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Association between leisure-time physical activity and sedentary behavior with cardiometabolic health in the ELSA-Brasil participants

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Abstract

Objectives: To assess associations, both individually and in combination, between leisure-time physical activity and sedentary behavior, and cardiometabolic health.

Methods: This cross-sectional study included 13,931 civil servants participating in the Brazilian Longitudinal Study of Adult Health (ELSA-Brasil). Leisure-time physical activity was analyzed using the leisure-time domain of the long-form International Physical Activity Questionnaire, while questions related to cumulative sitting time and leisure-based screen time on a weekday and on one day on the weekend were used to establish sedentary behavior. Data analysis was performed using multivariate logistic regression.

Results: Following adjustment for confounding variables, high levels of leisure-time physical activity and low levels of sedentary behavior were both associated with favorable cardiometabolic health markers in both genders. When these two factors were analyzed in conjunction, taking the combination of low levels of leisure-time physical activity and high levels of sedentary behavior as the reference, the inverse associations with cardiometabolic variables became even more significant.

Conclusion: High levels of leisure-time physical activity and low levels of sedentary behavior were both inversely associated with the cardiometabolic variables analyzed; however, the two variables when evaluated in conjunction appear to produce more consistent associations, particularly when sedentary behavior is evaluated according to leisure-based screen time.

Keywords

Leisure-time physical activity, sedentary behavior, cardiometabolic health

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Introduction

Chronic non-communicable diseases, including cardiometabolic disorders, constitute a public health issue worldwide and represent one of the principal sources of disease burden.[1] The increasing prevalence rates of obesity and other cardiometabolic disorders have led to an expressive volume of studies worldwide focusing on the behavioral risk factors involved in the genesis and progression of these diseases. Most of these studies deal with issues related to lifestyle, diet, and physical activity, with few having focused on factors associated with sedentary behavior, principally in a combined or comparative analysis with leisure-time physical activity.[2]

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Sedentary behavior refers to any activity characterized by very low energy expenditure, that is, not exceeding 1.5 metabolic equivalents, and includes specific behaviors such as sitting for reading, studying, and watching television. Generally, these habits are considered different from practicing small amounts of physical activity, a behavior in which the individual also fails to engage in moderate or vigorous physical activity that would require energy expenditure above 3 metabolic equivalents.[3]

More recently, the definition of sedentary behavior was broadened after a group of investigators reached a consensus defining sedentary behavior as any waking behavior characterized by energy expenditure ⩽1.5 metabolic equivalents while in a sitting, reclining, or lying position.[4]

Various studies have shown an association between more time spent in sedentary activities and a greater occurrence of cardiovascular disease,[5] type 2 diabetes,[6] obesity,[7] and metabolic syndrome,[8] as well as a greater risk of death from cardiovascular disorders irrespective of physical activity level.[9,10] There is evidence that excess sedentary behavior such as television viewing and computer use represents a relevant risk factor and merits as much investigation as that conducted on physical activity levels. Sitting for prolonged periods of time constitutes an important risk factor for all causes of mortality irrespective of the regular practice of physical activity.[11]

On the other hand, various studies have shown that physical activity, particularly when performed within the domain of leisure time, is inversely associated with cardiometabolic diseases including diabetes, dyslipidemias, hypertension, and inflammatory markers.[12–17]

Despite the evidence of inverse associations between the variables *increased physical activity* and *reduced sedentary behavior*, evaluated individually, and cardiometabolic variables, studies aimed at evaluating which of these behaviors plays a more significant role in the control of these diseases are sparse. It has already been documented that individuals with low levels of physical activity and high levels of sedentary behavior are more likely to develop cardiovascular disease compared to individuals with low levels of both physical activity and sedentary behavior.[18]

Establishing a quantitative association between leisure-time physical activity, sedentary behavior, and cardiometabolic health may encourage public health managers to review educational messages that could encourage both an increase in physical activity and a reduction in sedentary behavior.

Therefore, the objective of this study was to assess the individual and combined associations of leisure-time physical activity and sedentary behavior, and cardiometabolic health.

