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HEALTH SCIENCES

Association of physical activity and sedentary behavior with metabolic syndrome and its components among older adults: a cross-sectional study

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Abstract: The aim of this study is to examine the independent and combined associations of physical activity (PA) and sedentary behavior (SB) with metabolic syndrome (MS) components in older adults. This cross-sectional study included 473 older adults aged ≥60 years, living in the urban area of the municipality of Alcobaça, Brazil, and enrolled in the municipality's Family Health Strategy. Sociodemographic information, anthropometric measurements, laboratory and behavioral data were collected. The prevalence of MS was 52.8%. Longer time spent in SB was associated with central obesity (OR 2.85; 95% CI: 1.52-5.25) and hypertension (OR 1.86; 95% CI: 1.23-2.85). In the combined analysis, insufficiently active older adults with longer SB time were more likely to have two (OR 3.90; 95% CI: 1.46-10.42) to four (OR 4.18; 95% CI: 1.12-15.62) components. Even sufficiently active older adults with longer SB time had higher odds of central obesity (OR 3.44; 95% CI: 1.51-7.87), hypertension (OR 2.30; 95% CI: 1.30-4.05), and low HDL-c levels (OR 1.84; 95% CI: 1.03-3.28). SB is a determining factor in the prevalence of MS in older adults, with implications for public health policies that promote frequent interruptions of sedentary time and encourage regular PA.

Key words: Physical Activity, Sedentary Behavior, Metabolic Syndrome, Older Adults, Aging.

INTRODUCTION

Metabolic syndrome (MS) is a complex pro-inflammatory and pro-thrombotic condition characterized by a cluster of cardiometabolic risk factors including central obesity, arterial hypertension, dyslipidemia, hyperglycemia, and low high-density lipoprotein cholesterol (HDL-c) (Basu et al. 2023). MS is associated with several diseases, including type II diabetes mellitus, cardiovascular disease, cancer, mild cognitive impairment, and progression to dementia, with its impact being particularly pronounced among older populations (Feinkohl et al. 2019, McCarthy et al. 2023).

Given that MS is associated with increased morbidity and mortality, the consequences of accelerated population aging and the concomitant increase in other chronic diseases, further exacerbate (Hirode & Wong 2020). Studies support this statement, showing that the prevalence of MS increases with age, affecting 38.4% of the Brazilian population and can reach 66.1% in older adults (Oliveira et al. 2020). In the United States, rates vary, with approximately 34.7% in the general population and 48.6% in older adults (Hirode & Wong 2020).

In this context, modifiable factors such as physical activity (PA) stand out for their significant impact on human health, promoting healthier aging by mitigating the effects of the aging process (Zhang & Liu 2024). Studies indicate that insufficient PA is associated with a greater risk of developing MS (Kim et al. 2019, Lee et al. 2012, Park & Larson 2014).

Similarly, sedentary behavior (SB) has been strongly associated with an increased likelihood of developing MS (De la Cámara et al. 2022). The reduction in PA levels, driven by economic growth and industrialization, has contributed to an increase in the time spent in SB in adults, especially older adults (Katzmarzyk 2010). Such activities tare defined by an energy expenditure below 1.5 metabolic equivalents (METs) and typically occur in a seated or reclining position during waking hours (Tremblay et al. 2017).

Recent studies have demonstrated the harms associated with prolonged exposure to SB, regardless of the level of PA practiced (Katzmarzyk et al. 2009, Kim & Kang 2019, Meneguci et al. 2015, Van der Ploeg et al. 2012). In other words, even for individuals who meet weekly or daily PA recommendations, excessive exposure to SB may have negative health effects. It is therefore essential to recognize that these behaviors do not occur independently (Matias et al. 2018). When combined, PA and SB time can form different behavioral patterns with a synergistic effect, highlighting the importance of interventions that stimulate a positive behavioral pattern to achieve health benefits (Ekelund et al. 2016).

In Brazil, most studies based on combined analyses of PA and SB have been conducted in adolescents (Jordão et al. 2018, Maia et al. 2018, Mesquita et al. 2017) and in workers and students (Del Duca et al. 2015, Tan et al. 2020), with only two in older adults (dos Santos et al. 2022, Manta et al. 2019). This research gap in the older adult population is particularly concerning, given the progressive aging of the Brazilian population and the importance of understanding the behavioral patterns of this age group. Such studies are relevant because they show that positive and negative behaviors can coexist (Manta et al. 2019) and indicate possible behavioral patterns that can be followed by the population.

