Nutrición Hospitalaria

Nutr Hosp. 2015;32(6):2692-2700
ISSN 0212-1611 • CODEN NUHOEQ
S.V.R. 318

Original / *Síndrome metabólico*

Association between daily sitting time and prevalent metabolic syndrome in an adult working population: the AWHS cohort

Belén Moreno-Franco[1,2], José Luis Peñalvo[3,4], Eva María Andrés-Esteban[5], Sara Malo[6], María Jesús Lallana[7], José Antonio Casasnovas[1,2] and Montserrat León-Latre[1]

[1]Cardiovascular Prevention Unit, Instituto Aragonés de Ciencias de la Salud (IACS), Fundación Instituto de Investigación Sanitaria de Aragón (IIS Aragón), Zaragoza, Spain. [2]Department of Medicine, Psychiatry and Dermatology, University of Zaragoza, Zaragoza, Spain. [3]Department of Epidemiology, Atherothrombosis and Cardiovascular Imaging, Fundación Centro Nacional de Investigaciones Cardiovasculares (CNIC), Madrid, Spain. [4]School of Nutrition Science and Policy, Tufts University. Boston, Massachusetts. [5]CIBER, Epidemiology and Public Health, (CIBERESP), Madrid, Spain. [6]Department of Microbiology, Preventive Medicine and Public Health, University of Zaragoza, Zaragoza, Spain. [7]Primary Care Pharmacy Service, Aragon Health Service, Zaragoza, Spain.

Abstract

Objective: **the aim of this analysis was to measure the association between daily sitting time and prevalent metabolic syndrome, independently of the physical activity performed.**

Subjects and methods: **the Aragon Workers' Health Study cohort consists of 5865 participants from which a sample of 1415 male participants (40-55 years old) with completed data at baseline was selected. Sitting time and physical activity were assessed by validated questionnaires, and the socio-demographic, clinical and biochemical covariates needed to diagnose metabolic syndrome were collected as part of the study protocols. Metabolic syndrome was defined according to the modified National Cholesterol Education Program - Adult Treatment Panel III. Multiple linear and logistic regression models were carried out to quantify this association using sitting time categorized into tertiles.**

Results: **mean sitting time was 5.78 ± 1.72 h/day, and the prevalence of metabolic syndrome was 19.2%. Comparing participants in the highest (>6.57 h/day) versus lowest (1.85-4.57 h/day) tertile of sitting time, a positive association was observed for metabolic syndrome (OR 1.77, 95%CI: 1.25-2.49) and triglyceride (OR 1.70, 95%CI: 1.30-2.24), HDL-cholesterol (OR 1.65, 95%CI: 1.06-2.58), waist circumference (OR 1.57, 95%CI: 1.17-2.11) and fasting blood glucose (OR 1.35, 95%CI: 1.03-1.77) criteria, adjusting the level of physical activity.**

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

Recibido: 29-VIII-2015.
Aceptado: 9-X-2015.

ASOCIACIÓN ENTRE TIEMPO SENTADO Y PREVALENCIA DE SÍNDROME METABÓLICO EN UNA POBLACIÓN ADULTA TRABAJADORA: LA COHORTE AWHS

Resumen

Objetivo: **el objetivo del presente análisis fue medir la asociación entre el tiempo sentado y la prevalencia de síndrome metabólico, de forma independiente a la actividad física realizada.**

Sujetos y métodos: **la cohorte del Aragon Workers' Health Study está formada por 5.865 participantes de los cuales se seleccionó una muestra de 1.415 voluntarios varones (40-55 años) con datos completos al inicio del estudio. El tiempo sentado y la actividad física se valoraron mediante cuestionarios validados, y las variables sociodemográficas, clínicas y bioquímicas necesarias para el diagnóstico del síndrome metabólico fueron recogidas como parte de los protocolos del estudio. Para la definición de síndrome metabólico se siguieron los criterios del Programa Nacional de Educación del Colesterol en el marco del III Panel de Tratamiento de Adultos (NCEP-ATP III). Se llevaron a cabo modelos de regresión lineal y logística para cuantificar esta asociación usando el tiempo sentado categorizado en tertiles.**

Resultados: **la media de tiempo sentado fue de 5,78 ± 1,72 h/día, y la prevalencia de síndrome metabólico del 19,2%. Comparando los participantes en el tertil superior de tiempo sentado frente a los del tertil inferior observamos una asociación positiva para síndrome metabólico (OR 1,77, 95%CI: 1,25-2,49) y los criterios de triglicéridos (OR 1,70, 95%CI: 1,30-2,24), HDL-colesterol (OR 1,65, 95%CI: 1,06-2,58), circunferencia de cintura (OR 1,57, 95%CI: 1,17-2,11) y glucosa en ayunas (OR 1,35, 95%CI: 1,03-1,77), ajustando por el nivel de actividad física.**

Conclusions: **higher sitting time is associated with an increased prevalence of metabolic syndrome independently of physical activity performed. These results could be useful to carry out effective strategies for cardiovascular health promotion especially in workplaces.**

