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Differences by sex in the association of physical activity level and sitting time with cardiometabolic risk in Mexican adults aged 20–59 years

Diferencias por sexo en la asociación del nivel de actividad física y tiempo sentado con riesgo cardiometabólico en adultos mexicanos de 20-59 años

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ABSTRACT

Introduction: There is a lack of research in middle-income countries about the relationship between physical activity, sedentary behavior, and cardiometabolic risk using representative samples. Objective: To determine whether physical activity level and sitting time are associated with cardiometabolic risk in Mexican adults. Methods: Data from the 2018 National Health and Nutrition Survey were analyzed (n = 9,797 participants, 59.1% were women). The independent variables were sitting time and five physical activity indicators: total volume (MET minutes/week), physical activity level (inactive, moderate, and vigorous), vigorous physical activity (minutes/week), moderate activity (minutes/week), compliance with the World Health Organization recommendation for physical activity, and walking time (minutes/week). Sitting time was analyzed in minutes/day. Cardiometabolic risk was assessed using measurements of blood pressure, total cholesterol, LDL cholesterol, HDL cholesterol, and insulin resistance. Poisson regression models were estimated. Results: In men (but not women), physical activity level and time engaged in vigorous or moderate physical activity were associated with a lower probability of cardiometabolic risk; whereas the opposite was true for sitting time. Physical activity volume, adherence to the World Health Organization recommendation, and walking were not associated with cardiometabolic risk. Conclusion: In men, physical activity may have a protective effect on cardiometabolic risk, whereas sitting time could be a risk factor.

Keywords: Body movement; Exercise; Cardiovascular risk; Sedentary behavior; Questionnaire; Vigorous activity.

RESUMÉN

Introducción: Hay poca investigación en países de ingreso medio sobre la relación de actividad física, sedentarismo y riesgo cardiometabólico utilizando muestras representativas. Objetivo: Dterminar si el nivel de actividad física y el tiempo sentado se asocian con la presencia de riesgo cardiometabólico en adultos de México. Métodos: Se analizaron datos de la Encuesta Nacional de Salud y Nutrición 2018 (n = 9,797 participantes, 59.1% fueron mujeres). Las variables independientes fueron el tiempo sentado y cinco indicadores de actividad física: volumen total (MET minutos/semana), nivel de la actividad física (inactivo, moderada y alto), actividad física vigorosa (minutos/semana), actividad moderada (minutos/semana), cumplimiento de la recomendación de la Organización Mundial de la Salud de actividad física y el tiempo de caminata (minutos/semana). El tiempo sentado se analizó en minutes/día. Para medir el riesgo cardiometabólico se consideraron: presión arterial, colesterol total, colesterol LDL, colesterol HDL y resistencia a la insulina. Se estimaron modelos de regresión de Poisson. Resultados: En los varones (pero no en las mujeres), el nivel de actividad física y el tiempo de actividad física vigorosa o moderada se asociaron con menor probabilidad de presentar riesgo cardiometabólico; mientras que lo contrario ocurrió con el tiempo sentado. El volumen de actividad física, el cumplimiento de la recomendación de la Organización Mundial de la Salud y la caminata no se relacionaron con el riesgo cardiometabólico. Conclusión: En los varones la actividad podría tener un efecto protector para el riesgo cardiometabolico, mientras que el tiempo sentado podría ser un factor de riesgo.

Palabras-clave: Movimiento; Ejercicio; Riesgo cardiovascular; Sedentarismo; Cuestionario; Actividad vigorosa.

Introduction

In recent decades, due to its high frequency, physical inactivity has become a public health problem[1]. Physical inactivity may be linked to cardiometabolic risk (CMR), which in turn increases the likelihood of developing chronic non-communicable diseases. At least 60% of the world's population does not engage in the level of physical activity (PA) necessary to achieve ben-

efits such as reduced overall mortality and improved quality of life[2]. In 2018, 29% of the Mexican adult population engaged in less than 150 minutes/week of moderate-to-vigorous PA. At the same time, chronic non-communicable diseases are highly prevalent among adults in Mexico; for example, the prevalence values of high blood pressure, abdominal obesity, diabetes mellitus, and high total cholesterol in adults were 20.5%, 81.4%, 10.6%, and 19.5% respectively[3].

Given this scenario, there is evidence of a relationship between PA and the appearance of chronic non-communicable diseases[4-7]. However, a limitation of existing studies is that they include small and non-representative samples[8]. Co-occurrence studies, including associations with PA and a sedentary lifestyle, are required, since studies tend to analyze CMR indicators in isolation[6,9]. Analyzing whether PA is related to the simultaneous presence of several CMR factors is relevant, since the latter has a multiplicative (i.e., not just additive) effect on overall mortality[10]. Additionally, to date, research is scarce in low- or middle-income countries[6,11,12]. Thus, it is necessary to verify whether the results observed in high-income countries can be applied to low- and middle-income countries, as they differ in terms of the time and type of PA[11]. In low- and middle-income countries, more time is spent walking and less time is spent on sedentary behavior[13]. In these contexts, socioeconomic status may be a confounding factor in the association of PA and a sedentary lifestyle with health[14]. Finally, it is essential to identify the independent effects of PA and sedentary behavior. Although both behaviors are related to human movement, they are not mutually exclusive; especially in urban settings, a person can be sedentary (sitting for recreational and/or occupational activities) and physically active (exercising).