Given the above, this study aimed to assess the independent and combined associations of PA and SB with MS components in older adults. Our hypothesis is that there is a significant association between SB and the isolated components of MS in older adults, in addition to a significant relationship between the combination of PA and SB levels with the grouping of MS components, and behavioral patterns characterized by longer SB time and lower PA levels significantly influence the prevalence of central obesity and arterial hypertension in older adults.

Ethical Approval and Consent to Participate

All participants were invited to sign an Informed Consent Form, and all other protocols and procedures of the study were conducted in accordance with the Declaration of Helsinki, having been previously approved by the Research Ethics Committee on Human Beings of the Federal University of the Triângulo Mineiro (Ordinance 966.983/2015).

MATERIALS AND METHODS

Study sample and design

This cross-sectional study is part of the '*Estudo Longitudinal de Saúde do Idoso de Alcobaça*' (ELSIA). It began in 2015 and involved a sample of the urban population associated with the Family Health Strategy (ESF) program, aged 60 years or older in the city of Alcobaça, Bahia, Brazil.

Details of the study, data collection procedures and inclusion criteria have been described previously (Galvão et al. 2018, da Silva et al. 2019). In brief, the initial population consisted of 743 older adults registered in the Family Health Strategy, of whom 54 refused to participate in the study, 58 were excluded for not meeting the inclusion criteria, and 158 could not be located after three attempts. The final study sample consisted of 473 older adults of both sexes aged ≥ 60 years, with 296 (62.5%) women and 177 (37.5%) men.

Exclusion criteria were: a) not meeting the minimum score (12 points) on the Mini Mental State Examination (MMSE) (Folstein et al. 1975), adapted for the Brazilian population (Almeida 1998); b) severe visual and/or hearing impairment; c) use of a wheelchair; d) severe sequelae of stroke with localized loss of strength; and e) terminal illness.

Ethical procedures

The study complied with to the Declaration of Helsinki and was approved by the Human Research Ethics Committee of the Universidade Federal do Triângulo Mineiro (nº 966.983/2015; on February 25, 2015). The research was conducted between June and September 2015.

We invited individuals to participate and share information about the nature and objectives of the research. After receiving consent and having the interviewee sign the Informed Consent Form, the study was carried out while maintaining participants' anonymity.

Data collection

The interview protocol was pilot-tested to assess psychometric properties, and the researchers used data provided by the Municipal Health Department of Alcobaça as a reference. The older adults were contacted through a home visit, where they were informed about the objectives and asked to participate in the research, which was voluntary.

Data collection was done in three stages. First, a multidimensional questionnaire (socio-demographic information, health indicators and behavioral variables) was administered in the form of an individual interview by previously trained students and health professionals. In the second stage, anthropometric measurements (body mass, height and waist circumference) were taken. Finally, a visit to a partner health center for blood sampling was scheduled.

Covariates

Sociodemographic variables included age group (60-69 years; 70-79 years and ≥80 years), sex (male and female), marital status (single, married/living with partner, widowed, separated/divorced), years of education (illiterate or 1 year; 2-4 years; 5-9 years and ≥10 years), current occupation (retired and working, only retired, housewife, working and pensioner) and family arrangement (living alone, living with spouse only, more children, more grandchildren).

Health indicators included health perceptions (positive and negative), self-reported illnesses (presence/absence) and behavioral indicators such as alcohol consumption (yes/no) and tobacco use (yes/no), all self-reported. In addition, anthropometric measurements were taken, including height and body mass. Body mass was measured using a Wiso digital scale (W721) with a capacity of 180 kg and an accuracy of 0.1 kg. Height was measured using a stadiometer with an accuracy of 0.1 cm. The body mass index (BMI) was then calculated using the following equation: BMI = body mass (kg) / height² (m²), classifying participants as underweight, normal weight, or overweight (World Health Organization 2000).

Dependent variables

We used the National Cholesterol Education Program Adult Treatment Panel III definition of metabolic syndrome: Three or more of the following risk factors, such as high blood pressure ≥ 130 mmHg systolic or ≥ 85 mmHg diastolic; central obesity (waist circumference > 102 cm for men and > 88 cm for women); high triglycerides (≥ 150 mg/dL or ≥ 175 mg/dL if the sample is obtained without fasting); low high-density lipoprotein cholesterol (HDL-c) (< 40 mg/dL in men and < 50 mg/dL in women); and high fasting glucose (≥ 100 mg/dL) or medical treatment for these conditions (Rezaianzadeh et al. 2012).