(*Nutr Hosp*. 2015;32:2692-2700)

DOI:10.3305/nh.2015.32.6.9806

Key words: *Sedentary behavior. Sitting time. Physical activity. Metabolic syndrome. Cardiovascular disease.*

Conclusiones: **un mayor tiempo sentado se asocia con un aumento de la prevalencia de síndrome metabólico independientemente de la actividad física realizada. Estos resultados podrían ser útiles para llevar a cabo estrategias efectivas de promoción de la salud cardiovascular, especialmente en los lugares de trabajo.**

(*Nutr Hosp*. 2015;32:2692-2700)

DOI:10.3305/nh.2015.32.6.9806

Palabras clave: *Sedentarismo. Tiempo sentado. Actividad física. Síndrome metabólico. Enfermedad cardiovascular.*

Abbreviations

MetS: Metabolic syndrome.
CVD: Cardiovascular disease.
MET: Metabolic equivalent.
LTPA: Leisure time physical activity.
CI: Confident interval.
OR: Odds ratio.

Introduction

The metabolic syndrome (MetS) is a cluster of cardiovascular disease (CVD) risk factors including central obesity, reduced HDL-cholesterol and raised fasting plasma glucose, triglycerides and blood pressure. Although its physiopathology is still a matter of debate, insulin resistance seems to be on the basis of this condition. Currently, MetS constitutes an important problem of public health due to the increasing worldwide prevalence in general population and its association with CVD[1]. Although the etiopathogenesis of the MetS appears to be based on genetic and metabolic factors, it is known that certain lifestyle habits could play an important role in its prevention and control. Sedentary behavior measured as sitting time has been postulated as a risk factor for MetS[2] and it has also been related with a worse inflammatory and insulin resistance profile[3] and a higher incidence of total CVD[4], some types of cancer[5] and all cause morality[6].

Sedentary behavior has been defined as all activities that involve energy expenditure at the level of 1.0-1.5 metabolic equivalents (METs) during walking hours[7]. This definition takes into account a wide range of activities that involve low energy expenditure, but does not differentiate those implying sedestation (lying or standing quietly, standing in a line, etc.)[8]; therefore this approach does not address the impact that a long period of sitting time may have on the occurrence and development of CVD-related conditions[9]. Furthermore, in recent years there has been a growing interest in studying the occurrence of these negative effects on people who following the physical activity recommendations and guidelines, are still considered sedentary because of their occupational or leisure time sedentary manners[10].

We carried out this cross-sectional study with the aim to describe the relationship between sedentary behavior measured as sitting time, and the MetS, independently of leisure time physical activity (LTPA), conducted in a male Spanish active population.

Subjects and methods

Study population

A detailed description of the cohort assembly procedures including collection of information of exposure variables and outcomes definitions has been reported previously[11]. Briefly, the Aragon Workers' Health Study is a prospective cohort study based on the routine annual health exams of voluntary workers of a Spanish automobile assembly plant which aim is to characterize the factors associated with metabolic abnormalities and subclinical atherosclerosis in a middle aged working population. Each year, one random third of study participants 40 – 55 years of age and free of CVD at baseline, are 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 1505 volunteers. We excluded participants with missing data on sitting time (N=9) or on data necessary to diagnose the MetS (N=81). The final sample was composed of 1415 volunteers. All procedures performed were in accordance with the ethical standards of the Clinical Research Ethics Committee of Aragon. Informed consent was obtained from all participants prior to their inclusion in the study.

Biochemical, clinical and sociodemographic data

Fasting (>8 h) blood samples were drawn from each participant by venipuncture into evacuated tubes Vacutainer™. Fasting serum glucose, triglycerides, total cholesterol and HDL-cholesterol were measured by spectrophotometry (Chemical Analyzer ILAB 650, Instrumentation Laboratory). LDL-cholesterol levels were calculated using the Friedewald equation when triglycerides levels were lower than 400 mg/dL[12].

Blood pressure was measured three consecutive times using an automatic oscillometric sphygmomanometer OMRON M10-IT (OMRON Healthcare Co. Ltd., Japan). Physical examination included weight, height and waist circumference. Smoking was defined as current smoking status or having smoked in the last year. Being a former smoker was considered when subjects had smoked at least 50 cigarettes in their lifetime, but they did not smoke in the last year. Moreover, participants completed an additional questionnaire on sociodemographic characteristics including: date of birth, gender, education level, marital status, number of children and number of people that integrate their family unit, years in company, work shift and type of job performed.