To date, PA and sedentary behavior guidelines do not account for sex differences. However, there is evidence that the effect of PA and sedentary behavior on cardiovascular risk may differ between men and women[15]. On average, men tend to have larger hearts and airways, which may lead to greater benefits from PA. At the same time, the hormonal profile in pre-menopausal women may offer a protective effect[16]. Nevertheless, the evidence regarding these sex differences remains insufficient.

Based on the above, the objective of the current study was to determine whether the levels of PA and sitting time are associated with the presence of CMR in adults in Mexico. Considering that there are differences between men and women in the time dedicated to PA and its intensity[13], the potential role of sex as an effect modifier was evaluated.

Methods

The databases of the Mexican 2018 National Health and Nutrition Survey, a cross-sectional survey with national representativeness, were analyzed [17]. Fieldwork was conducted from July 30, 2018, to February 15, 2019. The National Health and Nutrition Survey employs complex sampling, which involves clustering, stratification, and random selection. Most of the information was collected using questionnaires, which were administered through face-to-face interviews[17]. The National Health and Nutrition Examination Survey defines an adult as a person aged 20 years and older. In total, 43,070 people in this age group were interviewed, and a fasting venous blood sample was obtained from a subsample of 13,490 adults. Adults aged 20 to 59 were selected for the study. Records of pregnant and/or breastfeeding women, individuals who had undergone limb amputation, and individuals with extreme values in biological determinations were excluded. After eliminating cases with missing information, the analytical sample consisted of 9,797 participants, of whom 58.9% were women.

The Ethics Committee of the National Institute of Public Health approved the protocol for data collection for the National Health and Nutrition Survey. Participants signed informed consent forms.

Physical activity and sedentary lifestyle

The study included two independent variables: PA level and sitting time, assessed using the short version of the International Physical Activity Questionnaire (IPAQ)[16]. This instrument assesses PA in three categories: walking, moderate-intensity activities, and vigorous-intensity activities. In Mexican adults, the IPAQ presents modest reliability and poor validity compared to accelerometry for assessing moderate-to-vigorous PA[18] Five PA variables were created: total volume, PA level, compliance with the World Health Organization recommendations, time spent on vigorous activities, and time spent on moderate activities.

According to the data cleaning criteria proposed by the IPAQ[19], variables were truncated at 1260 minutes/week. Total PA volume was calculated in metabolic equivalent score minutes/week: 3.3 for walking, 4.0 for

moderate activity, and 8.0 for vigorous activity. Based on PA volume, the following criteria were created: 1) Low, failing to meet at least a sum of activities equal to 600 metabolic equivalent minutes/week; 2) Moderate, reaching 600 to 2,999 metabolic equivalent minutes/week; 3) High, 3,000 metabolic equivalent minutes/week or more.

The following groups were formed according to the PA level proposed for the IPAQ[19]: 1) High level, included participants who performed vigorous PA on more than three days and accumulated at least 1500 metabolic equivalent minutes/week, or who performed all three activities assessed (walking, moderate and vigorous activity) on seven days and reached 3,000 metabolic equivalent minutes/week; 2) Moderate level, included participants who met any of the following conditions: performed vigorous PA on at least three days, with a minimum duration of 20 minutes, or between the sum of moderate activity and walking achieved at least five days of PA for 30 minutes or more, or accumulated 600 metabolic equivalent minutes/week. 3) When participants did not meet any of the previous criteria, they were considered inactive.

The World Health Organization's PA recommendations for adults were used[20]. According to these guidelines, adults meet the recommendations when they accumulate at least 150 minutes/week of moderate PA, 75 minutes/week of vigorous PA, or an equivalent combination of both. In addition, time spent in vigorous and moderate activities was analyzed separately. Quartiles were created for vigorous and moderate activity. In the case of vigorous PA, more than half of the participants reported not meeting the minimum criteria for this intensity. The third quartile of vigorous activity corresponded to a range of 1 to 199 minutes/week, and the fourth quartile corresponded to 200 to 1,260 minutes/week. For moderate activity, 0 minutes/week were recorded in the first quartile; the second quartile ranged from 1 to 199 minutes/week; the third quartile, from 200 to 749 minutes/week; and the fourth quartile, from 750 to 1,260 minutes/week.

For the walking variable, the following question was asked: "In the last seven days, on how many days did you walk for 10 continuous minutes?" and "In the last seven days, how much time, in hours, did you spend walking in hours?" The time in hours was converted to minutes per week. In the quartile I of walking the range was 0 to 69 minutes/week; quartile II, 70 to 179 minutes/week; quartile III, 180 to 449 minutes/week; and quartile IV, 450 to 1,260 minutes/week.