Self-reported arterial hypertension and diabetes data were used to assess MS components. Systolic (SBP) and diastolic (DBP) blood pressures were also measured after 5 minutes of rest using a digital sphygmomanometer (Omron - HEM 7113).

Central obesity was assessed by measuring waist circumference according to the method proposed by Grundy et al. (2005), which involved identifying the upper edge of the iliac crest and positioning the tape measure horizontally around the abdomen at this level. Measurements were taken at the end of expiration with the participant standing upright.

Blood was drawn to assess HDL-c, fasting blood glucose and triglycerides. Blood samples were taken in the morning, after a minimal fasting period, in two formats on demand, according to days previously established at the municipal health unit, and at home, as needed. All venipuncture and sample processing procedures were performed by health professionals associated with the Municipal Regional Reference Laboratory (LACEN Network - Central Public Health Laboratory) of the extreme south of Bahia.

Blood samples were collected using 10 ml plastic vacuum blood collection tubes with coagulation activator, 16 x 100 mm in diameter. After venipuncture, the blood was stored for later centrifugation (procedure carried out in a balanced manner, checking the calibration and pairing the tubes according to their physical characteristics), in pairs, for 10 minutes at 3,000 rpm, using an Inbrás ALB 18 VT serological centrifuge. The serum obtained was then transferred, using a variable volume automatic pipette, to a duly labelled tube containing a minimum of 2.0 mL of serum and stored in a thermobox (at a temperature of 2°C to 8°C) and then transferred to LACEN for sample processing by absorbance photometry, according to the Standard Operating Procedure (SOP) of the Cobas INTEGRA 400 plus analyzer.

Independent variables

PA and SB levels were assessed using the International Physical Activity Questionnaire (IPAQ), which has been validated for the Brazilian older adult population (Benedetti et al. 2004, 2007). PA levels were determined based on the four PA domains: leisure, work, transport and domestic activities. Older adults were dichotomized into physically active (≥150 min/week) and insufficiently active (<150 min/week) (Bull et al. 2020).

SB was determined by time spent sitting, assessed by questions about time spent sitting on a usual weekday and a usual weekend day. The total time spent sitting, minutes/day, was determined from the weighted average of the time spent sitting on a weekday and a weekend day: [(time spent sitting on a weekday x 5 + time spent sitting on a weekend day x 2) / 7]. SB was considered high from the 50th percentile (≥ 423 min/day). This methodological choice was made due to the absence of universally established or validated cutoffs for the Brazilian older adult population (Silva et al. 2020). It is noteworthy that this strategy is consistent with previous epidemiological studies that adopted sample-derived percentiles as reference values when standard cutoffs were not available, including approaches based on regression quantiles (D'Silva et al. 2018, Mitchell et al. 2014, Ullrich et al. 2018).

For analysis purposes, combinations between AF and CS were constructed together, creating four groups with different behaviors: The group considered to have the best behavior was ≥ 150 min/week of PA and SB <P50, groups of moderate behavior were individuals with <150 min/week of PA and SB <P50 and ≥ 150 min/week of PA and SB ≥ P50; the group with the least favorable behavior was characterized by <150 min/week of PA and SB ≥P50.

Statistical analysis

The database was created using double data entry in Edpidata 3.1b software, and analyses were performed using SPSS 23.0.

Descriptive statistics of absolute and relative frequencies were used to describe the sample, and the chi-squared test was used to compare the distribution of socio-demographic and health variables by sex.

Binary logistic regression, with an estimated odds ratio (OR) and 95% confidence interval, was used to determine the association between the behavioral variables PA (150 min/week) and SB (423 min/day), independently and in combination, with the isolated components of MS (diabetes, hypertension, high cholesterol and waist circumference) and controlled for the variables sex, age group, marital status, education, family structure, health perception, body mass index (BMI), tobacco and alcohol consumption.

Multinomial regression with estimated OR and 95% confidence interval was used to assess the association of PA combined with SB with the grouped components of MS (0, 1, 2, 3 and 4 components) and adjusted for sex, age group, marital status, education, family structure, health perception, BMI, tobacco and alcohol consumption. A 5% significance level was used for all statistical procedures.