Dietary, physical and sedentary behavior assessment

Dietary habits were assessed by means of a semi-quantitative food frequency questionnaire previously validated in Spain[13-14], capturing long-term intake during the preceding year. The questionnaire is based on 136 food items, including questions about consumption of supplements and special diets tracking. For LTPA assessment we used the Spanish validated version[15] of the Nurses' Health Study and Health Professionals' Follow-up physical activity questionnaires[16-17]. Participants were asked about the time and frequency devoted to the practice of 17 different sports during the year preceding the date of the interview. To compute the volume of activity performed for each participant, metabolic cost were assigned for each activity using Ainsworth´s compendium for physical activities[8], 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. To estimate the sedentary time, we included the hours, from "never" to "nine or more than nine hours a day" that the volunteer reported have been sitting, considering both working and leisure time and differentiating between a typical week day and a typical day weekend. Subsequently, weighted average was calculated.

Metabolic syndrome definition

MetS was diagnosed when subjects met at least 3 of the 5 following criteria: elevated 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 Program - Adult Treatment Panel III definition[18].

Statistical analysis

Kolmogorov-Smirnov test was used to assess the normality of data. We estimated the median value and interquartile range for all continuous variables and percentages for the categorical variables and compared them across tertiles of sitting time through the nonparametric Kruskal-Wallis and chi-square test. A multivariate analysis was performed using linear regression models. Dependent variables were systolic and diastolic blood pressure, waist circumference, triglycerides, HDL-cholesterol and fasting blood glucose (as continuous), and independent variable was sitting time categorized into tertiles. Results are presented adjusted for age (continuous), studies completed, smoking status, energy intake (continuous) and for the rest of the MetS variables (continuous) (Model 1) and further adjusted for LTPA (METs-h/week) (continuous) (Model 2). We also evaluated the association of sitting time and the presence of the MetS. For this aim, a multivariate analysis was performed using binary logistic regression models. Dependent variables were MetS and its criteria and independent variable was sitting time categorized into tertiles. The discriminatory power was assessed using the area under the receiver-operator characteristics curve obtained by analyzing the probability of the value predicted by the multivariate model. Models are presented as crude and adjusted by age (continuous), studies completed, smoking status and energy intake (continuous) (Model 1) and additionally adjusted for LTPA (METs-h/week) (continuous) (Model 2). Results are presented as unadjusted and adjusted odds ratios (OR) and 95% confidence interval (CI). P for trend was calculated for each model. Statistical analyses were performed with STATA (version 12) and $P < .05$ was considered statistically significant for all analysis.

Results

The overall prevalence of MetS in this sample was 19.2% (272 of the 1415 participants), with the following prevalence of the diagnosis criteria: elevated waist circumference in 30.0%, elevated triglycerides in 40.4%, reduced HDL-cholesterol in 10.6%, elevated blood pressure in 20.5% and elevated fasting glucose in 41.3%. Mean and standard deviation for sitting time among participants were 5.78 ± 1.72 h/day. Differences in sociodemographic characteristics, CVD risk factors and lifestyle habits according to tertiles of sitting time are shown in table I. We observed significant differences in the level of studies completed and type and work shift, where that individuals with higher educational

Tab1e I
Participants' characteristics according to tertiles of sitting time (h/day)

	Sitting time (h/day)			
	Tertile 1 (1.85 - 4.57)	*Tertile 2 (4.71 - 6.42)*	*Tertile 3 (> 6.57)*	*P value*
Participants, N	463	459	493	
Sociodemographic characteristics				
Age (years)	51.8 (48.6-54.4)	52.0 (48.8-54.5)	52.0 (49.2-54.7)	0.007
Level of studies completed (%)				< 0.001
Primary studies	52.9	56.4	45.5	
Secondary studies	13.5	8.9	11.2	
Professional training	32.1	32.7	33.3	
University studies	1.5	2.0	10.0	
Shift work (%)				< 0.001
Rotary Morning-Afternoon	69.3	63.6	54.2	
Rotary Morning-Afternoon-Night	20.1	21.8	21.1	
Day shift	2.7	3.7	19.5	
Night shift	8.4	10.9	5.3	
Type of work (%)				< 0.001
Hand worker	94.8	94.1	73.2	
Office worker	5.2	5.9	26.8	
Carcliovascular risk factors				
BMI (Kg/m^2)	27.1 (25.2-29.3)	27.8 (25.7-29.9)	27.7 (25.6-30.6)	0.002
Waist circumference (cm)	95.5 (90.0-101.8)	97.5 (92.0-104.0)	99.0 (92.2-105.0)	< 0.001
Systolic blood pressure (mmHg)	124.5 (116.0-133.0)	124.0 (116.0-133.0)	126.0 (117.0-135.3)	0.111
Diastolic blood pressure (mmHg)	83.0 (77.0-89.0)	83.0 (77.0-89.0)	85.0 (79.0-90.0)	0.035
Fasting blood glucose (mg/dL)	97.0 (89.0-104.0)	96.0 (89.0-103.0)	98.0 (91.0-107.0)	< 0.001
Total cholesterol (mg/dL)	223.0 (200.0-249.0)	223.0 (200.0-247.0)	222.0 (198.0-243.0)	0.767
Triglyceride (mg/dL)	117.0 (85.0-181.0)	135.0 (91.0-202.0)	142.0 (99.0-201.5)	< 0.001
HDL-cholesterol (mg/dL)	53.0 (46.0-60.0)	51.0 (45.0-58.0)	50.0 (43.0-57.0)	< 0.001
LDL-cholesterol (mg/dL)	139.4 (120.4-160.9)	139.2 (120.4-159.2)	139.8 (118.0-158.7)	0.660
Lifestyle habits				
Diet				
Energy intake (Kcal/day)	2957.7 (2442.4-3459.9)	2954.1 (2496.3-3468.0)	2781.8 (2263.4-3401.6)	0.003
Total carbohydrate intake (%)	45.8 (41.4-50.0)	45.5 (40.8-49.4)	44.8 (39.6-48.6)	0.004
Total protein intake (%)	14.6 (13.2-16.2)	14.6 (13.5-16.1)	14.6 (13.3-16.1)	0.868
Total fat intake (%)	34.2 (30.2-37.8)	35.0 (31.1-38.8)	35.3 (31.9-39.0)	0.007
Saturated fat intake (%)	9.4 (8.2-11.0)	9.9 (8.5-11.4)	9.8 (8.5-11.1)	0.037
Polyunsaturated fat intake (%)	5.5 (4.5-6.6)	5.4 (4.5-6.7)	5.5 (4.6-6.9)	0.179
Trans fat intake (%)	0.23 (0.15-0.32)	0.24 (0.17-0.32)	0.23 (0.16-0.30)	0.309
Alcohol (g/day)	14.8 (5.9-33.2)	14.8 (5.9-33.2)	14.9 (5.9-34.0)	0.958
LTPA (METs-h/week)	38.1 (19.6-52.9)	33.7 (19.6-46.3)	28.3 (17.0-43.5)	< 0.001
Smoking status (%)				0.436
Never	34.1	32.1	31.3	
Former	36.5	33.5	34.2	
Current	29.3	34.4	34.6	