Methods

Design and sample

The ELSA-Brasil is a cohort study involving 15,105 active or retired civil servants of 35–74 years of age from six different institutions of higher learning located in the cities of Salvador, Vitória, Belo Horizonte, Rio de Janeiro, São Paulo, and Porto Alegre. Sample size estimation was based on the main study outcomes of type 2 diabetes and myocardial infarction. Considering an alpha value of 5%, statistical power of 80%, exposure prevalence of 20%, and a relative risk of 2.0, the required sample size was estimated at approximately 6400 individuals. In order to perform gender-specific analyses and allow for possible losses to follow-up, the desired sample size was approximately 15,000 individuals.[19] Details of the methodology of this study have already been published elsewhere.[19,20] All the participants who took part in the second wave of the study (2012–2014) and whose data on leisure-time physical activity and sedentary behavior were complete were selected for the present analysis: a total of 13,931 participants of both sexes.

The internal review boards of the six research centers involved in the ELSA-Brasil approved the study protocol. All the participants signed an informed consent form. The use of anonymized data guaranteed the confidentiality of the participants.

Measures

The data were produced by a team of interviewers and then verified by personnel trained and certified by a quality control committee.[20] The supervisory personnel were authorized to apply the study protocol in any of the ELSA-Brasil study centers. The interviews were conducted face-to-face, with blocks of questionnaires being applied.

Evaluation of physical activity

The International Physical Activity Questionnaire (IPAQ) was used to identify and quantify physical activity. This instrument is made up of questions on the frequency and duration of physical activities (i.e. moderate and vigorous physical activity and walking) performed during occupational activities and in household chores or for transport and during leisure time.[21] In the ELSA-Brasil, only the domains of leisure-time physical activity and physical activity for transport were evaluated. To measure physical activity, the weekly frequency was multiplied by the duration of each one of the activities performed, with the results obtained being expressed in minutes per week. For the effects of this analysis, only the leisure-time domain was used, with leisure-time physical activity being classified as follows: 0 = insufficiently active (<150 min/week of moderate physical activity or walking and/or <60 min/week of vigorous physical activity or <150 min/week of any combination of walking, moderate or vigorous physical activity); and 1 = physically active (⩾150 min/week of moderate physical activity or walking and/or ⩾60 min/week of vigorous physical activity or ⩾150 min/week of any combination of walking, moderate or vigorous physical activity).

Evaluation of sedentary behavior

Sedentary behavior was documented for the first time in the second wave of the study. Participants were asked questions on the number of hours they spent sitting down (cumulative sitting time) and the number of hours they spend watching television, playing video games, and using a mobile phone or computer (leisure-based screen time) on a weekday and on one day on the weekend. A low level of sedentary behavior was classified as ⩽2 h/day of leisure-based screen time[10] and ⩽8 h/day of cumulative sitting time.[11]

Evaluation of cardiometabolic variables

The following cardiometabolic variables were analyzed: obesity, low levels of high-density lipoprotein cholesterol (HDL-C), hypertriglyceridemia, and hypertension. The data on medical assessments and clinical and subclinical parameters included in this analysis were obtained in the second wave of the ELSA-Brasil visits.[22] Body mass index (BMI) was defined as weight in kilograms divided by height in square meters. Blood pressure was taken using a validated oscillometric device (Omron HEM 705CPINT) after a 5-min resting period, with the subject in a seated position in a quiet, temperature-controlled room (20°C–24°C). Three measurements were taken at 1-min intervals. The mean of the last two measurements was used for the analyses. Triglyceride and HDL-C levels were determined using enzymatic colorimetric methods.

A participant was classified as hypertensive if systolic blood pressure was ⩾140 mmHg, if diastolic blood pressure was ⩾90 mmHg, or if he or she had taken any medication to treat hypertension in the preceding 2 weeks. Obesity was defined as BMI ⩾30.0 kg/m^2. Hypertriglyceridemia was defined as values >150 mg/dL and low HDL-C as values <35 mg/dL.

