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ORIGINAL ARTICLE

Does physical activity moderate the association between device-measured sedentary time patterns and depressive symptoms in adults?

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Objectives: To investigate the association between sedentary time (ST) patterns and depressive symptoms, and whether moderate-to-vigorous physical activity (MVPA) can moderate this association.
Methods: This cross-sectional study included a representative sample of 243 adults (mean age 41.8±16.7 years, 56.4% women) from a city in Southeast Brazil. Depressive symptoms were estimated through the Hospital Anxiety and Depression Scale (HADS). ST patterns (i.e., number of breaks, mean length of sedentary bouts, and number of long sedentary bouts), total ST, and MVPA were assessed using accelerometers.
Results: Poisson regression models revealed associations of total ST (β = 0.063; 95%CI 0.011 to 0.116) and number of long bouts (0.108; 0.047 to 0.171) with depressive symptoms among men. MVPA moderated the associations of breaks and longer bouts of ST with depressive symptoms, with an increase of one break/hour, the increase of one long bout, and a decrease of 1 minute in mean bout length being associated with a reduction of 0.211 and increases of 0.081 and 0.166, respectively, in the number of depressive symptoms among men with physical inactivity (breaks = -0.211; -0.360 to -0.063; mean bout length = 0.081; 0.003 to 0.158; number of long bouts = 0.166; 0.090 to 0.242).
Conclusions: Interventions that encourage breaking up ST should be helpful to reduce depressive symptoms among people with physical inactivity.
Clinical trial registration: ClinicalTrials.gov (NCT03986879).

Keywords: Exercise; sedentary behavior; sitting; depression; mood

Introduction

Depressive disorders are associated with premature mortality and are one of the leading causes of disability worldwide.[1] Depression can lead not only to elevated rates of suicide, but also to increased premature mortality due to cardiovascular diseases.[2,3] Among the factors associated with depression, different studies have shown that sedentary behavior, defined as any waking behavior with a low energy expenditure (i.e., ⩽ 1.5 metabolic equivalents) in sitting, reclining, or lying positions,[4] is a risk factor for depression, regardless of physical activity levels.[5,6]

Randomized clinical trials have observed that induced sedentary behavior is associated with an increase in depressive symptoms as well as alterations in inflammatory markers.[7,8] However, different studies have shown that the total sedentary time (ST) per se is not sufficient to explain the association between sedentary behavior and depressive symptoms. For instance, some specific activities, such as those considered mentally passive (e.g., TV-viewing, listening to music), are more associated with depressive symptoms than others.[9,10] Similarly, the pattern of ST, involving bouts (periods of uninterrupted sedentary behavior) and breaks (interruptions of sedentary behavior), can also be associated with higher depressive symptoms and mechanisms linking sedentary behavior to depressive symptoms, such as inflammation.[11-15]

In addition, the occurrence of sedentary behavior is independent of physical activity practice. Therefore, physical inactivity and high sedentary behavior can occur concomitantly. Although physical activity and sedentary behavior can present independent associations with depressive symptoms, they can also share mechanisms in the association with elevated depressive symptoms,

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and previous studies found that physical activity can moderate the association between ST and elevated depressive symptoms.[16,17] However, the role of physical activity in the association between ST patterns and depressive symptoms is unclear. Thus, we aimed to investigate the association between ST patterns and depressive symptoms, as well as whether physical activity can moderate this association.