Finally, to determine the amount of time participants spent sitting, they were asked: "How much time do you spend sitting?", indicating the time in hours and minutes per day. The responses were totaled and grouped into quartiles for analysis. Hours were converted to minutes and the following quartiles were obtained: quartile I ranged from 1 to 68 minutes/day; quartile II from 69 to 159 minutes/day; quartile III from 160 to 249 minutes/day; and quartile IV from 250 to 960 minutes/day.

Cardiometabolic risk

To define CMR, the indicators used to define healthy obesity in a Luxembourg population were considered[21]: blood pressure (systolic and diastolic), total cholesterol, low-density lipoprotein and high-density lipoprotein cholesterol, glucose, and insulin levels. CMR was considered present when participants presented at least three alterations in these indicators. For measurements of total cholesterol, low-density lipoprotein cholesterol, high-density lipoprotein cholesterol, insulin, and fasting glucose, a venous blood sample was drawn after a minimum of eight hours of fasting. Values of >500 mg/dL and <50 mg/dL for glucose and total cholesterol, and <20 mg/dL for low-density lipoprotein cholesterol were excluded. Insulin resistance was defined using the HOMA-IR (Homeostatic Model Assessment for Insulin Resistance) index calculated with the formula HOMA-IR = (fasting insulin μU/mL/18) × (fasting glucose (mg/dL) /22.5).

For the classification of hypercholesterolemia, a cholesterol level of 131.27 mg/dL was adopted[22] , and for hypoalphalipoproteinemia, high-density lipoprotein levels were considered to be <35 mg/dL for both women and men. Since high-density lipoprotein levels tend to be lower in the Latino population, a lower cut-off was used[22,23]. HOMA-IR ≥ 3.8 was utilized to classify insulin resistance, based on studies conducted in the Mexican population[24].

Blood pressure was measured twice, both systolic and diastolic. Measurements were performed by specialized personnel (male and female nurses). The OMRON HEM-907 XL digital sphygmomanometer was used, following the protocol recommended by the American Heart Association[25]. High blood pressure was considered for systolic blood pressure values ≥ 130 mmHg and diastolic blood pressure ≥ 85 mmHg, according to the guidelines of the American Heart As-

sociation and the American College of Cardiology[25].

Sociodemographic variables

Covariates included age, sex, socioeconomic status, tobacco use, alcohol use, and body mass index. The participant's gender expression was assigned by the interviewer through observation and then confirmed with the participant by the interviewer, their biological sex. Household socioeconomic status was based on the 2018 Mexican Association of Market Research Agencies rule, which considers specific dwelling characteristics, household possessions, and education level, especially for the head of household[26]. A calculation is performed, and according to the score obtained in each category, a cut-off of seven socioeconomic levels is defined: A/B: 205 or more, C+: 166 to 204, C: 136 to 165, C-: 112 to 135, D+: 90 to 111, D: 48 to 89, and E: 0 to 47. For the current study, the original levels were grouped into 4, as follows: A/B/C+, C, C-, and D/D+/E.

Smoking status was obtained by asking the questions: "Do you currently smoke tobacco (every day, some days, do not currently smoke)?" and "In the past, have you smoked tobacco products (every day, some days, have never smoked)?". Based on both questions, participants were categorized as follows[27]: 1) Non-smoker: A person who reported never having smoked in their life. 2) Ex-smoker: A participant who reported having smoked at some point in their life and quit smoking more than a year ago. 3) Light smoker: A participant who reported smoking only on a few or some days during the past year. 4) Frequent smoker: A participant who reported having smoked daily during the past year.

Alcohol consumption was obtained using the questions "Do you currently drink?" (options: yes, no, and never), and "Approximately, how many glasses of alcohol do you drink (or used to drink), and how often?" (options: daily, weekly, monthly, occasional, no answer; and the number of drinks consumed). Weekly drinking frequency was classified, and the average number of drinks consumed was calculated. Based on the previous answers, participants were categorized as follows: 1) Never consumed alcohol; 2) Former drinkers, consumed alcohol occasionally or whose average number of drinks was less than or equal to one; 3) Light drinkers, who occasionally consume alcohol or whose average number of drinks is less than or equal to one; 4) Frequent drinkers are those who currently consumed alcohol and whose average number of drinks was greater than one.

The World Health Organization cut-off points were used as a reference to classify the body mass index, calculated by dividing the participant's weight (expressed in kilograms) by their height in squared meters (m^2). Body mass index values <12.0 and >50.0 kg/m^2 were excluded.

Statistical analysis

Statistical analyses were performed using Stata 17.0. For descriptive analysis, means are reported for continuous variables, and absolute frequencies and proportions for categorical variables. Quartiles were obtained for vigorous and moderate PA, walking, and sitting time. The prevalence of CMR was estimated according to PA indicators and sitting time. Poisson regression models were used, with CMR as the dependent variable and PA indicators and sitting time as the independent variables. Although the odds ratio (estimated by logistic regression models) is usually estimated, this measure of association is appropriate for use in case-control studies, as the National Health and Nutrition Examination Survey is a cross-sectional survey, the appropriate measure of association is the prevalence ratio. This measure can be derived from Poisson regression models[28]. All analyses were stratified by sex. The models were adjusted for age, socioeconomic status, alcohol consumption, and smoking status. Two additional models were estimated using data only for men. The listed variables were included in one model, plus sitting time (when the independent variable was PA) or PA levels (when the independent variable was sitting time). In addition, the potential mediating role of body mass index was assessed by incorporating it into another model; p values < 0.05 were considered significant.