Data analysis procedures

Descriptive measures (proportions) were calculated for all the categorical variables. All the analyses were stratified by sex. This decision is supported by the scientific literature in which evidence has accumulated on gender differences in the use of time in work and at leisure.[23] The associations between the dependent variables (the cardiometabolic variables) and the independent variables (*leisure-time physical activity* and *sedentary behavior*), either individually or in conjunction, were analyzed using multivariate logistic regression. The following variables were considered potential confounding factors: age, BMI, education level, beer consumption, and smoking. Variables evaluated simultaneously (tetrachoric correlation) with correlation coefficient rho <0.60 and $p \leqslant 0.05$ at bivariate analysis were selected for the model.

Associations were sought between leisure-time physical activity alone and the cardiometabolic variables (obesity, low HDL-C, hypertriglyceridemia, and arterial hypertension) and between sedentary behavior alone and the same cardiometabolic variables. Next, logistic regression models were proposed using combinations of leisure-time physical activity and low levels of sedentary behavior (cumulative sitting time and leisure-based screen time on a weekday and on a Saturday or Sunday), with the cardiometabolic variables as the endpoint. In all the analysis models, the combination of low levels of physical activity and high levels of sedentary behavior was defined as the reference. A confidence interval of 95% was established. The STATA software program, version 12.0 was used for the statistical analysis, which was performed in 2016.

Results

Overall, 6324 men and 7607 women were included in the analysis. The characteristics of the sample are shown in Table 1. The men were more likely to be smokers and consumed more beer on weekdays than the women. In addition, they were more likely to have hypertriglyceridemia and hypertension. Furthermore, although they were more active in their leisure time, the men tended to sit for longer periods of time on weekends and tended to watch more television, both during the week and on weekends. Women had better education levels and were more likely to be obese, with low HDL-C levels. There were no statistically significant differences between men and women in relation to their age or to the amount of weekday sitting time.

The associations between leisure-time physical activity and sedentary behavior, and cardiovascular variables are shown in Table 2 for both men and women. In men, associations were found between leisure-time physical activity and all the cardiometabolic endpoints analyzed except for hypertension. While in men sedentary behavior was strongly associated with obesity and hypertriglyceridemia, in women it was strongly associated with obesity alone. It should be noted that weekday leisure-based screen time was associated with all the cardiometabolic variables analyzed, in both men and women.

Tables 3 and 4 show the associations between the combined factors *leisure-time physical activity* and *sedentary behavior*, and the cardiometabolic variables in men and women, respectively. Inverse associations were found for all the cardiometabolic variables, particularly when increased leisure-time physical activity and decreased weekday leisure-based screen time were analyzed together. These inverse associations were stronger in the combined analyses than when each variable was analyzed individually.

Discussion

This study sought to assess the individual and combined associations of leisure-time physical activity and sedentary behavior, and cardiometabolic health. Although the associations found when each variable was analyzed alone were statistically significant, the combinations of high

Table 1. Characteristics of the sample according to the study variables (Longitudinal Study of Adult Health (ELSA-Brasil, 2012–2014).