Data are expressed as percentage or median and interquartile range.
BMI: Body mass index, LTPA: Leisure time physical activity, MET: Metabolic equivalents.

level (10.0% vs. 1.5% and 2.0%, $P < .001$) and those who work in the day shift (19.5% vs. 2.7% and 3.7%, $P < .001$) showed the greatest differences between the first and the third tertile of sitting time. With regard to CVD risk factors, those participants in the highest tertile of sitting time had higher waist circumference (99.0 vs. 95.5 and 97.5 mg/dL, $P < .001$), fasting blood glucose (98.0 vs. 97.0 and 96.0 mg/dL, $P < .001$) and also higher diastolic blood pressure (85.0 vs. 83.0 and 83.0 mmHg, $P = .035$) compared to those in the lowest one. The plasma lipid profile was also significantly different on those who reported spending more time sitting, with higher triglycerides (142.0 vs. 117.0 and 135.0 mmHg, $P < .001$) and lower HDL-cholesterol levels (50.0 vs. 53.0 and 51.0 mmHg, $P < .001$) than those participants classified into the lower tertile of sitting time. With respect to lifestyle habits, sedentary individuals consumed a greater amount of total fat (35.3% vs. 34.2% and 35.0%, $P < .007$) and practiced less LTPA (28.3 vs. 38.1 and 33.7 METs-h/week, $P < .001$).

The adjusted linear regression models for the association between tertiles of sitting time and the parameters of MetS as continuous variables are presented in table II. We observed an association between the highest tertile of sitting time and HDL-cholesterol ($\beta = -1.72$; $P = .018$) and fasting blood glucose ($\beta = 2.86$; $P = .021$) even after adjusting for LTPA, whereas no significant association was found for systolic and diastolic blood pressure, waist circumference or triglycerides.

Crude and adjusted OR for MetS and individual criteria are shown in table III. The multivariable model showed that once adjusted, those individuals in the highest tertile of sitting time had 1.77 (95%CI: 1.25-2.49) times higher chance of having MetS compared with those in the lowest one. They also showed a higher risk of presenting triglyceride (OR 1.70, 95%CI: 1.30-2.24), HDL-cholesterol (OR 1.65, 95%CI: 1.06-2.58), waist circumference (OR 1.57, 95%CI: 1.17-2.11) and fasting blood glucose (OR 1.35, 95%CI: 1.03-1.77) criteria even after adjusting for LTPA (METs-h/week). No significant association was found for blood pressure criterion.

Discussion

In this study the probability of finding prevalent MetS is 77.0% higher in the group of individuals spending more than 6.57 h/day sitting compared to those with less frequent sitting time (1.85-4.57 h/day), independently of the level of physical activity performed. Furthermore, this association held when additional adjusting by total energy intake was used. This is the first study carried out in a Mediterranean adult working population suggesting that sitting time, independently of other lifestyle factors such as physical activity or diet, is associated with prevalent MetS.

