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Daily sitting time and its association with non-communicable diseases and multimorbidity in Catalonia

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Background: Non-communicable diseases (NCDs) account for 71% of deaths worldwide and individual behaviours such as sedentariness play an important role on their development and management. However, the detrimental effect of daily sitting on multiple NCDs has rarely been studied. This study sought (i) to investigate the association between sitting time and main NCDs and multimorbidity in the population of Catalonia and (ii) to explore the effect of physical activity as a modifier of the associations between sitting time and health outcomes. **Methods:** Cross-sectional data from the 2016 National Health Survey of Catalonia were analyzed, and multivariable logistic regression, adjusting for socio-demographics and individual risk factors (tobacco and alcohol consumption, diet, hyperlipidaemia, hypertension, body mass index) was used to estimated odds ratios (ORs) and 95% confidence intervals (CIs) of the association between sitting time and NCDs. **Results:** A total of 3320 people ≥15 years old were included in the study. Sitting more than 5 h/day was associated with a higher risk of cardiovascular disease (OR 1.90, 95% CI: 1.21–2.97), respiratory disease (OR 1.61, 95% CI: 1.13–2.30) and multimorbidity (OR 2.80, 95% CI: 1.53–5.15). Sitting more than 3 h/day was also associated with a higher risk of multimorbidity (OR 2.26, 95% CI: 1.23–4.16). Physical activity did not modify the associations between sitting time and any of the outcomes. **Conclusions:** Daily sitting time might be an independent risk factor for some NCDs, such as cardiovascular disease, respiratory disease and multimorbidity, independently of the level risk of physical inactivity.

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Introduction

Burden of non-communicable diseases in Europe and Catalonia

According to the World Health Organization (WHO), non-communicable diseases (NCDs) account for 71% of deaths worldwide.[1] Cancer, diabetes, heart disease, mental disorders, stroke and chronic lung disease cause the death of around 15 million per year.[1] Europe is the continent most affected by the burden of NCDs, with cardiovascular disease and cancer causing around 40% and 25% of deaths, respectively.[2] For cancer, lung and breast account for the highest mortality among females (3.9% and 3.2%, respectively), while lung (7%) and colorectal (2.9%) are the most mortal among men. Respiratory diseases are the third most mortal type of NCDs, accounting for around 7.5% of mortality in both sexes.[2] Almost 30 million people in Europe have diabetes (6.9% of population ≥15 years).[3] Catalonia, the Spanish north-east autonomous community, contains 16.1% of the population of Spain, with more than 7.5 million inhabitants.[4] It is an aging society, with more than 18.5% of the population aged over 65 years, and high life expectancy (80.5 years for men and 85.8 for women).[5,6] Thirty-nine percent of the Catalan population (aged ≥15) have an NCD or a chronic condition (36% men; 42% women).[7] In 2016, the main cause of mortality in Catalonia was

malignant tumours (28% of total deaths), followed by cardiovascular diseases (27% deaths), respiratory diseases (10%) and nervous system diseases (8%).[7]

Risk factors to NCDs

The determinants for developing NCDs are both social and individual. Underlying determinants as a combination of genetic, physiological, environmental and behavioural factors are risk factors associated with a higher incidence of cancer, diabetes, cardiovascular and respiratory diseases.[8] Socio-economic determinants influence the lifestyle habits of individulas, contributing to the risk of developing an NCD. The main behavioural risk factors associated with the development of NCDs are tobacco consumption, unhealthy diet, the harmful use of alcohol and insufficient physical activity (PA).[9] The lack of PA increases the risk of cardiovascular disease, hypertension, diabetes, certain forms of cancer, mental health diseases and chronic health conditions.[10] It also has an important role in increasing obesity prevalence among the population, which is associated with disorders of almost every system in the body.[11] It is estimated that nearly one in two adults in the Organisation for Economic Co-operation and Development-related countries, and 2 billion worldwide, have overweight or obesity.[2] Adults with obesity have increased incidence of cardiovascular disease, diabetes, high cholesterol and hypertension.[12–14]

PA, sedentary behaviour and NCDs

One of the main risks for NCDs is the lack of PA.[9,10] The Sedentary Behaviour Research Network defines physical inactivity (PI) as insufficient PA to meet recommended individual level of PA.[15] Although sedentary behaviour is often conceptualized as equivalent to PI, it is differently defined and so should be considered as a different concept. Sedentary activities are defined as those activities with a metabolic expenditure lower than 1.5 Metabolic Equivalent Task (MET),[16] while PI is defined as not reaching the levels of moderate to vigorous PA (MVPA) recommended for health.