	Men (n = 6.324)	Women (n = 7.607)	p-value*
Age (years), n (%)			
34–50	2060 (32.4)	2350 (30.7)	
51–60	2193 (34.5)	2762 (36.1)	
>60	2104 (33.1)	2545 (33.2)	0.06
Education, n (%)			
Failed to complete elementary school	452 (7.1)	268 (3.5)	
Elementary school	488 (7.7)	390 (5.1)	
High school	1941 (30.6)	2456 (32.1)	
University/postgraduate	3467 (54.6)	4540 (59.2)	<0.01
Smoking, n (%)			
Never-smoker	3297 (51.9)	4890 (63.9)	
Smoker/former smoker	3049 (48.1)	2761 (36.1)	<0.01
Weekly beer consumption, n (%)			
<750 mL	4018 (63.2)	6638 (86.7)	
⩾750 mL	2339 (36.8)	1019 (13.3)	<0.01
Leisure-time physical activity (M ± SD)	181.0 ± 242.3	130.2 ± 187.0	<0.01
n (%)			
Insufficiently active	3307 (52.3)	4742 (62.4)	
Active	3017 (47.7)	2865 (37.6)	<0.01
Sedentary behavior			
Weekday sitting time (M ± SD)	5.9 ± 3.4	5.8 ± 3.5	0.05
n (%)			
>8 h	1340 (21.1)	1642 (21.4)	
⩽8 h	5017 (78.9)	6015 (78.6)	0.60
Weekend sitting time (M ± SD)	4.9 ± 3.1	4.4 ± 2.9	<0.01
n (%)			
>8 h	737 (11.6)	645 (8.4)	
⩽8 h	5620 (88.4)	7012 (91.6)	<0.01
Weekday screen time at leisure (M ± SD)	2.3 ± 1.9	2.2 ± 1.7	<0.01
n (%)			
>2 h	2355 (37.0)	2627 (34.3)	
⩽2 h	4002 (63.0)	5030 (65.7)	<0.01
Weekend screen time at leisure (M ± SD)	3.2 ± 2.2	2.9 ± 2.1	<0.01
n (%)			
>2 h	3669 (57.7)	3987 (52.1)	
⩽2 h	2688 (42.3)	3670 (47.9)	<0.01
Obesity			
No	4842 (76.6)	5385 (71.0)	
Yes	1477 (23.4)	2200 (29.0)	<0.01
Hypertriglyceridemia			
No	4082 (64.6)	5998 (78.8)	
Yes	2237 (35.4)	1611 (21.2)	<0.01
Hypertension			
No	3475 (54.9)	4775 (62.6)	
Yes	2855 (45.1)	2849 (37.4)	<0.01
Low levels of HDL-C			
No	4931 (78.0)	5569 (73.2)	
Yes	1388 (22.0)	2040 (26.8)	<0.01

HDL-C: high-density lipoprotein cholesterol.
*Values for men and women were compared using the chi-square test for categorical variables and Student t-test for continuous variables.

levels of leisure-time physical activity and less sitting time and of high levels of leisure-time physical activity and less leisure-based screen time, both on weekdays and on the weekend, resulted in more significant associations with the cardiometabolic endpoints analyzed, both in men and in women.

Table 2. Associations independent between leisure-time physical activity and sedentary behavior with cardiometabolic disorders in men and women (ELSA-Brasil, 2012–2014).

	Obesity[a]	Low levels of HDL-C[b]	Hypertriglyceridemia[b]	Hypertension[b]
Men				
Leisure-time physical activity				
Insufficiently active	1.00	1.00	1.00	1.00
Active	0.71 (0.62–0.82)*	0.76 (0.67–0.86)*	0.77 (0.69–0.85)*	0.90 (0.81–1.00)
Sedentary behavior				
Weekday sitting time				
>8 h	1.00	1.00	1.00	1.00
⩽8 h	0.76 (0.64–0.91)*	0.92 (0.80–1.07)	0.84 (0.74–0.96)*	1.02 (0.89–1.17)
Weekend sitting time				
>8 h	1.00	1.00	1.00	1.00
⩽8 h	0.72 (0.58–0.90)*	0.93 (0.77–1.12)	0.77 (0.66–0.91)*	0.92 (0.78–1.09)
Weekday screen time at leisure				
>2 h	1.00	1.00	1.00	1.00
⩽2 h	0.68 (0.59–0.78)*	0.87 (0.77–0.99)*	0.68 (0.61–0.76)*	0.82 (0.74–0.92)*
Weekend screen time at leisure				
>2 h	1.00	1.00	1.00	1.00
⩽2 h	0.66 (0.57–0.76)*	0.89 (0.79–1.01)	0.78 (0.70–0.87)*	0.86 (0.77–0.95)*
Women				
Leisure-time physical activity				
Insufficiently active	1.00	1.00	1.00	1.00
Active	0.57 (0.50–0.65)*	0.79 (0.70–0.88)*	0.79 (0.70–0.89)*	0.86 (0.77–0.96)*
Sedentary behavior				
Weekday sitting time				
>8 h	1.00	1.00	1.00	1.00
⩽8 h	0.72 (0.71–0.94)*	1.09 (0.96–1.25)	1.06 (0.92–1.23)	1.11 (0.98–1.27)
Weekend sitting time				
>8 h	1.00	1.00	1.00	1.00
⩽8 h	0.87 (0.62–0.95)*	1.04 (0.86–1.27)	1.01 (0.83–1.24)	1.05 (0.87–1.26)
Weekday screen time at leisure				
>2 h	1.00	1.00	1.00	1.00
⩽2 h	0.76 (0.67–0.85)*	0.88 (0.79–0.98)*	0.75 (0.67–0.85)*	0.85 (0.77–0.95)*
Weekend screen time at leisure				
>2 h	1.00	1.00	1.00	1.00
⩽2 h	0.76 (0.70–0.88)*	0.98 (0.88–1.08)	1.03 (0.92–1.15)	1.00 (0.90–1.10)

