholesterol and fasting blood glucose criteria, on the highest quartile of insoluble fibre intake. However, for soluble fibre, only significant differences were found for MetS diagnosis and waist circumference criterion. Model A, was adjusted for age, gender, level of studies completed and type of work. This adjustment affected the association between HDL cholesterol criterion and insoluble fibre as well as MetS diagnosis and soluble fibre intake. Model B was further adjusted for energy intake, physical activity, smoking status and alcohol. With respect to insoluble fibre, prevalence of MetS was found to be lower (OR 0.62, 95% CI: 0.40-0.96) in those participants in the highest quartile while no association were found for soluble fibre intake.

Discussion

The present study shows the association of different sources of dietary fibre and the prevalence of MetS as well as different parameters of CVD, in a mostly male middle-aged population of Spanish workers. Nevertheless, we didn´t want to exclude women with the aim to adjust for gender and then obtain more generalizable and extrapolable results for being compared with other studies. Total amount of fibre intake found in this study agrees with the European Food Safety Authority (EFSA) Panel on Dietetic Products Nutrition, and Allergies (NDA) and the Spanish Society of Community Nutrition (SENC) recommendations for the Spanish population established in 25.0 g/day. Likewise, a similar intake has been reported in other epidemiological Spanish cohort studies, such as the SUN cohort follow-up[17], the PREDIMED study[18] and in the Spanish European Prospective Investigation into Cancer and Nutrition (EPIC) cohort study[19].

Although the AWHS study carries a rigorous general protocol applied to the quality of each clinical and biochemical technique and dietary intake assessment includes personal interviews by trained interviewers, the use of SFFQ is unlikely to be quantitatively precise[20]. However this is not a lack of validity due to the fact that the measurement error used to be concentrate in the middle categories and in epidemiological studies we tend to compare extremes[21].

Higher dietary fibre intake is associated with lower rates of obesity, which have been hypothesized to be related to a satiating effect of fibre which contributes to a subsequent decreased appetite[22]. This, however, usually depends on the type of fibre and can vary depending on whether fibre is from natural foods or supplements. The association between a higher practise of physical activity and soluble and insoluble fibre shows a healthy trend also seen in other studies[23].

Elevated blood pressure is a known risk factor for CVD, but the pathophysiological mechanisms involved in its relationship with fibre intake are unclear. In our study, insoluble fibre was inversely associated with both systolic and diastolic blood pressure. This effect was also observed in a cohort of 5880 Spanish university graduates, where cereal fibre was inversely associated with the risk of hypertension[17]. A similar association was found in a cohort of 5961 French adults where those with higher insoluble fibre intake had a significant lower risk of high blood pressure[24]. Moreover, a randomized controlled trial carried out in a sample of middle age healthy individuals found that the consumption of three servings of whole grain foods could significantly reduce the risk of CVD through the control of blood pressure mechanisms[25]. It has been postulated that the hypotensive effects of dietary fibre could be related with the presence of antioxidant or mineral compounds that may influence the production of regulators of vascular tone[26].

The association between a healthy dietary pattern and an optimal plasma lipid profile has been largely proven. The mechanisms of the changes in levels of plasma lipids are diverse, but most are related to healthy lifestyle habits such as the intake of dietary fibre-rich foods[27]. In the most widely accepted hypothesis, soluble fibre is associated with decreased levels of total and LDL cholesterol and triglycerides through a direct mechanism of increased bile acids and total cholesterol faecal excretion[28] that, subsequently, stimulates hepatic LDL cholesterol uptake thus reducing its concentration in plasma[4]. In fact, although no association was found in the crude model, once adjusted, the analysis showed that an increase of

Table III
Adjusted odds ratios for metabolic syndrome by quartiles of insoluble fibre intake (glday), using logistic regression models