Numerous studies have focused on quantifying the levels of PA required to decrease the risk of NCDs. The WHO launched the 'Global Recommendations on PA for Health' in 2010, suggesting moderate (between 3 and 6 METs) to vigorous (more than 6 METs) PA (MVPA) as the optimum levels for individuals to maintain health and prevent diseases.[17]

Sedentary behaviour is independent of the amount of PA and can coexist with high levels of PA.[18,19] Thus, sedentary behaviour has been progressively considered as an independent risk factor from PI associated with higher risk of poor health outcomes.[19,20] Recent studies have studied the associations between sedentary behaviour and the risk of developing type 2 diabetes, some cancers and cardiovascular diseases.[21–31] George et al.[22] studied the association between time spent sitting while watching screens and renal cell carcinoma, without finding significant association between them. Television and video time were found to be associated with a slightly elevated, but non-significant, increase of prostate cancer amongst obese men.[23] The meta-analysis conducted by Shen et al.[24] concluded that prolonged sitting time was associated with some types of cancers (endometrial, colorectal, breast and lung cancers) but not with other type of cancers. Detrimental association between TV watching and the risk of type 2 diabetes has been found, with an increased risk ratio for diabetes comparing the highest quintile of TV watching (>40 h/wk) with the lowest quintile (0–1 h/wk).[25,26] In the Chilean population, sitting time was found positively associated with the risk of diabetes, independent of obesity, socio-demographic and PA levels.[27] Three or more hours per day of screen time were found to be associated with higher risk of developing hypertension compared with individuals reporting <3 h/day in a cross-sectional study among 5527 adults 16–99 years old in Scotland.[28] Howard et al. stated that sitting >6 h/day, compared with those sitting ≤3 h/day, was associated with higher cardio-metabolic biomarkers in plasma in older adults.[29] Some others have confirmed the strong relationships between sitting time and all-cause mortality, independently of the levels of PA.[30,31] However, all these studies used different measurements of sedentary behaviour and focused the study on the associations with only one type of NCD or mortality rates. Thus, we are still lacking of understanding about which amount of daily sitting time is associated with the risk of several main NCDs in the same population, independently of the levels of PA.

Using a national survey from Catalonia, this study aims to explore the association between the daily sitting time and the presence of four main NCDs: diabetes, cancer, cardiovascular disease and respiratory disease as well as multimorbidity (defined for the purpose of this study as the condition of suffering from two or more of these diseases at the same time). This is the first study to analyze five different health outcomes in the same population using daily sitting time as an independent risk factor. It explores as well, for the first time, the variable of sitting time in the population of Catalonia using the National Health Survey. To date, this variable was not explored as a risk factor for the health outcomes of the survey. Furthermore, the study aims to investigate the potential effect of PA on the associations between sitting time and NCDs.

Methods

Study design and population

The data were taken from a cross-sectional study, namely, the 2016 Catalan Health Survey (CHS). Participants signed a confidentiality form provided by the Department of Health and information was anonymized. The data collection was made in two waves within 2016 with a sample of 4818 people from Catalonia: 2389 men and 2429 women, aged 0–99 years old. The confidence interval in all statistical analysis was 95.45% and sampling error +1.4%. Only respondents who were at least 15 years old and able to complete the survey themselves were included. The exclusion criteria were (i) respondents who reported an average daily sitting time of <60 minutes (1 h) or >960 minutes (16 h) per day and (ii) Respondents who answered 'I do not know' or 'Not answer' in any of the variables of interest included in the analysis.