HDL-C: high-density lipoprotein cholesterol.
[a]Adjusted for age, education level, beer consumption, and smoking.
[b]Adjusted for age, obesity, education level, beer consumption, and smoking.
*Statistically significant.

In this study, inverse associations were found both between obesity and leisure-time physical activity and between obesity and lower levels of sedentary behavior; however, these associations were stronger when the combined effect of the two variables was analyzed, both for men and women.

The present findings are in agreement with the results of other studies conducted recently that analyzed the combined effect of physical activity and sedentary behavior on cardiometabolic endpoints. For example, a cohort study carried out in London with 3670 participants reported a lesser likelihood of obesity in individuals reporting a high level of physical activity and less leisure-time sitting.[18]

The mechanisms that contribute toward making this combination more effective in preventing obesity remain unclear. Lower levels of sedentary behavior may reinforce the protective effects of a greater amount of physical activity, probably through independent mechanisms. The combination of higher levels of physical activity and lower levels of sedentary behavior may also represent an increase in energy expenditure, with the combination of less physical activity

Table 3. Associations between the combined factors *leisure-time physical activity* and *sedentary behavior* with cardiometabolic disorders in men (ELSA-Brasil, 2012–2014).

Combinations of LTPA and sedentary behavior	Obesity[a]	Low levels of HDL-C[b]	Hypertriglyceridemia[b]	Hypertension[b]
Weekday sitting time				
Little LTPA—Much sitting time (n = 705)	1.00	1.00	1.00	1.00
Active—Little sitting time (n = 2412)	0.55 (0.44–0.70)*	0.70 (0.57–0.86)*	0.66 (0.55–0.80)*	0.89 (0.74–1.07)
Little LTPA—Little sitting time (n = 2602)	0.76 (0.61–0.95)*	0.91 (0.74–1.10)	0.89 (0.75–1.07)	0.99 (0.83–1.20)
Active—Much sitting time (n = 605)	0.70 (0.51–0.98)*	0.73 (0.56–0.96)*	0.83 (0.66–1.04)	0.86 (0.67–1.10)
Weekend sitting time				
Little LTPA—Much sitting time (n = 411)	1.00	1.00	1.00	1.00
Active—Little sitting time (n = 2721)	0.53 (0.40–0.71)*	0.77 (0.60–0.98)*	0.64 (0.51–0.79)*	0.79 (0.63–0.99)*
Little LTPA—Little sitting time (n = 2896)	0.72 (0.55–0.95)*	1.01 (0.79–1.29)	0.83 (0.67–1.03)	0.86 (0.69–1.08)
Active—Much sitting time (n = 296)	0.70 (0.45–1.10)	0.94 (0.64–1.36)	0.92 (0.67–1.27)	0.78 (0.56–1.08)
Weekday screen time at leisure				
Little LTPA—Much sitting time (n = 1264)	1.00	1.00	1.00	1.00
Active—Little sitting time (n = 1957)	0.49 (0.40–0.59)*	0.69 (0.58–0.81)*	0.52 (0.45–0.61)*	0.76 (0.65–0.89)*
Little LTPA—Little sitting time (n = 2043)	0.66 (0.55–0.79)*	0.87 (0.73–1.02)	0.66 (0.57–0.77)*	0.82 (0.71–0.96)*
Active—Much sitting time (n = 1060)	0.70 (0.57–0.87)*	0.75 (0.61–0.92)*	0.75 (0.66–0.89)*	0.89 (0.75–1.07)
Weekend screen time at leisure				
Little LTPA—Much sitting time (n = 1989)	1.00	1.00	1.00	1.00
Active—Little sitting time (n = 1369)	0.48 (0.39–0.60)*	0.71 (0.60–0.85)*	0.62 (0.53–0.73)*	0.80 (0.69–0.94)*
Little LTPA—Little sitting time (n = 1318)	0.66 (0.55–0.80)*	0.87 (0.72–1.00)	0.81 (0.70–0.94)*	0.83 (0.71–0.96)*
Active—Much sitting time (n = 1648)	0.74 (0.62–0.89)*	0.71 (0.60–0.83)*	0.79 (0.69–0.91)*	0.87 (0.76–1.01)