Results

The majority of participants were women, and the age groups were evenly distributed (Table 1). One-third of the participants belonged to socioeconomic level D. More than half of the sample did not smoke or consume alcohol, and one-third were overweight or obese. Compared to women, more men were in a higher socioeconomic class, had higher tobacco and alcohol consumption, and a lower body mass index.

Two-thirds of the population did not meet the PA recommendations (Table 2). Approximately a quarter of participants reported walking for more than 150 minutes/week. More than half of the participants

Table 1 – Sociodemographic and lifestyle characteristics of Mexican adults, 2018

	Total		Men		Women	
	Weighted mean	Standard error	Weighted mean	Standard error	Weighted mean	Standard error
Age, years	38.8	0.2	38.8	0.3	38.7	0.3
Weight (kg)	74.2	0.3	79.8	0.5	70.2	0.4
Height (cm)	160.0	0.2	167.7	0.2	154.7	0.2
Body mass index (kg/m2)	28.9	0.1	28.3	0.1	29.3	0.1
	Freq (n)	Freq (%)	Freq (n)	Freq (%)	Freq (n)	Freq (%)
Sex						
Men	4,029	40.9				
Women	5,768	59.1				
Age						
20-29 years	2,365	27.3	986	27.7	1,379	27.0
30-39 years	2,690	23.2	1,055	22.4	1,635	23.7
40-49 years	2,682	27.7	1,101	26.8	1,581	28.4
50-59 years	2,060	21.8	887	23.1	1,173	20.9
Socioeconomic level						
E	284	1.8	113	1.4	171	2.0
D	3,146	22.5	1,231	20.4	1,915	24.0
D+	2,042	18.3	862	18.3	1,180	18.3
C-	1,782	20.8	689	19.6	1,039	21.6
C	1,417	18.8	598	19.7	819	18.1
A/B	1,126	17.8	536	20.5	590	16.0
Smoking status						
Non-smoker	6,303	62.6	1,653	41.3	4,650	77.3
Ex-smoker	1,861	19.3	1,201	27.6	660	13.5
Light smoker	1,002	10.5	723	17.8	279	5.5
Frequent smoker	631	7.6	452	13.4	179	3.7
Alcohol consumption						
Does not drink alcohol	3,392	34.4	468	13.9	2,824	48.6
Former drinker	2,712	28.2	1,145	27.6	1,567	28.6
Light drinker	1,241	12.8	965	24.8	276	4.5
Frequent drinker	2,552	24.6	1,451	33.7	1,101	18.3
Nutricional status						
Normal	2,242	24.5	1,015	26.5	1,227	23.1
Overweight	3,776	38.1	1,692	40.7	2,084	36.3
Obesity	3,779	37.4	1,322	32.8	2,457	40.6

spent at least four hours/day sitting. Men spent more time engaged in vigorous activity and walking, but less time engaged in moderate-intensity activities.

More than a third of the participants presented high systolic blood pressure, and nearly a quarter had hypercholesterolemia and hypertriglyceridemia, respectively. Insulin resistance was present in just over a quarter of the individuals. Three out of ten participants had CMR (Table 3). Men had higher prevalence values in four of the five CMR components, so the prevalence of CMR was also higher in this group.

The prevalence of CMR did not differ according to PA and sedentary lifestyle variables (Table 4). After adjusting for other covariates (sex, age, socioeconomic status, alcohol consumption, and smoking), it was observed that individuals with a high PA level, those in the quartile IV of vigorous PA, and those in the quartile III of moderate PA were less likely to have CMR compared to their counterparts. Furthermore, individuals who spent more time sitting (quartile IV) were more likely to present CMR compared to those in quartile I. These differences were observed in men, but not in women. Furthermore, in men, PA volume and compliance with World Health Organization PA recommendations were

Table 2 – Distribution according to physical activity indicators and sitting time (n = 9,797) in Mexican adults, 2018