Comparison of results across studies relating sedentary behavior (such as daily sitting time) and MetS is somewhat complex due to the different criteria used for the definition of MetS or even in the definition of what constitutes a sedentary lifestyle. In some instances, sedentary behavior is defined as those activities with low-intensity physical activity. At other times, is related with the time spent in screen activities[19]. When the measurement has been carried out objectively, by accelerometry, is usually characterized as those activities involving 100 or less counts per minute[20]. Despite this heterogeneity in the definitions, our results are in agreement with those recently reported in a Danish population, where higher prevalence (48.0%) of MetS among those participants sitting for 10 or more h/day, even in physically active participants, was observed[10]. Furthermore, a recent meta-analysis[21] combining the effects sizes found on ten different studies, showed that greater time spent in sedentary increased the odds of MetS by 73.0%, although four of this studies included did not considered covariates such as physical activity, diet or body mass index as potential confounders.

Our results contribute to the growing evidence pointing to prolonged sitting time as an independent cardiovascular risk factor. Defining sedentary behavior in terms of energy expenditure does not account for the pathophysiological effects associated with the sedestation posture. The most widely accepted physiopathological hypothesis[22] points to the regulation of the lipoprotein lipase activity as the key player in the impact of sedestation on cardiovascular risk. Animal models have demonstrated that the loss of local contractile stimulation leads to the suppression of lipoprotein lipase activity in skeletal muscle, limiting the uptake of triglycerides and free fatty acid and also reducing HDL-cholesterol plasma levels[22]. In this hypothesis, people with longer daily sitting times could be at higher cardiovascular risk even if they follow the physical activity recommendations[9]. In this vein, we also observed higher levels of triglycerides and reduced HDL-cholesterol in those participants who spent more time sitting. Nonetheless, the demonstration of the lipoprotein lipase activity theory in humans remains to be explored and it is possible that this effect can only be observed after prolonged periods in sedestation.

The prevalence of MetS observed in this study is considerably higher than the one reported from previous studies carried out in other Spanish working populations such as the MESYAS Registry[23] and the DARIOS[24] or ICARIA[25] studies. This difference could be related with the use of different definitions of MetS, with a change in the threshold diagnosis of fasting blood glucose from 100 to 110 mg/dL or the use of body mass index instead of waist circumference for the diagnosis of obesity, parameter that although widely accepted tends to underestimate the prevalence of MetS. However, could be also be related to a rising

Table II
Adjusted beta-coefficients of variables included in metabolic syndrome using linear regression models

	Sitting time (h/day)		
	Tertile 1 *1.85 - 4.57*	*Tertile 2* *4.71 - 6.42*	*Tertile 3* *> 6.57*
Systolic blood pressure (mmHg)			
Model 1[a] (95%CI)	0.00 (ref)	-0.62 (-2.59 - 1.35)	0.01 (-1.95 - 1.97)
p value		0.537	0.991
Model 2[b] (95%CI)	0.00 (ref)	-0.42 (-2.40 - 1.54)	0.31 (-1.65 - 2.29)
p value		0.671	0.751
Diastolic blood pressure (mmHg)			
Model 1[a] (95%CI)	0.00 (ref)	0.34 (-0.94 - 1.64)	0.61 (-0.66 - 1.90)
p value		0.600	0.345
Model 2[b] (95%CI)	0.00 (ref)	0.43 (-0.86 - 1.72)	0.75 (-0.53 - 2.04)
p value		0.514	0.253
Waist circumference (cm)			
Model 1[a] (95%CI)	0.00 (ref)	2.10 (-0.53 - 4.74)	1.65 (-0.96 - 4.27)
p value		0.118	0.217
Model 2[b] (95%CI)	0.00 (ref)	1.90 (-0.74 - 4.54)	1.32 (-1.31 - 3.96)
p value		0.158	0.324
Triglycerides (mg/dL)			
Model 1[a] (95%CI)	0.00 (ref)	6.76 (-4.94 - 18.5)	5.98 (-5.64 - 17.6)
p value		0.257	0.313
Model 2[b] (95%CI)	0.00 (ref)	6. 76 (-4.98 - 18.5)	5.9 7 (-5.74 - 17.7)
p value		0.259	0.317
HDL-cholesterol (mg/dL)			
Model 1[a] (95%CI)	0.00 (ref)	-0.29 (-1.75 - 1.15)	-2.2 7 (-3.71 - -0.83)
p value		0.688	0.002
Model 2[b] (95%CI)	0.00 (ref)	0.01 (-1.42 - 1.45)	-1.72 (-3.16 - -0.29)
p value		0.986	0.018
Fasting blood glucose (mg/dL)			
Model 1[a] (95%CI)	0.00 (ref)	-0.58 (-3.02 - 1.85)	3.17 (0.76 - 5.59)
p value		0.638	0.010
Model 2[b] (95%CI)	0.00 (ref)	-0.76 (-3.20 - 1.67)	2.86 (0.43 - 5.29)
p value		0.537	0.021

[a]Multiple linear regression model adjusted for age, studies completed, smoking status, energy intake (Kcal/day) and the rest of metabolic syndrome parameters.
[b]Multiple linear regression model additionally adjusted for leisure time physical activity (METs-hour/week).
95%CI: Confidence interval of 95%.

prevalence of cardiovascular risk factors in an increasingly younger population[26].