Exposure and outcomes

The exposure variable was 'sitting time', used as proxy of sedentariness. The reported sitting time was exported from the short version of the International Physical Activity Questionnaire (IPAQ),[32] included in the CHS. Question 7 of the IPAQ questionnaire records number of hours and minutes of average sitting time per day in the previous week. The answer is collected as:

'_____hours (0:24) _____minutes (0:59)/day'. Sitting time was categorized in tertiles, in order to have similar amount of cases in each group for statistical purposes, resulting on three categories: ≤3 h/day, >3 to ≤5 h/day and >5 h/day.

The outcomes of interest in this study were diabetes, cancer, cardiorvascular disease and respiratory disease. An additional outcome of 'multimorbidity' was defined as the presence of two or more diseases of these. Each outcome was analyzed separately. The outcomes were self-reported through the CHS questionnaire and included (i) diabetes type 1 or 2, (ii) malignant tumour, (iii) stroke, coronary heart diseases and vascular diseases and (iv) asthma, chronic bronchitis and other respiratory diseases. Respondents were asked about the presence of any of these conditions in the last 12 months diagnosed by a physician.

Statistical analysis

Only individuals with complete information on disease status and variables included in the model were included in the analysis. Univariable and multivariable logistic regression models were used to test for associations between sitting time and health outcomes. Multivariable models were adjusted for (i) sociodemographic variables: age, sex, social class by occupation and education level; (ii) behavioural risk factors: alcohol and tobacco consumption, adherence to mediterranean diet; (iii) and metabolic risk factors: hypertension, hyperlipidaemia, and body mass index (BMI). The variables included followed the risk factors for NCDs highlighted in the model of Dans et al.[33] and the WHO.[9] Hyperglycamia was not included as a risk factor as diabetes was considered an outcome itself for the aims of the study. All the variables were modelled as categorical variables.

The categorization of the social classes followed the social classification by occupation defined by the Epidemiological Spanish Society, based on the 1990 Standard Occupational Classification.[34] Alcohol consumption risk was categorized according to volume, frequency and the standard drink measure in Spain (UBE), which is equivalent to 8–13 g of pure alcohol. The categories of adherence to Mediterranean followed the classification of the PREDIMED questionnaire.[35]

A sensitivity analysis was performed by including PA in the fully adjusted multivariable model. This analysis was conducted only for the group of age from 15 to 69 years old, as the IPAQ calculations

Table 1 Demographic characteristics and prevalence of NCDs of the study population[a]

	n	Diabetes	Cancer	Cardiovascular diseases	Respiratory diseases	Multimorbidity
Total population	3320	230 (6.9%)	49 (1.5%)	150 (4.5%)	209 (6.3%)	92 (2.8%)
Sitting time						
≤3 h/day	1,378 (41.5%)	78 (33.9%)	19 (38.8%)	42 (28.0%)	68 (32.6%)	19 (20.6%)
>3 h to ≤5 h/day	870 (26.2%)	78 (33.9%)	17 (34.7%)	49 (32.7%)	59 (28.2%)	33 (35.9%)
>5 h/day	1,072 (32.3%)	74 (32.2%)	13 (26.5%)	59 (39.3%)	82 (39.2%)	40 (43.5%)
Gender						
Men	1,666 (50.2%)	122 (53.0%)	16 (32.6%)	91 (60.7%)	110 (52.6%)	54 (58.7%)
Women	1,654 (49.8%)	108 (47.0%)	33 (67.4%)	59 (39.3%)	99 (47.4%)	38 (41.3%)
Age						
15–44	1,532 (46.1%)	21 (9.1%)	10 (20.4%)	18 (12.0%)	68 (32.5%)	5 (5.4%)
45–64	1,080 (32.5%)	78 (33.9%)	15 (30.6%)	37 (24.7%)	58 (27.7%)	23 (25.0%)
65–74	341 (10.3%)	62 (27.0%)	13 (26.5%)	27 (18.0%)	35 (16.7%)	24 (26.1%)
≥75	367 (11.1%)	69 (30.0%)	11 (22.5%)	68 (45.3%)	48 (23.0%)	40 (43.5%)
Education level						
University	695 (20.9%)	23 (10.0%)	11 (22.4%)	12 (8.0%)	23 (11.0%)	2 (2.2%)
Secondary school	1,825 (55.0)	95 (41.3%)	27 (55.1%)	55 (36.7%)	108 (51.7%)	40 (43.5%)
Primary school	571 (17.2%)	69 (30.0%)	7 (14.3%)	45 (30.0%)	53 (25.3%)	27 (29.3%)
No studies	229 (6.9%)	43 (18.7%)	4 (8.2%)	38 (25.3%)	25 (12.0%)	23 (25.0%)
Social class by occupation						
I Directors ≥10 employees	333 (10.0%)	13 (5.6%)	9 (18.4%)	7 (4.7%)	14 (6.7%)	2 (2.2%)
II Directors <10 employees	392 (11.8%)	26 (11.3%)	5 (10.2%)	15 (10.0%)	20 (9.6%)	9 (9.8%)
III Freelance, administration	597 (18.0%)	31 (13.5%)	4 (8.2%)	18 (12.0%)	32 (15.3%)	9 (9.8%)
IV Technicians	524 (15.8%)	39 (17.0%)	8 (16.3%)	32 (21.3%)	34 (16.3 %)	17 (18.5%)
V Manual work, qualified	1,091 (32.9%)	93 (40.4%)	16 (32.6%)	60 (40.0%)	79 (37.8%)	42 (45.6%)
VI Not qualified	323 (9.7%)	26 (11.3%)	3 (6.1%)	13 (8.3%)	24 (11.5%)	10 (10.9%)
VII Never worked	60 (1.8%)	2 (0.9%)	4 (8.2%)	5 (3.3%)	6 (2.9%)	3 (3.2%)