RESULTS

The most prevalent age group was 60-69 years (55.2%), with 58.1% being women. The majority were married or living with a partner (46.0%), a large proportion lived with grandchildren (34.7%). Most participants (68.3%) had no more than four years of formal education, with 38.2% classified as illiterate or semi-literate, and 65.8% were retired (Table I). The prevalence of metabolic syndrome was 52.8%, while the prevalence of its individual components varied between 21.7% and 7.3%, respectively, for one and five components.

Table II shows the distribution of health and behavioral variables. Most older adults had a negative perception of health (63.6%), the prevalence of tobacco use was 11.8%, while 18.6% of the population consumed alcohol regularly. Additionally, 64.3% of the subjects were found to be overweight, 47.4% were insufficiently active, and 50.1% spent a significant amount of time engaged in sedentary behavior.

The group exhibiting optimal behavior was defined as those engaging in a minimum of 150 min/wee PA and SB per week, with a cut-off point of P50. This group demonstrated a prevalence of 30.2%. Subsequently, groups exhibiting moderate behavior were categorized as follows: those engaging in less than 150 minutes of PA and SB per week, with a cut-off point of P50, and those engaging in a minimum of 150 minutes of PA and SB per week, with a cut-off point of P50. The latter group exhibited a prevalence of 19.7%.

Table I. Sociodemographic characteristics of older adults from Alcobaça, Bahia, Brazil.

Variables	Overall (n=473)		Women (n=296)		Men (n=177)		*p*
	%	*n*	%	*n*	%	*n*	
Age group							0.245
60-69 years	55.2	261	58.1	172	50.3	89	
70-79 years	29.6	140	27.4	81	33.3	59	
≥80 years	15.2	72	14.5	43	16.4	29	
Marital Status							<0.001
Single	8.9	42	8.8	26	9.0	16	
Married/living with partner	46.0	217	33.2	98	67.2	119	
Widowed	27.5	130	38.0	112	10.2	18	
Separated/divorced	17.6	83	20.0	59	13.6	24	
Family arrangement							<0.001
Living alone	16.1	76	15.3	45	17.4	31	
Just the spouse	18.6	88	12.2	36	29.4	52	
More children	21.0	99	23.4	69	16.9	30	
More grandchildren	34.7	164	39.7	117	26.6	47	
Other	9.5	45	9.5	28	9.6	17	
Years of education							0.063
Illiterate or 1 year	38.2	180	42.7	126	30.7	54	
2-4 years	30.1	142	27.5	81	34.7	61	
5-9 years	16.6	78	16.3	48	17.0	30	
≥10 years	15.1	71	13.6	40	17.6	31	
Current occupation							<0.001
Retired and working	16.3	77	11.2	33	24.9	44	
Only retired	65.8	311	67.9	201	62.1	110	
Housewife	4.4	21	6.1	18	1.7	03	
Working	6.8	32	4.4	13	10.7	19	
Pensioner	6.8	32	10.5	31	0.6	01	

Data are presented as percentage (%) and absolute frequency (n). P-values were obtained using Pearson's chi-square test.

Moreover, groups exhibiting less than optimal behavior were categorized as follows: those engaging in less than 150 minutes of PA and SB per week, with a cut-off point of P50, and those engaging in a minimum of 150 minutes of PA and SB per week, with a cut-off point of P50. The latter group exhibited a prevalence of 22.4%. Finally, the group exhibiting the most problematic behavior was defined as those engaging in less than 150 minutes of PA and SB per week, with a cut-off point of P50. This group demonstrated a prevalence of 27.7%.

Table II. Distribution of health and behavioral characteristics of older adults in Alcobaça, Bahia, Brazil.

Variables	Geral (n=473)		Women (n=296)		Men (n=177)		*p*
	%	*n*	%	*n*	%	*n*	
Health Perception							0.266
Positive	36.4	172	34.5	102	39.5	70.0	
Negative	63.6	301	65.5	194	60.5	107	
Tobacco use							0.003
No	88.2	417	91.6	271	82.5	146	
Yes	11.8	56	8.4	25	17.5	31	
Alcohol consumption							<0.001
No	81.4	385	89.2	264	68.4	121	
Yes	18.6	88	10.8	32	31.6	56	
Body Mass Index (kg/m²)							0.003
Underweight	2.4	11	2.1	06	2.9	05	
Eutrophic	33.3	155	27.7	81	42.8	74	
Overweight	64.3	299	70.2	205	54.3	94	
Physical Activity							0.591
Sufficiently active	52.6	249	51.7	153	54.2	96	
Insufficiently active	47.4	224	48.3	143	45.8	81	
Sedentary Behavior							0.610
<P50 (<423min/day)	49.9	236	49.0	145	51.4	91	
≥P50 (≥423min/day)	50.1	237	51.0	151	48.6	86	

Data are presented as percentage (%) and absolute frequency (n). P-values were obtained using Pearson's chi-square test. P50 corresponds to the median sedentary time (423 min/day).