Methods

Sample

This is a cross-sectional study conducted with a representative sample of adults (age $\geqslant$ 18 years) from the city of Santo Anastácio, located in the west of the state of São Paulo, in the Southeastern region of Brazil. The sampling process has been described in more detail elsewhere.[18,19] The study protocol was registered at ClinicalTrials.gov (NCT03986879). Sample randomization was carried out considering the number of census tracts in the urban area of the city (n=23) as registered in the national database of Instituto Brasileiro de Geografia e Estatística (IBGE) and the number of streets, blocks, and households. The proportionality of residents in each census tract was considered in randomization. To carry out this procedure, the neighborhoods were registered and numbered, as were the streets, blocks, and households; subsequently, neighborhoods, streets, blocks, and households were randomly selected. All residents aged 18 years or older were considered eligible for the study. If the residents were not found or did not agree to take part in the study, the residents of the neighboring household were invited until the necessary sample size was reached in each census tract. Data were collected in two visits. Initially, participants who agreed to participate received accelerometers to use for 7 consecutive days. After the accelerometer use period, the participants answered questionnaires during the second visit. A total of 969 households were visited, including 364 in which the residents were not found and 299 that refused to participate in the study. Therefore, 306 participants agreed to participate. Of the initial 306 participants, 15 were excluded due to accelerometer misuse, 19 dropped out without completing all the assessments, and three were excluded due to assessment error.

Depressive symptoms

The presence of depressive symptoms was assessed using the Hospital Anxiety and Depression Scale (HADS), which has 14 items scored from 0 to 3 according to each response. The instrument includes seven items related to depression symptoms, including items related to anhedonia, lack of energy, and low mood.[20] The questionnaire was previously validated in Portuguese[21] and exhibited good internal consistency in the present sample (Cronbach's alpha = 0.745).

Sedentary time patterns and physical activity

Actigraph GT3X accelerometers (ActiGraph, LLC, Pensacola, USA) were used for the measurement of physical activity. The participants were instructed to wear the device positioned laterally on the waistline, during the entire waking period, for 7 days, removing it only when in contact with water (whether for personal hygiene, rain, or doing any water activities) and to sleep (except for daytime naps). The accelerometers were set with epochs of 60 seconds and we adopted the criterion of 60 minutes of consecutive 0 counts for non-wear time. Participants with at least 5 valid days ($>$ 600 minutes/day, with at least 1 weekend day) recorded by the accelerometer were included in the analyses.

For classification of physical activity intensities, the cutoff points by Freedson et al.,[22] namely, $<$ 100 counts/minute for sedentary behavior, 100-1,951 counts for light physical activity, 1,952-5,724 counts/minute for moderate physical activity, 5,725-9,498 counts/minute for vigorous physical activity, and $>$ 9,498 counts/minute for very vigorous physical activity, were used. Bouts were defined as uninterrupted periods of sedentary behavior, and breaks, as the non-sedentary period (involving at least light physical activity) between two sedentary bouts.[23] As indicators, based on previous studies,[11,12,14] we adopted the number of breaks per hour, mean length of sedentary bouts, and number of long sedentary bouts ($\geqslant$ 30 min). For the moderation analysis, an indicator of physical activity was created considering the cutoff point of daily 30 minutes of moderate physical activity, at least 15 minutes of vigorous physical activity, or a sum of at least 30 minutes in moderate-to-vigorous physical activity (MVPA), based on the World Health Organization (WHO) recommendations for physical activity.[24]

Covariates

Chronological age was included as a continuous variable. Educational attainment was collected through the question: What is your highest academic qualification? The responses were pooled into three categories (1 = less than secondary; 2 = secondary; 3 = higher). Employment status was assessed through a question asking about current occupation. Socioeconomic status was evaluated through the Associação Brasileira de Empresas de Pesquisa (ABEP) questionnaire, which evaluates purchasing power.[25]

Statistical procedures

Absolute and relative frequencies, as well as means and SD and medians and interquartile ranges (IQR) as appropriate, were used as descriptive statistics. We used Mann-Whitney *U* and chi-square tests to compare genders. Poisson regression models were used to analyze the association between each sedentary behavior pattern (i.e., total ST, breaks, mean bout length, and number of long bouts) and depressive symptoms.