It has been postulated that the main cause explaining the higher prevalence of CVD, MetS and obesity in sedentary individuals, is the positive association with poorer dietary habits, with a high-caloric diets and frequent consumption of energy-dense foods and therefore a disrupted energy balance, observed in young adults and teenagers[27-28] more than in adults[29]. In this regard, our results indicated no association between sitting time and diet quality supporting the idea of daily sitting time as an independent contributor to increased

Table III
Crude and adjusted odds ratios for metabolic syndrome by tertiles of sitting time (h/day), using logistic regression models

	Sitting time (h/day)			
	Tertile 1 1.85 - 4.57	*Tertile 2 4.71 - 6.42*	*Tertile 3 > 6.57*	*P trend*
MetS diagnosis (%)	14.3	17.7	25.4	
Crude (95%CI)	1.00 (ref)	1.28 (0.90 - 1.83)	2.04 (1.46 - 2.84)	< 0.001
Model 1[a] (95%CI)	1.00 (ref)	1.20 (0.83 - 1.73)	1.92 (1.36 - 2.69)	< 0.001
Model 2[b] (95%CI)	1.00 (ref)	1.14 (0.79 - 1.65)	1.77 (1.25 - 2.49)	0.001
Blood pressure criterion for MetS (%)	19.2	20.3	21.9	
Crude (95%CI)	1.00 (ref)	1.06 (0.77 - 1.47)	1.17 (0.86 - 1.61)	0.303
Model 1[a] (95%CI)	1.00 (ref)	1.00 (0.71 - 1.41)	1.05 (0.75 - 1.46)	0.757
Model 2[b] (95%CI)	1.00 (ref)	0.97 (0.69 - 1.37)	0.99 (0.71 - 1.38)	0.979
Waist circumference criterion for MetS (%)	24.0	30.3	35.5	
Crude (95%CI)	1.00 (ref)	1.37 (1.02 - 1.84)	1.74 (1.31 - 2.31)	< 0.001
Model 1[a] (95%CI)	1.00 (ref)	1.37 (1.02 - 1.85)	1.68 (1.26 - 2.25)	< 0.001
Model 2[b] (95%CI)	1.00 (ref)	1.32 (0.98 - 1.78)	1.57 (1.17 - 2.11)	0.002
Triglyceride criterion for MetS (%)	32.0	42.9	46.0	
Crude (95%CI)	1.00 (ref)	1.60 (1.22 - 2.09)	1.81 (1.39 - 2.36)	< 0.001
Model 1[a] (95%CI)	1.00 (ref)	1.53 (1.16 - 2.01)	1.81 (1.38 - 2.37)	< 0.001
Model 2[b] (95%CI)	1.00 (ref)	1.47 (1.12 - 1.94)	1.70 (1.30 - 2.24)	< 0.001
HDL-cholesterol criterion for MetS (%)	7.8	10.9	13.0	
Crude (95%CI)	1.00 (ref)	1.45 (0.92 - 2.27)	1.76 (1.15 - 2.71)	0.009
Model 1[a] (95%CI)	1.00 (ref)	1.35 (0.85 - 2.14)	1.67 (1.08 - 2.60)	0.026
Model 2[b] (95%CI)	1.00 (ref)	1.34 (0.85 - 2.13)	1.65 (1.06 - 2.58)	0.026
Fasting blood glucose criterion for MetS (%)	39.1	35.7	48.7	
Crude (95%CI)	1.00 (ref)	0.86 (0.66 - 1.13)	1.47 (1.14 - 1.91)	0.002
Model 1[a] (95%CI)	1.00 (ref)	0.84 (0.64 - 1.11)	1.43 (1.09 - 1.86)	0.007
Model 2[b] (95%CI)	1.00 (ref)	0.81 (0.61 - 1.07)	1.35 (1.03 - 1.77)	0.022

[a]Odds ratios adjusted for age, studies completed, smoking status and energy intake (kcal/day).
[b]Odds ratios additionally adjusted for leisure time physical activity (METs-hour/week).
95%Cl: Confidence interval of 95%; MetS: Metabolic syndrome.

risk of MetS, although workers who spent more time in sedentary activities showed also less time invested in physical activity performing.

The detrimental effects of a sedentary lifestyle are currently the subject of intense research, and constitute a priority in the public health agenda. The time spent on sedentary behavior and especially in sedestation is expected to increase in the coming years. The increasing burden of CVD should be addressed also from the perspective of lifestyle, promoting not only to compliance with diet and physical activity recommendations but also promoting actions to reduce the time spent in sedentary activities. Increasing the time dedicated to practice of physical activity remains a challenge for many individuals, but reducing sedentary lifestyle seems a more feasible approach, especially for those with reduced mobility or difficulties to carry out any physical activity. Although prospective and controlled intervention studies are still needed in order to evaluate the effects of sitting time on cardiovascular risk factors, and in light of these results, it seems reasonable to suggest that guidelines for the prevention of CVD should not only be aimed at increasing physical activity but also to reduce long periods of sedentary time, recommending short breaks to allow us to get muscle activation and a slightly increased energy expenditure, that seems to be beneficial for the control and management of cardiovascular risk factors[30].