	Total		Men		Women	
	Weighted mean	Standard error	Weighted mean	Standard error	Weighted mean	Standard error
Moderate and vigorous physical activity (minutes/week)	688.0	13.0	935.2	23.2	517.2	13.1
Physical activity levels according to metabolic equivalents (minutes/week)	3,840.3	61.5	5,001.2	106.1	3,037.8	63.1
Vigorous activity (minutes/week)	167.1	5.2	312.0	10.1	66.9	4.0
Moderate activity (minutes/week)	353.8	7.3	311.2	10.5	383.3	9.6
Walking (minutes/week)	329.7	6.5	381.9	10.5	293.7	7.6
Sitting time (hours/day)	2.5	0.0	2.7	0.0	2.4	0.0
	n	%	n	%	n	%
Physical activity volume (metabolic equivalent minutes/week)						
Low <600	1,681	17.5	555	13.7	1,126	20.2
Moderate 600-2999	3,091	34.6	1,070	28.8	2,021	38.6
High >3000	5,025	47.8	2,404	57.5	2,621	41.2
Physical activity level						
Inactive	1,859	18.6	630	15.4	1,229	20.8
Moderate	2,745	31.0	905	24.8	1,840	35.2
High	5,193	50.5	2,494	59.9	2,699	43.9
Meets World Health Organization recommendations						
Yes	6,705	66.2	2,990	73.3	3,715	61.4
Vigorous activity						
Quartile I-II	5,936	60.7	1,573	39.6	4,363	75.4
Quartile III	1,552	16.9	791	21.7	761	13.6
Quartile IV	2,309	22.4	1,665	38.7	644	11.1
Moderate activity						
Quartile I	2,569	27.8	1,116	28.5	1,453	27.4
Quartile II	2,411	26.1	1,168	29.8	1,243	23.5
Quartile III	2,512	25.2	1,022	25.2	1,490	25.2
Quartile IV	2,305	20.9	723	16.5	1,582	23.9
Walking						
Quartile I	2,514	25.6	934	23.8	1,580	26.8
Quartile II	2,391	25.2	870	22.3	1,521	27.2
Quartile III	2,635	28.0	1,053	27.5	1,582	28.3
Quartile IV	2,257	21.3	1,172	26.5	1,085	17.7
Sitting						
Quartile I	2,524	24.9	19.9	19.9	1,678	28.4
Quartile II	2,404	23.1	23.0	23.0	1,459	23.2
Quartile III	2,579	26.2	27.6	27.6	1,434	25.3
Quartile IV	2,290	25.8	29.5	29.5	1,197	23.2

Table 3 – Distribution according to cardiometabolic risk indicators in Mexican adults, 2018 (n = 9,797)

	Total		Men		Women	
	Weighted mean	Standard error	Weighted mean	Standard error	Weighted mean	Standard error
Systolic blood pressure (mmHg)	131.7	0.8	136.6	1.1	128.3	1.1
Diastolic blood pressure (mmHg)	92.3	1.2	94.4	1.5	90.9	1.4
Total cholesterol (mg/dl)	185.6	0.7	187.2	1.1	184.5	0.8
Non-high-density lipoprotein cholesterol (mg/dl)	141.0	0.6	144.5	1.0	138.6	0.8

Continue…

Continuation of **Table 3 –** Distribution according to cardiometabolic risk indicators in Mexican adults, 2018 (n = 9,797)

	Total		Men		Women	
	Weighted mean	Standard error	Weighted mean	Standard error	Weighted mean	Standard error
Low-density lipoprotein cholesterol (mg/dl)	103.8	0.6	103.7	0.6	103.9	0.7
High-density lipoprotein cholesterol (mg/dl)	44.6	0.2	42.7	0.3	45.9	0.2
Blood glucose (mg/dl)	102.5	0.8	102.0	1.1	102.9	1.1
Insulin (μU/mL)	15.2	0.4	14.6	0.5	15.6	0.4
Homeostatic Model Assessment for Insulin Resistance (%)	4.2	0.1	4.1	0.2	4.3	0.2
	n	%	n	%	n	%
Hypertension (systolic blood pressure)	3,330	33.5	1,747	42.0	1,583	27.6
Hypertension (diastolic blood pressure)	2,861	27.9	1,417	33.2	1,444	24.1
Hypercholesterolemia	1,684	17.3	709	18.7	975	16.4
Hypoalphalipoproteinemia	1,915	18.1	1,048	24.8	867	13.6
Insulin resistance	2,727	28.5	1,012	27.4	1,715	29.3
Cardiometabolic risk	3,842	38.7	1,853	44.9	1,989	34.5

Table 4 – Prevalence of cardiometabolic risk according to physical activity and sitting time indicators in Mexican adults, 2018.

	Total		Men		Women	
	%	Prevalence ratio[1]	%	Prevalence ratio[2]	%	Prevalence ratio[2]
Volume of physical activity						
Low	39.3	Ref.	52.5*	Ref.	33.2	Ref.
Medium	38.2	0.97	45.4	0.87†	34.5	1.07
High	38.9	0.94	42.9	0.83**	35.0	1.06
Physical activity level						
Inactive	42.1†	Ref.	54.8**	Ref.	35.6	Ref.
Moderate	36.6	0.89*	42.7	0.78**	33.7	0.99
High	38.8	0.89*	43.3	0.79**	34.5	0.99
Meets World Health Organization recommendations						
No	39.5	Ref.	49.9*	Ref.	34.5	Ref.
Yes	38.4	0.94	42.1	0.88*	34.4	1.00
Vigorous activity						
Quartile I-II	40.2	Ref.	51.8***	Ref.	36.0†	Ref.
Quartile III	35.6	0.87*	40.9	0.84*	29.8	0.93
Quartile IV	37.3	0.84**	40.2	0.82**	30.0	0.91
Moderate Activity						
Quartile I	41.1†	Ref.	50.4**	Ref.	34.4	Ref.
Quartile II	37.0	0.93	40.6	0.83*	33.9	1.06
Quartile III	35.9	0.89*	42.0	0.85*	31.7	0.93
Quartile IV	41.1	1.02	47.8	0.93	37.9	1.10
Walking, >150.0 minutes/week						
Quartile I	39.7	Ref.	47.0	Ref.	35.2	Ref.
Quartile II	37.7	0.98	42.4	0.94	35.0	1.02
Quartile III	38.0	0.97	45.4	0.97	33.0	0.97
Quartile IV	39.9	0.96	44.7	0.95	34.9	0.98
Sitting ≥ 4 h/d						
Quartile I	36.6	Ref.	40.4†	Ref.	34.8	Ref.
Quartile II	39.2	1.06	43.1	1.07	36.4	1.08
Quartile III	39.1	1.08	44.5	1.15†	35.0	1.06
Quartile IV	40.0	1.14*	49.8	1.30**	31.5	1.00