Table III shows the association of PA and SB independently and in combination with the components of MS (diabetes, central obesity, low HDL-c, and hypertension). In the individual analyses, physical inactivity alone did not increase the likelihood of the older adults studied developing any component of MS, whereas greater exposure to sedentary time (≥P50) presented a greater likelihood of having central obesity (OR 2.85; 95%CI 1.52-5.25) and arterial hypertension (OR 1.86; 95%CI 1.23-2.85) compared to older adults less exposed to SB.

When PA and SB were analyzed together, older adults with low PA levels and more exposure to SB were more likely to develop central obesity (OR 4.0; 95%CI 1.71-9.75) and arterial hypertension (OR 2.27; 95%CI 1.28-4.02). And older adults who were more exposed to SB, even though they were sufficiently active, were more likely to have central obesity (OR 3.44; 95%CI 1.51-7.87), low HDL-c concentration (OR 1.84; 95%CI 1.03-3.28), and arterial hypertension (OR 2.30; 95%CI 1.30-4.05) compared to physically active older adults with less exposure to SB.

Table IV shows the combined association of PA and SB with the clustering of MS components in older adults. It was found that high exposure to SB, even if the individual was physically active, was associated with the MS components through clustering of two (OR 3.90; 95%CI 1.46-10.42), three

Table III. Association of behavioral variables, physical activity and sedentary behavior, with the most frequent components of metabolic syndrome.

	Diabetes	Central Obesity	Low HDL-c	Hypertension
	OR (95% CI)	OR (95% CI)	OR (95% CI)	OR (95% CI)
Physical Activity				
≥150 min/week	1	1	1	1
<150 min/week	0.97 (0.58-1.61)	1.72(0.91-3.23)	0.69(0.44-1.09)	1.40 (0.91-2.15)
Sedentary Behavior				
<P50	1	1	1	1
≥P50	1.18 (0.72-1.93)	2.85 (1.52-5.25)*	1.32 (0.86-2.02)	1.86(1.23-2.85)*
PA and SB				
≥150 min/week of PA and SB <P50	1	1	1	1
<150 min/week of PA and SB <P50	0.74 (0.34-1.55)	2.00 (0.85-4.75)	0.93 (0.49-1.76)	1.68 (0.94-3.0)
≥150 min/week of PA and SB ≥P50	0.94 (0.47-1.88)	3.44 (1.51-7.87)*	1.84 (1.03-3.28)*	2.30 (1.30-4.05)*
<150 min/week of PA and SB ≥P50	1.13 (0.58-2.19)	4.00 (1.71-9.75)*	0.90 (0.49-1.65)	2.27 (1.28-4.02)*

PA: physical activity; SB: Sedentary behavior; OR: Odds Ratio; HDL-c; High-density lipoprotein cholesterol. *p<0.05. Controlled for: sex, age group, marital status, education, family arrangement, self-rated health, body mass index, smoking status, and alcohol consumption.

(OR 3.70; 95%CI 1.20-11.41), and four components (OR 7.34; 95%CI 1.98-27.29). The insufficiently active in older adults more exposed to SB had a higher probability of MS by two components (OR 2.89; 95%CI 1.13-7.03) and four components of MS (OR 4.18; 95%CI 1.12-15.62).

DISCUSSION

The present study aimed to analyze the association of PA and SB, independently and in combination, with the components of MS in older adults. When examined separately, no associations were found between any of the four components of MS and physical inactivity; for SB, associations were found with two factors (central obesity and hypertension). When the behaviors were analyzed jointly, older adults with a longer SB durations in different combinations showed two or three components as risk factors for MS compared with physically active older adults with low SB. Moreover, when PA and SB were evaluated in combination with the grouping of syndrome components, older adults with greater SB time had higher odds of presenting two to four components of MS.