a: 2016 Catalan Health Survey (ESCA).
n, Number of cases.

for individual levels of PA are only validated for people younger than 70 years.

PA is categorized in the survey following the three exclusive IPAQ levels as follows:[36]

- Low level of PA: when an individual does <3 days a week 20 minutes of vigorous PA; <5 days a week 30 minutes of moderate PA; or does not reach a minimum of 600 MET/week of total PA.
- Medium level of PA: 3 days of 20 minutes vigorous PA; 5 days of 30 minutes of moderate PA; or a minimum 600 METs/week of total PA.
- High level of PA: minimum 1500 METs/week of vigorous PA or 3000 METs/week of total PA.

Statistical significance level was set at 0.05, and all analyses were carried out using the statistical software STATA version 13.1.

Results

Associations between sitting time and NCDs

A total of 3320 people were included in the study (49.8% women; 53.9% ≥45 years old). Details on the demographic characteristics and prevalence of NCDs of the study population are shown in table 1. Details on the behavioural risk factors and metabolic risk factors and prevalence of NCDs of the study population are shown in table 2.

The results of the univariable and multivariable analysis investigating the association between sitting time and NCDs are shown in table 3.

Sitting between 3 and 5 h/day was significantly associated with diabetes [odds ratio (OR) 1.64, 95% confidence interval (CI): 1.18–2.27], cardiovascular diseases (OR 1.90, 95% CI: 1.24–2.89) and multimorbidity (OR 2.82, 95% CI: 1.59–4.99), compared with sitting <3 h/day in the univariate analysis. However,

Table 2 Behavioural risk factors, metabolic risk factors and prevalence of NCDs of the study population[a]