Ref. = reference group; * p < 0.050, ** p < 0.010, *** p < 0.001 and † 0.100 > p > = 0.050.
1 = The prevalence ratios were derived from models adjusted for age, sex, socioeconomic status, alcohol consumption, and smoking; 2 = The variables for which the models were adjusted are the same as for the total population, only sex was excluded.

Table 5 – Prevalence ratios where the dependent variable is cardiometabolic risk and the independent variables are physical activity and sitting time in Mexican adult men, 2018

	Model 1	Model 2	Model 3
	Prevalence ratio	Prevalence ratio	Prevalence ratio
Volume of physical activity			
Low	Ref.	Ref.	
Medium	0.87†	0.93	
High	0.83**	0.93	
Physical activity level			
Inactive	Ref.	Ref.	Ref.
Moderate	0.78**	0.81*	0.84*
High	0.79**	0.83**	0.89†
Meets World Health Organization recommendations			
No	Ref.	Ref.	
Yes	0.88*	0.90†	
Vigorous Activity			
Quartile I-II	Ref.	Ref.	Ref.
Quartile III	0.84*	0.84*	0.89
Quartile IV	0.82**	0.84**	0.88*
Moderate Activity			
Quartile I	Ref.	Ref.	Ref.
Quartile II	0.83*	0.85*	0.86*
Quartile III	0.85*	0.87*	0.88*
Quartile IV	0.93	0.96	0.93
Sitting ≥ 4 h/d			
Quartile I	Ref.	Ref.	Ref.
Quartile II	1.07	1.07	1.05
Quartile III	1.15†	1.14	1.12
Quartile IV	1.30**	1.26**	1.18*

Ref. = reference group; * p < 0.050, ** p < 0.010, *** p < 0.001 y † 0.100 > p > = 0.050.
Model 1: adjusted for age, socioeconomic status, alcohol consumption, and smoking; Model 2: the same variables as Model 1 plus sitting time for physical activity variables or higher levels of physical activity for sitting time; Model 3: the same variables as Model 2 plus body mass index.

associated with a lower likelihood of CMR.

Since there was no relationship between PA and CMR in women (Table 4), the models presented in Table 5 include data only for men. After adjusting for sitting time, PA volume and adherence to the World Health Organization recommendations were no longer associated with CMR. On the other hand, the relationship between PA levels, moderate PA, and vigorous PA with CMR remained after adjusting for sitting time. The positive association between sitting time and CMR persisted after adjusting for PA levels. In addition, after adjusting for body mass index, the relationship between moderate activity and CMR remained, while the association between CMR and PA levels, vigorous activity, and sitting time was attenuated or disappeared.

Discussion

The results of the current study found that, in Mexican male adults, PA level and time engaged in vigorous or moderate PA were associated with a lower likelihood of developing CMR; while the opposite occurred with sitting time. Furthermore, when adjusting for the body mass index, the relationship between CMR and PA levels, vigorous activity, and sitting time became weaker. In men, total PA volume, adherence to the World Health Organization recommendations, and walking were not related to CMR after adjusting for covariates. No relationships were observed in women.

Our results indicate that sex may modify the relationship between PA and CMR, as this relationship was only present in men, but not in women. As previously observed[16], among Mexican adults, the frequency of CMR and its components was higher in men than in women. It has been suggested that hormonal differences between the sexes may result in a decrease in CMR in women[16]. One possibility that could be ex-

plored in the future is whether the hormonal profile in women limits the protective effect of PA. Another finding observed in Mexican adults is that men presented higher averages of PA, and women had higher averages of walking. This could imply that the intensity of PA performed by women is lower than that required to observe protective effects for CMR. Furthermore, this would lead to less difference or heterogeneity in PA between women than between men.

In Mexican men, PA levels and vigorous and moderate PA were associated with a lower likelihood of CMR. In a meta-analysis[29], it was found that vigorous activity is associated with a lower risk of cardiovascular disease, although recommendations based on questionnaires suggest lower amounts of time in minutes/week, the study suggests a 3:1 equivalence of vigorous activity time measured with devices, and concludes that vigorous activity should be sustained and maintained for a considerable amount of time. In a systematic review [7], it was concluded that the levels of PA that reduce the risk of disease are higher than those recommended by the World Health Organization.