Contrary to expectations, we did not observe an overall protective association between self-reported PA and MS in our sample. This finding is consistent with the heterogeneity observed in trials and meta-analyses, in which exercise effects vary according to type, volume, and intensity. For example, a systematic review with meta-analysis of clinical trials reported significant effects for some outcomes (total cholesterol, HDL, fasting glucose, and diastolic blood pressure), with greater effectiveness of concurrent training across several MS indicators

Table IV. **Association of physical activity combined with sedentary behavior with clustering of metabolic syndrome components in older adults.**

Metabolic syndrome components	Physical activity and Sedentary Behavior		
	≥ 150 min/week of PA and SB ≥ P50	< 150 min/week of PA and SB <P50	< 150 min/week of PA and SB ≥ P50
	OR (95% CI)	OR (95% CI)	OR (95% CI)
0 component	1	1	1
1 component	2.07 (0.83-5.16)	1.95 (0.78-4.86)	1.70 (0.72-4.04)
2 components	3.90 (1.46-10.42)*	2.53 (0.95-6.75)	2.80 (1.13-7.03)*
3 components	3.70 (1.20-11.41)*	1.31 (0.40-4.30)	2.84 (0.98-8.23)
4 components	7.34 (1.98-27.29)*	2.99 (0.74-12.14)	4.18 (1.12-15.62)*

PA: physical activity; SB: Sedentary behavior. *p<0.05; Models were adjusted for sex, age group, marital status, education, family arrangement, self-rated health, body mass index, smoking status, and alcohol consumption. Reference group was the group considered to have the best behavior ≥ 150 min/week of PA and SB <P50.

and substantial heterogeneity among studies (I^2>50%) (Galván et al. 2025). Conversely, cohorts using objective measures indicate a robust dose–response gradient whereby higher levels of PA, including light-intensity activity, are associated with lower risk, whereas greater exposure to SB is associated with higher risk, reinforcing the independent contribution of these behaviors (Ekelund et al. 2019). In middle-aged and older populations, greater sedentary time has also been associated with higher odds of MS, indicating an effect that becomes more evident with higher PA exposure (Xu et al. 2022).

Differences in PA dosing, with more consistent benefits at higher intensities and volumes, as well as potential measurement error, may explain part of these discrepancies. PA questionnaires have limited reliability and validity, with recall and social desirability bias tending to overestimate PA and underestimate SB, which may attenuate associations and obscure benefits observed at higher doses. There is even evidence of intensity thresholds (≥6 METs) for benefits to emerge (Shephard 2003). Accelerometer-based studies suggest that associations are often underestimated when relying on self-report data (Ekelund et al. 2019).

Biological plausibility is well established: PA improves insulin sensitivity via muscular glucose uptake and hormonal signaling, reduces visceral adiposity, optimizes lipid metabolism, increases total energy expenditure, attenuates inflammatory processes and insulin resistance, stimulates lipase activity (reducing triglycerides and maintaining HDL levels), and improves endothelial function by increasing nitric oxide, decreasing peripheral vascular resistance, and lowering resting blood pressure (Gong & Baek 2025, Lavie et al. 2019, Myers et al. 2019). In contrast, SB exerts independent and adverse metabolic effects, such as early reductions in lipoprotein lipase activity, reinforcing that "sitting time" is not the inverse of "active time". Our results, obtained from self-reported measures, do not rule out a protective effect of PA on MS but suggest that this effect tends to manifest at higher doses and when SB is simultaneously reduced. Therefore, public health guidelines should prioritize objective measures and precise quantification of PA and SB, including the fragmentation of prolonged sedentary periods (Ekelund et al. 2019, Lavie et al. 2019).

In the socioeconomic context, Lemes et al. (2019), demonstrated that watching television for long periods, combined with physical inactivity, doubled the odds of MS (OR 1.89; 95%CI 1.08-3.29), with a stronger effect among individuals e with lower economic status. Considering that 85.2% of the older adults in this sample belonged to the lower economic classes, this factor may further increase MS risk.

When SB was assessed in isolation, greater exposure was associated with higher odds for two MS components, in agreement with prior research (Chastin et al. 2021, Jefferis et al. 2016, Rao et al. 2016, van der Berg et al. 2016). The theoretical reallocation of 30 min/day of SB to standing or was related to better cardiometabolic outcomes (e.g., lower odds of MS and type 2 diabetes; reductions in waist circumference and BMI) (van der Berg et al. 2017), indicating the need to reduce SB at the population level. In a combined analysis, higher SB exposure increased the likelihood of having at least two components of the syndrome (central obesity and hypertension), regardless of PA level (Kim & Kang 2019).