	n	Diabetes	Cancer	Cardiovascular diseases	Respiratory diseases	Multimorbidity
Total population	3320	230 (6.9%)	49 (1.5%)	150 (4.5%)	209 (6.3%)	92 (2.8%)
Sitting time						
≤3 h/day	1,378 (41.5%)	78 (33.9%)	19 (38.8%)	42 (28.0%)	68 (32.6%)	19 (20.6%)
>3 h to ≤5 h/day	870 (26.2%)	78 (33.9%)	17 (34.7%)	49 (32.7%)	59 (28.2%)	33 (35.9%)
> 5 h/day	1,072 (32.3%)	74 (32.2%)	13 (26.5%)	59 (39.3%)	82 (39.2%)	40 (43.5%)
Tobacco consumption						
Non-smoker	1900 (57.3%)	134 (58.3%)	30 (61.2%)	82 (54.7%)	112 (53.6%)	47 (51.1%)
Ex-smoker	605 (18.2%)	59 (25.6%)	13 (26.5%)	46 (30.7%)	52 (24.9%)	31 (33.7%)
Occasionally	64 (1.9%)	1 (0.4%)	0 (0.0%)	2 (1.3%)	0 (0.0%)	0 (0.0%)
Daily	751 (22.6%)	36 (15.6%)	6 (12.3%)	20 (13.3%)	45 (21.5%)	14 (15.2%)
Alcohol consumption						
No consumption	1062 (32.0%)	103 (44.8%)	25 (51.0%)	66 (44.0%)	75 (35.9%)	49 (53.3%)
Low risk	2097 (63.2%)	123 (53.5%)	24 (49.0%)	79 (52.7%)	127 (60.8%)	40 (43.5%)
High risk	161 (4.85%)	4 (1.7%)	0 (0.0%)	5 (3.3%)	7 (3.3%)	3 (3.2%)
Mediterranean diet						
High adherence	302 (9.1%)	23 (10.0%)	8 (16.3%)	22 (14.7%)	23 (11.0 %)	13 (14.2%)
Medium adherence	2117 (63.8)	161 (70.0%)	35 (71.4%)	94 (62.7%)	133 (63.6%)	58 (63.0%)
Low adherence	901 (27.1%)	46 (20.0%)	6 (12.3%)	34 (22.7%)	53 (25.4%)	21 (22.8%)
Hypertension						
Yes	633 (19.1%)	125 (54.3%)	19 (38.8%)	86 (57.3%)	76 (36.4%)	62 (67.4%)
No	2687 (80.9%)	105 (45.7%)	30 (61.2%)	64 (42.7%)	133 (63.6%)	30 (32.6%)
Hyperlipidaemia						
Yes	528 (15.9%)	111 (48.3%)	18 (36.7%)	59 (39.3%)	62 (29.7%)	47 (51.1%)
No	2792 (84.1%)	119 (51.7%)	31 (63.3%)	91 (60.7%)	147 (70.3%)	45 (48.9%)
BMI						
Low weight (BMI <18.5)	83 (2.5%)	2 (0.9%)	2 (4.1%)	0 (0.0%)	9 (4.31%)	2 (2.2%)
Normal weight (BMI ≥18.5 to <25)	1574 (47.4%)	46 (20.0%)	19 (38.8%)	57 (38.0%)	59 (28.2%)	24 (26.1%)
Overweight (BMI ≥25 to <30)	1166 (35.1%)	100 (43.5%)	18 (36.7%)	55 (36.7%)	81 (38.8%)	34 (37.0%)
Obesity (BMI ≥30)	497 (15.0%)	82 (35.6%)	10 (20.4%)	38 (25.3%)	60 (28.7%)	32 (34.8%)

a: 2016 Catalan Health Survey (ESCA).
n, Number of cases.

in the fully adjusted model sitting between 3 and 5 h/day was only significantly associated with multimorbidity (OR 2.26, 95% CI: 1.23–4.16).

Sitting more than 5 h/day was significantly associated with cardiovascular disease (OR 1.85, 95% CI: 1.24–2.77), respiratory diseases (OR 1.59, 95% CI: 1.14–2.22) and multimorbidity (OR 2.80, 95% CI: 1.53–5.15) in the univariate analysis. The association remained significant in the fully adjusted model: cardiovascular disease (OR 1.90, 95% CI: 1.21–2.97), respiratory diseases (OR 1.61, 95% CI: 1.13–2.30) and multimorbidity (OR 2.80, 95% CI: 1.53–5.15).

There was no evidence of associations between sitting time and cancer, neither for the univarable nor for the multivariable analysis. Supplementary table S1 shows the associations between sitting time and NCD, adding gender and age categories.

Sensitivity analysis

When using the fully adjusted model in the smaller sample (*n* = 2788), the risk of sitting >5 h/day associated with cardiovascular diseases lost its significance (*P* = 0.070). The risk associated with respiratory diseases and multimorbidity when sitting >5 h/day and the risk associated with multimorbidity when sitting >3 h/day remained significant. The results did not change when PA was adjusted to the model (table 4).