LTPA: leisure-time physical activity; HDL-C: high-density lipoprotein cholesterol.
[a]Adjusted for age, education level, beer consumption, and smoking.
[b]Adjusted for age, obesity, education level, beer consumption, and smoking.
*Statistically significant.

Table 4. Associations between the combined factors *leisure-time physical activity and sedentary behavior* with cardiometabolic disorders in women (ELSA-Brasil, 2012–2014).

Combinations of LTPA and sedentary behavior	Obesity[a]	Low levels of HDL-C[b]	Hypertriglyceridemia[b]	Hypertension[b]
Weekday sitting time				
Little LTPA—Much sitting time (n = 1041)	1.00	1.00	1.00	1.00
Active—Little sitting time (n = 2314)	0.47 (0.39–0.57)*	0.88 (0.74–1.05)	0.83 (0.69–1.01)	0.94 (0.79–1.12)
Little LTPA—Little sitting time (n = 3701)	0.80 (0.68–0.95)*	1.13 (0.96–1.33)	1.08 (0.91–1.29)	1.08 (0.92–1.27)
Active—Much sitting time (n = 551)	0.50 (0.37–0.67)*	0.76 (0.60–1.00)	0.83 (0.64–1.10)	0.78 (0.61–1.00)
Weekend sitting time				
Little LTPA—Much sitting time (n = 389)	1.00	1.00	1.00	1.00
Active—Little sitting time (n = 2659)	0.44 (0.36–0.57)*	0.87 (0.68–1.11)	0.79 (0.61–1.02)	0.85 (0.67–1.08)
Little LTPA—Little sitting time (n = 4353)	0.76 (0.59–0.97)*	1.14 (0.90–1.45)	0.99 (0.77–1.27)	0.96 (0.76–1.20)
Active—Much sitting time (n = 206)	0.55 (0.35–0.87)*	0.83 (0.55–1.26)	0.73 (0.47–1.14)	0.68 (0.45–1.02)
Weekday screen time at leisure				
Little LTPA—Much sitting time (n = 1617)	1.00	1.00	1.00	1.00
Active—Little sitting time (n = 1905)	0.42 (0.36–0.51)*	0.69 (0.58–0.81)*	0.56 (0.47–0.67)*	0.74 (0.63–0.86)*
Little LTPA—Little sitting time (n = 3125)	0.73 (0.64–0.84)*	0.95 (0.83–1.09)	0.79 (0.67–0.90)*	0.81 (0.71–0.93)*
Active—Much sitting time (n = 960)	0.55 (0.45–0.67)*	0.87 (0.72–1.05)	0.82 (0.68–0.99)*	0.81 (0.68–0.97)*
Weekend screen time at leisure				
Little LTPA—Much sitting time (n = 2490)	1.00	1.00	1.00	1.00
Active—Little sitting time (n = 1418)	0.44 (0.37–0.53)*	0.76 (0.64–0.89)*	0.80 (0.68–0.96)*	0.87 (0.75–1.02)
Little LTPA—Little sitting time (n = 2252)	0.80 (0.70–0.91)*	1.02 (0.90–1.16)	1.02 (0.89–1.17)	0.99 (0.87–1.12)
Active—Much sitting time (n = 1447)	0.58 (0.49–0.68)*	0.82 (0.70–0.96)*	0.78 (0.66–0.92)*	0.86 (0.74–1.00)