In Mexican adults, neither total volume nor activity levels were associated with CMR. In contrast, there is previous evidence indicating that these associations do exist. A meta-analysis[7] reported that performing higher levels of total PA was significantly associated with a decreased risk of diseases such as diabetes, heart disease, and stroke. In a longitudinal study of American adults[30], total weekly PA volume predicted lower cardiovascular mortality. However, in other studies, neither total volume nor PA level have been associated with CMR. In a cohort study[31], no protective effect was found between PA volume and the progression of coronary artery calcification; it is suggested that PA intensity rather than volume be taken into account. A systematic review[4] found no relationship between measured PA and metabolic equivalents in PA; the authors concluded that metabolic equivalents help establish a relationship with sedentary behavior because they break the cycle of inactivity. In addition, for the association with vigorous PA, it is important to use an objective measure (accelerometer or pedometer).

On the other hand, there is no certain evidence of the threshold for time spent sitting[5]; it is only recommended that the time spent be reduced to the shortest possible time because various studies[32,33] found that a sedentary lifestyle is associated with increased cardiovascular health problems. In Mexican adults, sitting time above 250 minutes per day was associated with a higher likelihood of CMR even after adjusting for PA and body mass index. This finding could be used to establish a recommended maximum time limit for sitting.

The relationship between certain PA variables and sitting time with CMR decreased when adjusted for the body mass index. This suggests that body weight may be a mediator of this relationship; that is, the protective effect of PA on CMR could be due to its negative relationship with body weight. However, the relationship between PA and sitting time and CMR remained the same, so the role of body mass index as a mediator is reduced. Other factors or processes could explain the beneficial effect of PA (independent of weight) on CMR, such as increased muscle mass, increased insulin sensitivity, reduction in low-grade inflammation, platelet stability, and improved endothelial function[34].

Limitations of the study include the fact that the IPAQ presents modest reliability and poor validity (intra-class r of 0.25 for moderate activity and 0.24 for vigorous activity) among adults aged 19-60 years compared with accelerometry[18]; therefore, PA may be overestimated. Furthermore, as this is a cross-sectional study, causality cannot be established. Additionally, ideally, blood pressure should be measured at the same time of day, as variations may occur depending on the time of measurement. However, this is not possible in a population survey, which is another limitation of the present study.

In conclusion, of the five PA variables investigated, only PA levels and vigorous and moderate PA were associated with a lower likelihood of developing CMR. In contrast, people who spent more time sitting (more than four hours) had a higher likelihood of developing CMR. These findings may have implications for promoting an active lifestyle. Current guidelines on sedentary behavior and PA[5] point out that participating in any PA is better than none, and that increasing PA has greater health benefits because it reduces the risk of hypertension, heart disease, stroke, type 2 diabetes, and some types of cancer. The recommendations also indicate reducing the time people spend sitting in all age groups[5]. However, the results showed that meeting walking recommendations did not have a protective effect on CMR, and that only 30% of the population met the World Health Organization recommendations. The protective effect of vigorous activity was only observed in people who spent more time walking. In addition, it was observed that people who remain seat-

ed for more than four hours had a higher probability of CMR, which supports the recommendation of taking active breaks while performing sedentary activities[2]. At the same time, the effect of sedentary behavior disappeared when adjusted for vigorous activity. This suggests that engaging in vigorous activity may somewhat reduce the effect of sedentary behavior. Future studies should investigate whether the lack of association between PA and CMR observed in the women in the current study is also present in other populations. Similarly, the physiological mechanisms by which such an association is not observed in women could be identified. Finally, further research is needed on interventions aimed at reducing the potential negative effects on cardiometabolic health associated with sitting time.

Declaration of conflict of interest

There is no potential conflict of interest.

Authors' contributions

Ortiz-Hernández L: Conceptualization; Methodology; Software development, implementation, and testing; Data validation and experiments; Data analysis; Search; Tool availability; Data curation; Supervision; Project management; Data presentation design; Funding receipt; Writing of the original manuscript; Writing: review and editing; Approval of the final version of the manuscript. Castro-Ramírez D: Methodology; Software development, implementation, and testing; Data analysis; Search; Data curation; Data presentation design; Writing of the original manuscript; Writing: review and editing; Approval of the final version of the manuscript.

Statement on the use of artificial intelligence tools in the article writing process

The manuscript did not use artificial intelligence tools in its development.

Availability of research data and other materials

The contents are available.

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Reviewers' assessment

The reviews of this article were originally conducted in Portuguese. This version has been translated using ChatGPT and subsequently reviewed by the Chief Editors.