Supplementary table S2 shows results of the sensitivity analysis adding gender and age categories.

Discussion

Sitting >3 h/day might be associated with higher risk of multimorbidity. Sitting >5 h/day might be associated with an increased risk of

Table 3 Odds ratios associated with sitting time for the risk of four main NCDs and multimorbidity in the population of Catalonia (≥15 years old)

	Crude OR (95% CI)	*P*-value	Multivariable aOR[a] (95% CI)	*P*-value
Diabetes				
≤3 h/day	Reference		Reference	
>3 h to ≤5 h/day	1.64 (1.18; 2.27)	0.003	1.28 (0.89; 1.82)	0.177
>5 h/day	1.23 (0.89; 1.72)	0.207	1.16 (0.90; 1.68)	0.438
Cancer				
≤3 h/day	Reference		Reference	
>3 h to ≤5 h/day	1.42 (0.74; 2.76)	0.292	1.15 (0.58; 2.30)	0.683
>5 h/day	0.88 (0.43; 1.78)	0.720	0.76 (0.36; 1.62)	0.483
Cardiovascular diseases				
≤3 h/day	Reference		Reference	
>3 h to ≤5 h/day	1.90 (1.24; 2.89)	0.003	1.55 (0.99; 2.44)	0.055
>5 h/day	1.85 (1.24; 2.77)	0.003	1.90 (1.21; 2.97)	0.005
Respiratory diseases				
≤3 h/day	Reference		Reference	
>3 h to ≤5 h/day	1.40 (0.98; 2.01)	0.066	1.24 (0.85; 1.79)	0.258
>5 h/day	1.59 (1.14; 2.22)	0.006	1.61 (1.13; 2.30)	0.008
Multimorbidity (≥2 diseases)				
≤3 h/day	Reference		Reference	
>3 h to ≤5 h/day	2.82 (1.59; 4.99)	<0.001	2.26 (1.23; 4.16)	0.008
>5 h/day	2.77 (1.60; 4.81)	<0.001	2.80 (1.53; 5.15)	0.001

aOR, adjusted odds ratio.

a: Adjusted by socio-demographic covariates (age, gender, social class by occupation, education level), behavioural risk factors (tobacco consumption, alcohol consumption, adherence to Mediterranean diet) and metabolic risk factors (hypertension, hyperlipidaemia—both as with or without the disease diagnosed by a doctor, and BMI).

Table 4 Odds ratios associated with sitting time for the risk of main NCDs and multimorbidity in the population of Catalonia with and without PA (≥15 to <70)

N = 2788	Multivariable aOR[a] Without PA (95% CI)	*P*-value	Multivariable aOR[a] With PA (95% CI)	*P*-value
Diabetes				
Sitting ≤3 h/day	Reference		Reference	
Sitting >3 h to ≤5 h/day	1.22 (0.76; 1.95)	0.403	1.23 (0.77; 1.97)	0.385
Sitting >5 h/day	1.37 (0.85; 2.21)	0.191	1.31 (0.81; 2.13)	0.271
Cancer				
Sitting ≤3 h/day	Reference		Reference	
Sitting >3 h to ≤5 h/day	0.79 (0.32; 1.98)	0.617	0.79 (0.32; 1.98)	0.619
Sitting >5 h/day	0.80 (0.32; 2.00)	0.638	0.80 (0.32; 2.02)	0.638
Cardiovascular diseases				
Sitting ≤3 h/day	Reference		Reference	
Sitting >3 h to ≤5 h/day	1.69 (0.90; 3.16)	0.104	1.68 (0.89; 3.15)	0.108
Sitting >5 h/day	1.82 (0.95; 3.48)	0.070	1.81 (0.93; 3.49)	0.079
Respiratory diseases				
Sitting ≤3 h/day	Reference		Reference	
Sitting >3 h to ≤5 h/day	1.18 (0.75; 1.86)	0.461	1.19 (0.76; 1.87)	0.448
Sitting >5 h/day	1.70 (1.11; 2.59)	0.014	1.67 (1.09; 2.57)	0.018
Multimorbidity				
Sitting ≤3 h/day	Reference		Reference	
Sitting >3 h to ≤5 h/day	2.77 (1.08; 7.10)	0.033	2.75 (1.07; 7.09)	0.035
Sitting >5 h/day	4.74 (1.89; 11.87)	0.001	4.23 (1.67; 10.74)	0.002

aOR, Adjusted odds ratio.