LTPA: leisure-time physical activity; HDL-C: high-density lipoprotein cholesterol.
[a]Adjusted for age, education level, beer consumption, and smoking.
[b]Adjusted for age, obesity, education level, beer consumption, and smoking.
*Statistically significant.

and more sitting time expending less energy than the combination of more physical activity and less sitting time.

In this study, both leisure-time physical activity and a lower level of sedentary behavior had a significant effect in preventing hypertriglyceridemia in men. However, in the case of low HDL-C levels, the associations were stronger with leisure-time physical activity than for sedentary behavior. For women, the independent associations were stronger for leisure-time physical activity than for sedentary behavior, both with respect to hypertriglyceridemia and for low HDL-C levels. It should be emphasized that very significant inverse associations were found between these two cardiometabolic variables and the particular sedentary behavior referred to as "weekday leisure-based screen time." When the variables *high levels of leisure-time physical activity* and *low levels of sedentary behavior* were analyzed in conjunction, the odds ratios became even more significant, both for low HDL-C levels and for hypertriglyceridemia in both men and women.

In another recent study conducted with 1331 individuals participating in an observational study on cardiovascular risk factors in Luxemburg, it was found that less time spent in sedentary behavior and more time spent in moderate to vigorous physical activities may be associated with a more favorable lipid profile, especially with respect to HDL-C and triglyceride levels.[24]

In this sample, no association was found between leisure-time physical activity alone and arterial hypertension in men, whereas the sedentary behaviors *weekday leisure-based screen time* and *weekend leisure-based screen time* were associated with arterial hypertension. When the combined effect of higher levels of leisure-time physical activity and lower levels of sedentary behavior on arterial hypertension was analyzed, the inverse associations became more consistent. In relation to women, associations with arterial hypertension were found both for leisure-time physical activity alone and for weekday leisure-based screen time alone. When combined, these associations also persisted, becoming even more significant.

In another study that analyzed the independent and combined effects of physical activity and sedentary behaviors on arterial hypertension in adolescents, it was found that complying with current recommendations regarding physical activity mediated the association between sedentary behaviors and diastolic blood pressure in both sexes. In boys, the combined effect of low levels of physical activity and excessive sedentary behavior increased systolic blood pressure levels. de Moraes et al.[25] suggest the need for further longitudinal studies to confirm these findings.

It is important to note that although previous studies have shown that total sitting time, TV viewing, and leisure-time computer use are all associated with poorer cardiometabolic risk profiles in adults,[26] in this study, the associations were more consistent when leisure-based screen time was analyzed. These results indicate the need for actions aimed at reducing screen time in the population.

The present findings add to data already published in the literature on the influence of the combined effect of practicing leisure-time physical activity and reducing sedentary behavior on cardiometabolic health, since a large proportion of the studies on this topic have analyzed each variable individually.[5–16] Recently, our research group published results on the baseline data (first wave) of the ELSA-Brasil showing inverse associations between leisure-time physical activity alone and hypertension, diabetes, and 10-year cardiovascular disease risk, both for men and women.[17]

Although the evidence of the association between higher levels of physical activity and lower levels of sedentary behavior, analyzed individually, on cardiometabolic health is extremely consistent, models have recently been proposed to substitute time spent in sedentary behavior for physical activity. One of these models showed that substituting 10 min of sedentary behavior for the same amount of time spent in moderate to vigorous physical activity was associated with favorable effects on all the cardiometabolic risk factors analyzed. Hamer et al.[27] concluded that the combined effect of decreasing sedentary behavior and increasing physical activity might depend on the type and intensity of that activity.