Reviewer A

Anonymous

Abstract

- Please correct this word and check the document for any other writing issues. (e.g., line 8 change "sendentarismo" to "sedentarismo").
- Page 1, Lines 11–12 (Methodology): In the description of the total sample, it would be useful to highlight the percentage/n of women in that sample (since women are generally the less represented group in such studies).
- Page 1, Lines 11–12 (Methodology): I suggest including the statistical method that was implemented for the analyses (although it is detailed in the manuscript, it is not in the abstract, which would provide more information for the reader). This helps to understand how the results were obtained and to assess whether the method is appropriate for the study design.
- Page 1, Lines 21–22 (Results): I suggest adding "%" when including CI95. I also recommend changing "two-thirds of the population did not meet physical activity recommendations" to "approximately two-thirds of the population did not meet physical activity recommendations" to improve the wording.
- Page 2, Line 2 (Conclusion): It would be important to briefly include the implications of these results.
- Page 2, Lines 4–5 (Keywords): It is advisable not to include in the keywords those words/concepts that are already used in the introduction and/or title. This increases the chance of visibility for future research. Therefore, I suggest using other concepts or synonyms in this section (e.g., movement, exercise, etc.).

Introduction

- Page 3, Line 9: Which benefits are being referred to? It would be appropriate to mention at least some.
- Page 3, Line 13: If the abbreviation "PA" (physical activity) is used, it should consistently be applied throughout the text. Please review the entire manuscript to ensure consistency in writing.
- Same applies for the concept "cardiometabolic risk."
- Page 3, Line 15: Why is it important to evaluate from the perspective of co-occurrence (beyond what is described, since factors are usually analyzed in isolation)? Please briefly explain why studying the combination of these factors is more relevant or clinically significant. I suggest elaborating further on this statement.
- Page 3, Line 16: It would be important to highlight, at least briefly, the difference between being physically active and having sedentary behavior, since both may coexist in an individual, especially given current work patterns.
- I suggest changing "se ha tendido a analizar indicadores de riesgo cardiometabólico de manera aislada" to "los estudios tienden a analizar los indicadores de riesgo cardiometabólico de forma aislada" [in English: "studies tend to analyze cardiometabolic risk indicators in isolation"] for better clarity.
- I suggest changing "confesores" to "confounding factors." I believe this is a more appropriate term.
- Page 3, Line 17: It could be helpful to introduce the term "cardiometabolic risk" earlier in the first paragraph or make the connection between physical inactivity/sedentary behavior and cardiometabolic risk (the specific NCD of interest here) more explicit. This would help focus the reader from the outset on the primary outcome.

Methodology

- The section reads as very long. It would be useful to include subheadings to make reading easier (e.g., sections: statistical analysis, covariates, participants, etc.).
- Page 4, Line 4: It is important to always mention the full name before using an acronym (e.g., ENSANUT).
- Page 4, Line 15: Please also add here the percentage of women in the total sample.
- Page 4, Line 20: I suggest including a reference for the IPAQ questionnaire.
- Page 4, Lines 14–18: Always keep in mind that readers may not be familiar with acronyms (which might be common for researchers), but "LDL" and

"HDL" were not previously described, especially since they are English acronyms, not Spanish. Please spell them out at first use.
- Same applies for HOMA-IR.
- Please briefly explain why a Poisson analysis was chosen instead of a traditional logistic regression (PR vs. OR).
- Page 7, Line 12: Same as above, the acronym "BMI" has not been previously explained. Please include it (since it only appears spelled out later on page 8, line 12, not at its first use).
- Has the possibility of conducting sex-stratified analyses been explored, at least as a sensitivity analysis?

Results
- Page 9, Line 5: It is mentioned that one-third of participants were overweight (BMI <30). Why highlight only the "overweight" category and not "obesity"? Considering that Table 1 is based on weighted means, it would still be important to at least briefly mention that the number of participants with overweight and obesity is quite similar (3,776 vs. 3,779).
- Page 9, Line 14: In general, avoid repeating data already presented in the tables. Add different information in the text.
- Please add the non-significant p-value.
- It is mentioned that "the group that spent more time sitting (quartile IV) had a higher probability of presenting cardiometabolic risk compared to quartile I." However, in Table 4, the confidence intervals are 0.99–1.28, making these results non-significant. Could you explain why this is considered significant?

Discussion
- In the "Limitations" section, it is important to emphasize that since this is a cross-sectional study, causality cannot be established.
- To improve clarity, it is important to state the criteria used to define cardiometabolic risk (in the methodology section). Does this involve 1 or more of the described variables? All of them? Is there a difference if an individual presents with 1 versus multiple variables?
- In the discussion, it is mentioned that when including BMI, significance disappears. It would be interesting to elaborate further on why this happens. Has the possibility of BMI acting as a mediator/moderator in cardiometabolic risk been explored? Would this be the same for people with normal weight, overweight, or obesity? A sensitivity analysis here might add further richness to the findings.
- Considering this is a cross-sectional study, it would be advisable to replace terms more suited to experimental studies (e.g., "effect," which appears several times in the discussion and implications sections). I recommend modifying this to concepts such as "association."
- It would be valuable to provide some guidelines for future research, outlining "next steps" to progressively refine research in this field, thereby contributing to future investigators.

Conclusion
- I believe there is a wording/clarity issue in this section. "(…) only vigorous PA associated with lower probability of presenting cardiometabolic risk." Please review the overall writing to improve understanding.

Tables
- Table 5: Check wording; it says "cardionetaboico." Please correct.

Final opinion (decision)
- Minor revisions required.

Reviewer B
Did not authorize the publication of their review