We constructed crude and models adjusted for age, gender (for whole-sample analyses), education, socioeconomic status, employment status, total accelerometer wear time, and MVPA. The moderation of MVPA in the association between ST patterns and depressive symptoms was evaluated by inserting interaction terms with the exposures. In case of significant interactions, we also conducted linear regression of the association between ST patterns and depressive symptoms, stratifying by MVPA status. We stratified all the analyses by gender, as there were significant interactions with total ST (p = 0.001) and number of long sedentary bouts (p = 0.002) in the association with depressive symptoms. All procedures were conducted using Stata 15.1 software.

Ethics statement

The authors assert that all procedures contributing to this work comply with the ethical standards of the relevant national and institutional committees on human experimentation and with the Helsinki Declaration of 1975, as revised in 2008. All procedures involving human subjects/patients were approved by the Universidade Estadual Paulista ethics committee (process: 2.215.037).

Results

Of the 269 participants that completed both visits, 26 presented missing data for at least one variable. Therefore, the final sample was composed of 243 adults (137 women), with a mean age of 41.8±16.7 years. There were no statistical differences between the included and excluded participants. However, the excluded participants were slightly older (included, median = 41; IQR = 27-53, vs. excluded, 53; 33-67; p = 0.084), with a higher proportion of women (included, 56.4% vs. excluded, 68.1%; p = 0.284), but with similar socioeconomic conditions (included, 32; 26-39 vs. excluded, 32.5; 23-37). The characteristics of the sample according to sex are presented in Table 1. Women were older, presented higher proportion of unemployment, lower socioeconomic status, higher depressive symptoms, higher number of sedentary breaks, and lower MVPA than men.

Table 2 shows the associations between ST patterns and depressive symptoms according to sex. The number of long bouts of ST was associated with higher depressive symptoms in the sample as a whole (β = 0.050; 95%CI 0.008-0.092) and among men (β = 0.108; 95%CI 0.047-0.171), while total ST was associated with elevated depressive symptoms only among men in both crude and adjusted analyses.

The inclusion of interaction terms with physical activity revealed that the association between breaks and longer bouts of ST was stronger among physically inactive participants (Table 3). Comparing with participants who met recommended levels of physical activity, the association between number of sedentary breaks was associated with lower depressive symptoms among men with physical inactivity (β = -0.331; 95%CI -0.583 to -0.078), while a higher number of long bouts of ST was associated with higher depressive symptoms among participants with physical inactivity (overall sample, β = 0.127; 95%CI 0.042 to 0.213; men, β = 0.214; 95%CI 0.075-0.353).

Table 1 Characteristics of the sample stratified by sex

	Whole sample (n=243)	Men (n=106)	Women (n=137)	p-value
Chronological age (years), median (IQR)	41.0 (27.0-53.0)	35.0 (24.0-49.0)	48.0 (28.0-55.0)	0.008
Education, n (%)				0.572
Less than secondary	56 (23.1)	21 (19.8)	35 (25.6)	
Secondary	116 (47.7)	53 (50.0)	63 (46.0)	
Higher	71 (29.2)	32 (30.2)	39 (28.5)	
Socioeconomic status score, mean (SD)	33.1 (9.2)	34.7 (9.8)	31.8 (8.5)	0.020
Employment status, n (%)				0.015
Not employed	55 (22.6)	15 (14.2)	40 (29.2)	
Student	29 (11.9)	16 (15.1)	13 (9.5)	
Employed	159 (65.4)	75 (70.8)	84 (61.3)	
Depressive symptoms score, median (IQR)	4 (2-7)	3 (0-6)	5 (3-8)	< 0.001
ST (hours/day), mean (SD)	8.1 (2.0)	8.2 (2.2)	8.0 (8.5)	0.457
Sedentary breaks (n/hour), median (IQR)	6.4 (5.8-7.1)	6.3 (5.6-7.0)	6.5 (5.9-7.4)	0.010
Mean sedentary bout length (minutes), median (IQR)	5.5 (4.7-6.8)	5.8 (4.7-6.7)	5.4 (4.7-6.9)	0.564
Number of long sedentary bouts (n/day), median (IQR)	2.4 (1.6-3.2)	2.5 (1.7-3.3)	2.4 (1.3-3.1)	0.091
MVPA (minutes/day), median (IQR)	20.9 (10.4-38.0)	26.2 (13.4-41.6)	19.3 (8.3-35.3)	0.009
Physical activity status, n (%)				0.038
Inactive	153 (63.0)	59 (55.7)	94 (68.6)	
Active	90 (37.0)	47 (44.3)	43 (31.4)	
Total wear time (hours/day), median (IQR)	13.5 (12.0-15.0)	13.7 (12.0-15.4)	13.4 (11.9-14.6)	0.129