More recently, it has been suggested that replacing time spent in sedentary behavior with time spent in physical activity could be a more effective strategy for improving overall health.[28]

Different mechanisms may explain the positive effects of both higher levels of physical activity and lower levels of sedentary behavior on cardiometabolic disorders. In relation to the association between physical activity and arterial hypertension, evidence points principally to a reduction in insulin levels with a consequent decrease in renal sodium retention and basal sympathetic tone, a reduction in catecholamine levels and release of vasodilator substances by skeletal muscles to the circulation.[29] With respect to physical activity and the lipid profile, the principal reason for the increase in HDL-C is the greater effect of lipoprotein lipase (LPL) in response to physical exercise. LPL accelerates the decomposition of very-low-density lipoprotein cholesterol (VLDL-C), removing triglycerides from the bloodstream to the muscles, resulting in transferal of cholesterol and other substances to HDL, which results in an increase in HDL-C concentration.[30]

On the other hand, there is evidence that an increase in the amount of sedentary time is associated with a reduction in LPL activity, which reduces the absorption of plasma triglycerides, particularly by the skeletal muscle.[31] Therefore, fats are deposited in the vessels or in adipose tissue, a fact that raises plasma triglyceride levels.

In this respect, studies conducted with rats have shown that the effects of muscle inactivity may lead to a decrease in the enzymatic activity of LPL, which serves to regulate the absorption of triglycerides and the production of HDL in the muscle.[32] The absence of contractions in the muscles of the lower limbs used to maintain posture is associated with a

75% reduction in the capacity to absorb fat from the bloodstream, particularly by the skeletal muscles.[33]

In this context, a recent study conducted with humans has shown that short breaks in sitting time at work can result in mild to moderate reductions in total cholesterol, triglycerides, and fasting blood glucose.[34]

Thus, the combination of an increase in physical activity and a reduction in sedentary behavior may maximize positive effects on dyslipidemias, arterial hypertension, and obesity, resulting in more consistent inverse associations with cardiometabolic disorders.

One of the strong points of this study is that this is a cohort of volunteer civil servants who, although not representative of the general population, make up a significant number of participants from six different Brazilian state capitals. Nevertheless, these results must be interpreted with caution when extrapolating the findings to the entire adult population of Brazil, since these data refer to a population of workers who share similar characteristics, but that differ from those of the general population of the country. In addition, the possibility of bias in this sample of healthy workers cannot be ruled out.

In addition, the fact that the study is cross-sectional does not allow any cause-effect relationship between the variables to be established. Another possible limitation of the study refers to the data collected on physical activity and sedentary behavior, which was obtained using questionnaires. Nevertheless, this same instrument has been widely used in studies conducted in Brazil and abroad. It is also important to mention that the ELSA-Brasil is a longitudinal study and the incorporation of a more objective measure, accelerometry, is planned. This would increase the validity of the data, both on physical activity and on sedentary behavior.

Conclusion

The results of this study may represent an important contribution to public health in that the management of public policies aimed at promoting health may be improved by making further information available on the importance both of increasing leisure-time physical activity and decreasing sedentary behavior. The information that the combined effect of these two behaviors maximizes the associations with the variables that reflect cardiometabolic health should be taken into consideration by public health managers so that actions to encourage the practice of physical activity, particularly in leisure time, can be implemented, in addition to incorporating actions to encourage individuals to reduce sedentary behavior, particularly the amount of leisure-based screen time.

Declaration of conflicting interests

The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

Ethical approval

The ELSA-Brasil was approved by internal review boards from all the six research centers involved. The study was approved by the ethics committee of the Institute of Public Health of the Federal University of Bahia under number 027-06/CEP-ISC.

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Informed consent

All the participants signed an informed consent form. The use of anonymized data guaranteed the confidentiality of the participant.

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