	Q1	*Q2*	*Q3*	*Q4*	*Ptrend*
	3.60-14.20	*14.21-17.16*	*17.18-20.85*	*20.87-56.04*	
MetS diagnosis (%)	30.1	26.1	18.6	19.8	
Crude OR (95% CI)	1.00 (ref)	0.81 (0.59-1.11)	0.53 (0.37-0.74)	0.57 (0.41-0.79)	<0.001
Adjusted OR model A[a] (95% CI)	1.00 (ref)	0.82 (0.58-1.15)	0.54 (0.38-0.78)	0.55 (0.38-0.79)	0.005
Adjusted OR model B[b] (95% CI)	1.00 (ref)	0.86 (0.60-1.25)	0.56 (0.37-0.85)	0.62 (0.40-0.96)	0.015
Blood pressure criterion for MetS (%)	21.4	20.6	16.6	17.1	
Crude OR (95% CI)	1.00 (ref)	0.95 (0.67-1.34)	0.73 (0.51-1.04)	0.75 (0.53-1.08)	0.056
Adjusted OR model A[a] (95% CI)	1.00 (ref)	0.90 (0.63-1.29)	0.66 (0.46-0.96)	0.71 (0.49-1.03)	0.010
Adjusted OR model B[b] (95% CI)	1.00 (ref)	1.01 (0.69-1.46)	0.79 (0.52-1.18)	0.91 (0.59-1.39)	0.657
Waist circumference criterion for MetS (%)	35.9	30.5	27.9	26.6	
Crude OR (95% CI)	1.00 (ref)	0.78 (0.57-1.06)	0.69 (0.50-0.94)	0.64 (0.47-0.88)	0.004
Adjusted OR model A[a] (95% CI)	1.00 (ref)	0.77 (0.56-1.05)	0.67 (0.49-0.92)	0.63 (0.46-0.87)	0.206
Adjusted OR model B[b] (95% CI)	1.00 (ref)	0.82 (0.59-1.14)	0.74 (0.52-1.04)	0.71 (0.49-1.03)	0.097
Triglyceride criterion for MetS (%)	44.0	42.9	36.7	33.7	
Crude OR (95% CI)	1.00 (ref)	0.95 (0.71-1.27)	0.73 (0.55-0.98)	0.64 (0.48-0.86)	<0.001
Adjusted OR model A[a] (95% CI)	1.00 (ref)	0.95 (0.71-1.27)	0.73 (0.54-0.98)	0.65 (0.48-0.87)	0.009
Adjusted OR model B[b] (95% CI)	1.00 (ref)	0.87 (0.63-1.19)	0.62 (0.45-0.87)	0.57 (0.40-0.81)	0.001
HDL cholesterol criterion for MetS (%)	14.7	7.9	10.6	9.7	
Crude OR (95% CI)	1.00 (ref)	0.49 (0.30-0.79)	0.69 (0.44-1.06)	0.62 (0.40-0.97)	0.090
Adjusted OR model A[a] (95% CI)	1.00 (ref)	0.51 (0.31-0.82)	0.71 (0.46-1.11)	0.64 (0.41-1.01)	0.310
Adjusted OR model B[b] (95% CI)	1.00 (ref)	0.54 (0.33-0.90)	0.74 (0.45-1.22)	0.69 (0.40-1.18)	0.146
Fasting blood glucose criterion for MetS (%)	47.7	41.9	34.6	38.9	
Crude OR (95% CI)	1.00 (ref)	0.78 (0.59-1.05)	0.57 (0.43-0.77)	0.69 (0.52-0.93)	0.002
Adjusted OR model A[a] (95% CI)	1.00 (ref)	0.77 (0.57-1.03)	0.56 (0.41-0.75)	0.69 (0.51-0.92)	0.054
Adjusted OR model B[b] (95% CI)	1.00 (ref)	0.81 (0.59-1.10)	0.61 (0.44-0.85)	0.78 (0.55-1.10)	0.201

Abbreviations: MetS. metabolic syndrome. [a]Adjusted for age, gender, level of studies completed and type of work. [b]Additionally adjusted for energy intake (kcal/d), physical activity (METs-h/hweek), smoking status and alcohol (g/week).

Table IV
Adjusted odds ratios for metabolic syndrome by quartiles of soluble fibre intake (glday), using logistic regression models

	Q1	*Q2*	*Q3*	*Q4*	*Ptrend*
	1.70-6.05	*6.06-7.45*	*7.46-9.01*	*9.02-18.37*	
MetS diagnosis (%)	27.6	23.7	22.5	21.0	
Crude OR (95% CI)	1.00 (ref)	0.81 (0.59-1.11)	0.75 (0.54-1.04)	0.69 (0.50-0.96)	0.025
Adjusted model A[a] (95% CI)	1.00 (ref)	0.75 (0.52-1.06)	0.72 (0.50-1.02)	0.69 (0.48-0.99)	0.070
Adjusted model B[b] (95% CI)	1.00 (ref)	0.80 (0.54-1.18)	0.83 (0.54-1.26)	0.87 (0.55-1.39)	0.847
Blood pressure criterion for MetS (%)	21.9	17.9	18.4	17.5	
Crude OR (95% CI)	1.00 (ref)	0.77 (0.54-1.10)	0.80 (0.57-1.14)	0.75 (0.53-1.07)	0.148
Adjusted model A[a] (95% CI)	1.00 (ref)	0.72 (0.50-1.04)	0.77 (0.53-1.11)	0.73 (0.51-1.05)	0.056
Adjusted model B[b] (95% CI)	1.00 (ref)	0.84 (0.57-1.23)	1.00 (0.66-1.51)	1.08 (0.68-1.69)	0.347
Waist circumference criterion for MetS (%)	35.4	29.6	28.2	27.6	
Crude OR (95% CI)	1.00 (ref)	0.76 (0.56-1.04)	0.71 (0.52-0.97)	0.69 (0.51-0.95)	0.020
Adjusted model A[a] (95% CI)	1.00 (ref)	0.74 (0.54-1.01)	0.70 (0.51-0.96)	0.69 (0.50-0.94)	0.405
Adjusted model B[b] (95% CI)	1.00 (ref)	0.78 (0.56-1.08)	0.77 (0.54-1.10)	0.80 (0.54-1.18)	0.420
Triglyceride criterion for MetS (%)	40.9	42.0	39.0	35.5	
Crude OR (95% CI)	1.00 (ref)	1.04 (0.78-1.39)	0.92 (0.68-1.23)	0.79 (0.59-1.06)	0.083
Adjusted model A[a] (95% CI)	1.00 (ref)	1.01 (0.75-1.36)	0.88 (0.66-1.19)	0.77 (0.57-1.04)	0.005
Adjusted model B[b] (95% CI)	1.00 (ref)	0.98 (0.71-1.34)	0.84 (0.60-1.18)	0.73 (0.50-1.06)	0.158
HDL cholesterol criterion for MetS (%)	12.4	9.8	10.8	9.8	
Crude OR (95% CI)	1.00 (ref)	0.76 (0.48-1.21)	0.85 (0.54-1.33)	0.76 (0.48-1.21)	0.342
Adjusted model A[a] (95% CI)	1.00 (ref)	0.76 (0.47-1.20)	0.86 (0.54-1.34)	0.76 (0.48-1.20)	0.170
Adjusted model B[b] (95% CI)	1.00 (ref)	0.89 (0.54-1.47)	1.05 (0.61-1.78)	0.98 (0.54-1.77)	0.762
Fasting blood glucose criterion for MetS (%)	45.7	39.6	37.6	40.1	
Crude OR (95% Cl)	1.00 (ref)	0.77 (0.58-1.04)	0.71 (0.53-0.96)	0.79 (0.59-1.06)	0.100
Adjusted model A[a] (95% CI)	1.00 (ref)	0.76 (0.57-1.03)	0.71 (0.53-0.96)	0.81 (0.61-1.09)	0.382
Adjusted model B[b] (95% CI)	1.00 (ref)	0.79 (0.58-1.08)	0.83 (0.59-1.16)	1.08 (0.74-1.55)	0.282