Long sedentary bouts are those longer than 30 minutes. IQR = interquartile range; MVPA = moderate-to-vigorous physical activity; ST = sedentary time.

Table 2 Association between patterns of ST and depressive symptoms stratified by sex

	Overall sample (n=243) β (95%CI)	Men (n=106) β (95%CI)	Women (n=137) β (95%CI)
Crude			
Total ST (hours/day)	0.018 (-0.011 to 0.048)	0.086 (0.040 to 0.132)	-0.019 (-0.058 to 0.021)
Breaks (n/day)	0.004 (-0.025 to 0.033)	-0.106 (-0.211 to 0.001)	-0.007 (-0.038 to 0.024)
Mean bout length (minutes)	-0.006 (-0.043 to 0.031)	0.008 (-0.052 to 0.067)	-0.002 (-0.050 to 0.046)
Number of long bouts (⩾ 30 minutes) (n/day)	0.049 (0.010 to 0.088)	0.145 (0.087 to 0.202)	0.018 (-0.024 to 0.071)
Adjusted			
Total ST (hours/day)	0.015 (-0.018 to 0.048)	0.063 (0.011 to 0.116)	-0.027 (-0.071 to 0.016)
Breaks (n/day)	-0.006 (-0.038 to 0.026)	-0.085 (-0.204 to 0.035)	-0.001 (-0.034 to 0.033)
Mean bout length (minutes)	-0.003 (-0.041 to 0.035)	0.048 (-0.014 to 0.110)	-0.002 (-0.053 to 0.048)
Number of long bouts (⩾ 30 minutes) (n/day)	0.050 (0.008 to 0.092)	0.108 (0.047 to 0.171)	-0.001 (-0.057 to 0.056)

ST = sedentary time.
Adjusted for age, education, socioeconomic status, employment status, total accelerometer wear time, and moderate-to-vigorous physical activity.

Table 3 Interactions of moderate-to-vigorous physical activity with patterns of sedentary behavior in the association with depressive symptoms

	Overall sample (n=243) β (95%CI)	Men (n=106) β (95%CI)	Women (n=137) β (95%CI)
Total ST (hours/day)	0.038 (-0.023 to 0.100)	0.044 (-0.054 to 0.142)	0.034 (-0.048 to 0.115)
Breaks (n/day)	-0.068 (-0.139 to 0.003)	-0.331 (-0.583 to -0.078)	-0.047 (-0.129 to 0.035)
Mean bouts length (minutes)	-0.064 (-0.144 to 0.016)	-0.021 (-0.149 to 0.107)	-0.121 (-0.229 to -0.013)
Number of long bouts (⩾ 30 minutes) (n/day)	0.127 (0.042 to 0.213)	0.214 (0.075 to 0.353)	0.084 (-0.029 to 0.197)

ST = sedentary time.
Values denote the inactive category, compared with the active category (reference). Adjusted for age, education, socioeconomic status, employment status, and total accelerometer wear time.