Study limitations

Although the AWHS study carries a rigorous general protocol and sedentary and physical assessment includes personal interviews by trained interviewers, the use of questionnaires is unlikely to be quantitatively precise and not let us to know if that sedentary time occurs continuously or intermittently, even though it has been previously validated using accelerometers. The cross-sectional design of the analysis does not address causality, and the multiple associations between lifestyle factors makes it difficult to rule out all potential residual confounding even after careful adjustment of the models. Finally, this sample is not totally representative of the general population; only healthy men or at least without known disabling diseases have been included in the study, so that the levels of sedentary and physical activity in the general population could be different.

Conclusions

Increased daily sitting time is associated with prevalent MetS independently of the level of physical activity performed, in this sample of Spanish workers. This information could be useful to improve the effectiveness of strategies for the promotion of cardiovascular health overall and could be specifically useful as part as wellness programs in workplaces.

Acknowledgments

This study was financially supported by the Fund for Health of Spain of the Institute of Health Carlos III (ISCIII-FIS), projects PI11/00403 and PI12/01434. We thank the participants and the personal of the AWHS study for their collaboration.

Conflict of interest

None.

References

1. Grundy SM. Metabolic syndrome pandemic. *Arterioscler Thromb Vasc Biol*. 2008;28(4):629-36.
2. Hamilton MT, Hamilton DG, Zderic TW. Sedentary behavior as a mediator of type 2 diabetes. *Med Sport Sci*. 2014;60:11-26.
3. Leon-Latre M, Moreno-Franco B, Andres-Esteban EM, Ledesma M, Laclaustra M, Alcalde V, Penalvo JL, Ordovas JM, Casasnovas JA. Sedentary lifestyle and its relation to cardiovascular risk factors, insulin resistance and inflammatory profile. *Rev Esp Cardiol (Engl Ed)*. 2014;67(6):449-55.
4. Borodulin K, Karki A, Laatikainen T, Peltonen M, Luoto R. Daily Sedentary Time and Risk of Cardiovascular Disease: The National FINRISK 2002 Study. *J Phys Act Health*. 2015 Jul;12(7):904-8.
5. Schmid D, Leitzmann MF. Television viewing and time spent sedentary in relation to cancer risk: a meta-analysis. *J Natl Cancer Inst*. 2014;106(7).
6. van der Ploeg HP, Chey T, Korda RJ, Banks E, Bauman A. Sitting time and all-cause mortality risk in 222 497 Australian adults. *Arch Intern Med*. 2012;172(6):494-500.
7. Pate RR, O'Neill JR, Lobelo F. The evolving definition of "sedentary". *Exerc Sport Sci Rev*. 2008;36(4):173-8.
8. Ainsworth BE, Haskell WL, Herrmann SD, Meckes N, Bassett DR, Jr., Tudor-Locke C, Greer JL, Vezina J, Whitt-Glover MC, Leon AS. 2011 Compendium of Physical Activities: a second update of codes and MET values. *Med Sci Sports Exerc*. 2011;43(8):1575-81.
9. Hamilton MT, Healy GN, Dunstan DW, Zderic TW, Owen N. Too Little Exercise and Too Much Sitting: Inactivity Physiology and the Need for New Recommendations on Sedentary Behavior. *Curr Cardiovasc Risk Rep*. 2008;2(4):292-98.
10. Petersen CB, Nielsen AJ, Bauman A, Tolstrup JS. Joint association of physical activity in leisure and total sitting time with metabolic syndrome amongst 15,235 Danish adults: a cross-sectional study. *Prev Med*. 2014;69:5-7.
11. Casasnovas JA, Alcaide V, Civeira F, Guallar E, Ibanez B, Borreguero JJ, Laclaustra M, Leon M, Penalvo JL, Ordovas JM, Pocovi M, Sanz G, Fuster V. Aragon workers' health study--design and cohort description. *BMC Cardiovasc Disord*. 2012;12:45.
12. Friedewald WT, Levy RI, Fredrickson DS. Estimation of the concentration of low-density lipoprotein cholesterol in plasma, without use of the preparative ultracentrifuge. *Clin Chem*. 1972;18(6):499-502.
13. de la Fuente-Arrillaga C, Ruiz ZV, Bes-Rastrollo M, Sampson L, Martinez-Gonzalez MA. Reproducibility of an FFQ validated in Spain. *Public Health Nutr*. 2010;13(9):1364-72.
14. Martin-Moreno JM, Boyle P, Gorgojo L, Maisonneuve P, Fernandez-Rodriguez JC, Salvini S, Willett WC. Development and validation of a food frequency questionnaire in Spain. *Int J Epidemiol*. 1993;22(3):512-9.
15. Martínez-González MA, López-Fontana C, Varo JJ, Sanchez-Villegas A, Martínez JA. Validation of the Spanish version of the physical activity questionnaire used in the Nurses´ Health Study and the Health Professionals´ Follow-up Study. *Public Health Nutr*. 2005;8(7):920-27.
16. Chasan-Taber S, Rimm EB, Stampfer MJ, Spiegelman D, Colditz GA, Giovannucci E, Ascherio A, Willett WC. Reproducibility and validity of a self-administered physical activity questionnaire for male health professionals. *Epidemiology*. 1996;7(1):81-6.
17. Wolf AM, Hunter DJ, Colditz GA, Manson JE, Stampfer MJ, Corsano KA, Rosner B, Kriska A, Willett WC. Reproducibility and validity of a self-administered physical activity questionnaire. *Int J Epidemiol*. 1994;23(5):991-9.
18. Grundy SM, Cleeman JI, Daniels SR, Donato KA, Eckel RH, Franklin BA, Gordon DJ, Krauss RM, Savage PJ, Smith SC, Jr., Spertus JA, Costa F. Diagnosis and management of the metabolic syndrome: an American Heart Association/National Heart, Lung, and Blood Institute Scientific Statement. *Circulation*. 2005;112(17):2735-52.
19. Wennberg P, Gustafsson PE, Howard B, Wennberg M, Hammarstrom A. Television viewing over the life course and the metabolic syndrome in mid-adulthood: a longitudinal population-based study. *J Epidemiol Community Health*. 2014;68(10):928-33.
20. Bankoski A, Harris TB, McClain JJ, Brychta RJ, Caserotti P, Chen KY, Berrigan D, Troiano RP, Koster A. Sedentary activity associated with metabolic syndrome independent of physical activity. *Diabetes Care*. 2011;34(2):497-503.
21. Edwardson CL, Gorely T, Davies MJ, Gray LJ, Khunti K, Wilmot EG, Yates T, Biddle SJ. Association of sedentary behaviour with metabolic syndrome: a meta-analysis. *PLoS One*. 2012;7(4):e34916.
22. Hamilton MT, Hamilton DG, Zderic TW. Exercise physiology versus inactivity physiology: an essential concept for understanding lipoprotein lipase regulation. *Exerc Sport Sci Rev*. 2004;32(4):161-6.