These patterns have been consistently reported, demonstrating that prolonged SB negatively impacts health independently of PA, (Katzmarzyk et al. 2009, Meneguci et al. 2015, van der Ploeg et al. 2012), whereas more PA and less SB are associated with a lower risk of obesity and diabetes (Chastin et al. 2015, Harrington et al. 2016). Frequent breaks that interrupt long sedentary bouts mitigate harm (Lai et al. 2023), and not only the amount but also the pattern of accumulation of SB matters (Owen et al. 2010).

To the best of our knowledge, only one study has examined combined PA and SB variables in older adults with MS as the outcome (Manta et al. 2019). The importance of similar studies should be emphasized, since favorable and unfavorable behaviors may coexist. The group with a better behavioral profile (more active and less time in SB) showed protection for obesity related MS. They also emphasized that reducing SB, combined with adequate PA levels, may confer protective health benefits. However, our results indicated that PA level did not play a significant protective role in individuals with higher SB.

Despite the absence of evidence in our data for an association between PA and isolated or combined MS components, a possibility that may be attributable to the self-reported measures employed, SB proved detrimental in this context, regardless of PA duration. Even physically active individuals with high SB levels were at increased risk, emphasizing the need to address both behaviors (Amirfaiz & Shahril 2019, Ekblom et al. 2015, Zhao et al. 2025). The existing literature provides substantial epidemiological and physiological evidence supporting the importance of these relationships.

Conversely, SB, such as excessive time sitting or watching television, has been consistently associated with a higher risk of MS, independent of PA, as shown in numerous epidemiological studies (Amirfaiz & Shahril 2019, Gao et al. 2025, Greer et al. 2015, Jones et al. 2025, Macías et al. 2021). Such SB can promote insulin resistance, visceral fat accumulation, dyslipidemia, and hypertension, often alongside excessive caloric intake, creating an environment conducive to the development of MS and its components (Gong & Baek 2025, Lavie et al. 2019, Myers et al. 2019).

PA is defined as bodily movements involving skeletal muscles with energy expenditure above resting levels (Brasil 2021). Examples include walking in the park, playing sports, and doing household chores. In contrast, SB encompasses activities with low energy expenditure, such as sitting and watching television or reading a book (Brasil 2021). Sedentary time has been shown to be a risk factor for MS, even in active older adults. However, it can be minimized through small behavioral changes, such as taking the stairs instead of the elevator, limiting screen time, and taking regular breaks (Santos et al. 2021). Implementing such strategies can help reduce MS risk.

Among the study's limitations are the impossibility of establishing causality between the variables and the fact that information on PA, SB and self-reported diseases is subjective (Lee et al. 2011). Future studies should use objective measures, such as accelerometry, to confirm and expand our findings. Additionally, the absence of confounding variables such as diet (Vega-Cabello et al. 2023) and polypharmacy (Khezrian et al. 2020) is notable, as these have been identified as potential risk factors for complications and multimorbidity in older adults. Among the strengths, we highlight the population-based design, the representative sample of older adults, and the combined analysis of PA and SB with MS components.

The results of this study show that prolonged SB exposure is positively associated with the presence of three or more MS components in older adults, independent of PA levels. Specifically, SB had an impact on the prevalence of central obesity and hypertension, suggesting that reducing SB may be an effective strategy for the prevention and management of MS. As evidenced in studies with participants from Belgium (Scheers et al. 2013), Spain (Ekblom et al. 2015), and the United States (Bankoski et al. 2011, Gong & Baek 2025).

Our findings emphasize the need for interventions that not only at promote regular PA while simultaneously aiming to reduce SB. The combined analysis of behavioral variables showed that even older adults considered sufficiently active, but with high SB exposure, were at increased risk of adverse metabolic conditions. This suggests that current health promotion recommendations should include more specific guidance on breaking up sedentary time through frequent interruptions.

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LLG, LCDL, ST made substantial contributions to the conception and design of the study. LLG, R-RS, collected the data. JES performed the statistical analysis and interpretation of the data. R-RS, JSVJ and DATS made substantial contributions to the writing of the manuscript. All authors critically revised the intellectual content of the manuscript and approved the final version as submitted.

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Data availability

All material is available in the document. The Database is available on the Figshare platform: https://figshare.com/articles/dataset/Banco_ELSIA_2015-2020/25854487 under DOI: 10.6084/m9.figshare.25854487.