a: Adjusted by demographic covariates (age, gender, social class by occupation, education level), behavioural risk factors (tobacco consumption, alcohol consumption, adherence to Mediterranean diet) and metabolic risk factors (hypertension, hyperlipidaemia—both as with or without the disease diagnosed by a doctor, and BMI).

respiratory diseases, cardiovascular diseases and multimorbidity in the population ≥15 years old. There was no evidence of an association between sitting time and diabetes and cancer when adjusted by socio-demographic and risk factors. PA does not appear to modify the associations between daily sitting time and the presence of respiratory disease or multimorbidity.

For cardiovascular diseases, our study suggests that when analyzing population younger than 70 years old, sitting >5 h/day loses its association with the presence of the disease. Therefore, sitting >5 h/day may be only associated with cardiovascular diseases for people

older than 69 years old. Petersen et al.[37] concluded that the risk of suffering from cardiovascular disease was associated with sitting more than 10 h/day, for a Danish population 18–99 years old. Based on our study, population older than 69 might be at risk already sitting more than 5 h/day, while the risk of sitting associated to younger people, although still undertermined, might appear when sitting longer hours.

To date, there are no studies that assess associations between sitting time and the presence of respiratory disease or multimorbidity, even though some studies suggest that highest sedentary

behaviour is associated with poorer perceived health among older adults with COPD.[38] Our study suggests that sitting more than 5 h/day seems associated to a higher risk of respiratory diseases, independent of the level of PA. In the case of multimorbidity, the fact of suffering from two or more diseases may influence individuals to have a sedentary behaviour, so the high odds ratio observed for sitting more than 3 and 5 h/day may be the consequence and not the cause of the multimorbidity condition.

The results of diabetes are different from the findings of de Heer et al.[39] carried out in the United States with a sample of Mexican adults. This study shows that people sitting >4 h had almost 30% higher odds of having diabetes than people sitting <2 h/day. Differences might be due to different covariates included in the analysis and other socio-economic and cultural factors, which may affect associations. On the other hand, the no association found for cancer is aligned with the results of Shen et al.,[24] who found that sedentary behaviour seemed independently associated with an increased risk of incidence of some type of cancers such as breast, endometrial, colorectal and lung, but not with other type of cancers. Therefore, when all types of cancer are analyzed together, the association between sitting time and prevalence of cancer may lose its significance.

Sitting time and PA

The sensitivity analysis conducted suggests that individual PA level may not attenuate neither the risks of respiratory diseases associated with sitting long periods of time (>5 h/day) nor the risk of multimorbidity associated with sitting >3 h/day. Therefore, in our study, PA does not seem to be a modifier of the associations between daily sitting time and the presence of respiratory diseases and multimorbidity for the population 15–69 years old. These results suggest that both variables may act independently: an individual can have a risk associated with sedentariness and, at the same time, have an added potential risk associated to not reaching the recommended levels of MVPA.

These results are broadly aligned with those of previous studies concerning the relationship between sedentariness and NCDs and mortality rates, which concluded that sedentariness was independent of levels of PA. An explanation for these findings was suggested by Tremblay et al.[40] who stressed that physiological responses and adaptations to sedentary behaviours may not be the opposite of exercise physiology and not necessarily affect physiological systems in the same way. Sedentary behaviour, commonly misunderstood and/or interpreted as insufficient PA, seems to have its own risk associated with NCDs. PA might attenuate the detrimental effect of sitting on health, but it seems that it does not eliminate it. The systematic review conducted by Ekelund[30] suggested that for individuals in the most active quartile of PA, level of daily sitting time was not associated with increased all-cause mortality. However, the study concluded that this high-level activity does not eliminate the increased risk for all-cause mortality specifically associated with high TV-viewing time.[30]