Abbreviations: MetS, metabolic syndrome. [a]Adjusted for age, gender, level of studies completed and type of work. [b]Additionally adjusted for energy intake (kcal/d), physical activity (METs-h/week), smoking status and alcohol (g/week).

1g/day of soluble fibre was associated with a reduction of 2.87 mg/dl of blood triglyceride levels. The association with insoluble fibre was significant but lower with a reduction of 1.57 mg/dl for each gram of fibre increase. There was no association between any sort of fibre and LDL cholesterol. However, apart from LDL concentration, some LDL modifications such as oxidation play an important role in the atherogenic capacity of these particles[29], and it has been postulated that the intake of some natural foods rich in antioxidants and polyphenols could provide antioxidant protection against LDL oxidation[30]. For this reason it has been proposed the use of apolipoprotein B100 as better predictor of CHD[31].

The TG/HDL ratio has been identified as an indicator of insulin resistance[32] and it has been even shown its usefulness to predict a first coronary event in active men workers independently of obesity[33], although its relationship to fibre intake has not been fully investigated. Moreover, we did not observe any association between fibre intake and other insulin resistance parameters, contrary to a recent cross-sectional study carried out in 264 women[34] were especially soluble fibre consumption was significantly related with lower level of insulin resistance.

The MetS is the result of specific metabolic abnormalities prevalent mainly in obese and overweight subjects, however is also present, although with less prevalence, in normoweight population. The prevalence of this syndrome in our sample (23.9% in men and 12.8% in women) was considerably higher than in other cohort studies based on healthy Spanish workers like the MESYAS (METabolic SYndrome in Active Subjects) Registry[35] (22% in men and 6.5% in women), probably due to a change in the threshold diagnosis of fasting blood glucose, from 110 to 100 mg/dl. Although the pathogenesis of the MetS is not fully elucidated, it is known that there is a genetic predisposition on which environmental factors, mainly the dietary pattern, contribute to the development of this disorder. This group of risk factors is important, due to the fact that doubles the risk of ischemic heart disease and is also a good predictor of diabetes, so that, its clinical utility seems to be presumable[36]. Nowadays, although there is no any specific pharmacologic treatment for this syndrome, changes in lifestyle habits, such as an increased physical activity and following a Mediterranean dietary pattern rich in fibre have been postulated as basic pillars in the treatment. In our study, we found a possible protective effect of insoluble dietary fibre intake based on the decreased risk of having MetS while no effect has been shown for soluble one.

The results derived from this study are in line with a recent meta-analysis, where an increase of insoluble fibre intake was related with a lower risk of CVD and CHD[3], whereas, another recently published meta-analysis showed a significant dose-response relationship between fibre intake and CHD especially from that derived from cereals and fruits[7], that is why further evidence is needed in order to establish what source of fibre involves more benefits, since so far, the results are still contradictory.

Conclusions

CVD are an important problem of public health due to the high prevalence in general population, where the prevention and treatment should be directed towards improving a healthy lifestyle. Our study supports the idea that a diet rich in sources of insoluble fibre could play an important role in the prevention and management of hypertension, lipid profile and MetS.

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