23. Alegria E, Cordero A, Laclaustra M, Grima A, Leon M, Casasnovas JA, Luengo E, del Rio A, Ferreira I. [Prevalence of metabolic syndrome in the Spanish working population: MESYAS registry]. *Rev Esp Cardiol*. 2005;58(7):797-806.
24. Fernandez-Berges D, Cabrera de Leon A, Sanz H, Elosua R, Guembe MJ, Alzamora M, Vega-Alonso T, Felix-Redondo FJ, Ortiz-Marron H, Rigo F, Lama C, Gavrila D, Segura-Fragoso A, Lozano L, Marrugat J. Metabolic syndrome in Spain: prevalence and coronary risk associated with harmonized definition and WHO proposal. DARIOS study. *Rev Esp Cardiol (Engl Ed)*. 2012;65(3):241-8.
25. Sanchez-Chaparro MA, Calvo-Bonacho E, Gonzalez-Quintela A, Fernandez-Labandera C, Cabrera M, Sainz JC, Fernandez-Meseguer A, Banegas JR, Ruilope LM, Valdivielso P, Roman-Garcia J. Occupation-related differences in the prevalence of metabolic syndrome. *Diabetes Care*. 2008;31(9):1884-5.
26. Portero MP, Leon M, Andres EM, Laclaustra M, Pascual I, Bes M, Luengo E, del Rio A, Giner A, Gonzalez P, Casasnovas JA. Comparison of cardiovascular risk factors in young Spanish men between the 1980s and after the year 2000. Data from the AGEMZA study. *Rev Esp Cardiol*. 2008;61(12):1260-6.
27. Stamatakis E, Hamer M, Tilling K, Lawlor DA. Sedentary time in relation to cardio-metabolic risk factors: differential associations for self-report vs accelerometry in working age adults. *Int J Epidemiol*. 2012;41(5):1328-37.
28. Thomson M, Spence JC, Raine K, Laing L. The association of television viewing with snacking behavior and body weight of young adults. *Am J Health Promot*. 2008;22(5):329-35.
29. Gao X, Nelson ME, Tucker KL. Television viewing is associated with prevalence of metabolic syndrome in Hispanic elders. *Diabetes Care*. 2007;30(3):694-700.
30. Healy GN, Dunstan DW, Salmon J, Cerin E, Shaw JE, Zimmet PZ, Owen N. Breaks in sedentary time: beneficial associations with metabolic risk. *Diabetes Care*. 2008;31(4):661-6.