Limitations and strengths of the study

Due to the cross-sectional design of the study and the lack of temporal relationships between exposure and outcomes, causality cannot be established. Data about sitting time of people ≥70 years old may not be correctly auto-reported as IPAQ questionnaire has been validated only for people from 15 to 69 years old. This means that the IPAQ questionnaire might not be effective for collecting real values of sedentary behaviour due to the general low understanding of what means 'sitting time' and which activities need to be included when reporting this information at this age range.[35] Therefore, daily sitting hours reported by people ≥70 years old might be underestimated when answering the questionnaire. In addition, the potential compensatory effects of PA have not been analyzed for this population. Data related to daily sitting time were relative to the previous week only, as PA levels. As IPAQ is a tool that is not focused in sitting time but in PA, the sensibility and specificity of this tool to measure sitting time could be compromised and does not allow to consider the potential long-term effect of sitting time (e.g. its effect during the past 10 or 20 years). Sitting time, PA and outcome information was collected by self-reported questionnaires, with risk for recall bias. However, outcome data were only counted if a physician made the diagnosis, providing strength to the associations found.

Despite these limitations, the study provides data on 3320 respondent's sitting time and NCD, allowing a robuts analysis of the associations between daily sitting time and the selected NCDs as well as multimorbidity. In addition, the study allows to assess the role of PA in the associations found between daily sitting time and NCDs in a population of 2788 individuals from 15 to 69 years old. The study used the WHO model of risk factors associated with NCDs but tested the effect of sitting time—as a proxy of sedentariness—rather than PI—understood as not reaching the recommended levels of MVPA—as one of the behavioural risk factors of the model. The substitution of this variable and the findings of the study open a new door for further research on the risk associated with sedentary behaviour with NCD as distinct risk from PI suggesting the inclusion of both behavioural risk factors in the WHO model. In addition, this is the first study that disaggregates the data from the IPAQ questionnaire analyzing separately the level of PA (result of the questionnaire) with the specific question about daily sitting time, which not included in the algorithm to calculate levels of PA. This study aims to add knowledge on the associations with the prevalence of NCDs—diabetes, cancer, cardiovascular disease, respiratory diseases—and multimorbidity for the first time in the population of Catalonia.

Implications for public health policy

Our research suggests that prolonged sitting time may be a public health problem that needs priorization, specially associated to respiratory disease, multimorbidity, and cardiovascular disease at older age. Action should be addressed to increase awareness of the potential harmful effect of sitting independently of the amount of individual PA. This action claims for urgency due to the changes in work and leisure time that worldwide population have experienced during the COVID-19 pandemic, activities that have often become more sedentary and home-based due to the general commuting and social restrictions. Specific research should be conducted on patterns of sitting time by different age ranges and social class by occupation, in order address appropriate public health actions accordingly to the needs of each population group. Further research is needed to understand the nature of sedentary behaviour, its reasons and its detrimental effect on individuals' health and the development of NCDs. Longitudinal studies on the health risk of sitting would help in assessing any causality, and hence help public health professionals to develop evidence-based programs to prevent and manage NCDs.

Supplementary data

Supplementary data are available at *EURPUB* online.

Funding

Conflicts of interest: The authors state to have no conflicts of interest associated with this study.

Key points

- This study adds knowledge on the importance of sedentary behaviour as a potential independent risk factor from PI associated with higher risk of poor health outcomes.
- This study explores for the first time the associations of daily sitting time with four main NCDs and multimorbidity in the same population.
- This study explores for the first time the information provided by question number seven of the IPAQ questionnaire about daily sitting time, which is not included in the algorithm of the questionnaire to assess individual's PA levels.
- This study suggests that sitting time may be a public health problem that needs priorization independently of physical activity levels, specially associated to respiratory diseases and multimorbidity, and cardiovascular disease at older age.
- The results of this study may be of special importance to public health authorities specially due to the current pandemic situation, where work and leisure times have often become more sedentary, suggesting to take immediate action to reduce daily sitting time of individuals and avoid poor health outcomes in the near future.

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