Table 4 Association between patterns of ST and depressive symptoms, stratified by moderate-to-vigorous physical activity

	Overall sample (n=243)		Men (n=106)		Women (n=137)	
	Inactive (n=153) β (95%CI)	Active (n=90) β (95%CI)	Inactive (n=59) β (95%CI)	Active (n=47) β (95%CI)	Inactive (n=94) β (95%CI)	Active (n=43) β (95%CI)
Total sedentary time (hours/day)	0.034 (-0.008 to 0.077)	-0.005 (-0.067 to 0.056)	0.066 (-0.001 to 0.134)	0.070 (-0.028 to 0.168)	-0.012 (-0.070 to 0.046)	-0.056 (-0.139 to 0.028)
Breaks (n/day)	-0.058 (-0.126 to 0.010)	0.009 (-0.025 to 0.044)	-0.211 (-0.360 to -0.063)	0.168 (-0.057 to 0.394)	-0.040 (-0.120 to 0.040)	0.003 (-0.038 to 0.044)
Mean bouts length (minutes)	-0.027 (-0.073 to 0.020)	0.054 (-0.013 to 0.122)	0.081 (0.003 to 0.158)	0.047 (-0.054 to 0.149)	-0.027 (-0.087 to 0.033)	0.128 (0.023 to 0.234)
Number of long bouts (⩾ 30min) (n/day)	0.097 (0.047 to 0.148)	-0.047 (-0.136 to 0.041)	0.166 (0.090 to 0.242)	-0.011 (-0.147 to 0.125)	0.039 (-0.031 to 0.108)	-0.085 (-0.202 to 0.032)

ST = sedentary time.
Adjusted for age, education, socioeconomic status, employment status, and total accelerometer wear time.

The associations between ST patterns and depressive symptoms, stratified by physical activity status, are presented in Table 4. Each additional break per hour was associated with a 0.211 reduction in symptoms of depression (inactive, β = -0.211; 95%CI -0.360 to -0.063 vs. active, β = 0.168; 95%CI -0.057 to 0.394); each 1-minute increase in sedentary bout length was associated with a 0.081 increase in depressive symptoms (inactive, β = 0.081; 95%CI 0.003 to 0.158 vs. active, β = 0.047; 95%CI -0.054 to 0.149); and each additional long sedentary bout was associated with a 0.166 increase in depressive symptoms (inactive, β = 0.166; 95%CI 0.090 to 0.242 vs. active, β = -0.011; 95%CI -0.147 to 0.125) among men with physical inactivity, while there were no such associations among men with recommended physical activity levels. Among women, only mean bout length was associated with higher depressive symptoms among active participants (β = 0.128; 95%CI 0.023 to 0.234).

Discussion

We sought to investigate whether different patterns of ST were associated with depressive symptoms and whether physical activity moderated these associations. We found that, among men, total ST and the number of longer ST bouts were associated with higher depressive symptoms. There were no associations among women. The interactions between patterns of ST and physical activity status revealed that the associations of sedentary breaks and longer sedentary behavior bouts with depressive symptoms were different according to physical activity status. Longer sedentary bout length, lower number of breaks, and higher number of longer sedentary bouts were associated with higher depressive symptoms only among participants with physical inactivity.

Considering that the sole previous study assessing the associations between device-measured sedentary behavior patterns and depressive symptoms was conducted among older adults,[12] this study advances in analyzing this association among young and middle-aged adults. Also, we found possible gender differences, which were somewhat in opposition to previous findings of a stronger association between ST and depressive symptoms among women.[5,6] However, further studies are warranted to further analyze these gender differences as well as possible mechanisms underlying them.

Also, our study found that the associations of breaks, time in longer bouts, and mean bout length were stronger among men with physical inactivity, which can be derived from convergent mechanisms that have been recently explored.[26,27] Although no previous studies investigated the mechanisms linking longer bouts of ST and breaks with depressive symptoms, different mechanisms can be speculated. Longer sedentary bouts can be associated with a reduced brain blood flow, which can be associated with lower cognition in the long term[28,29] and, consequently, associated with depressive symptoms.[30] Longer sedentary bouts are frequently concomitant to mentally passive sedentary activities during leisure time, which can be associated with higher depressive symptoms.[31,32] Furthermore, the prolonged lack of muscle contractions due to longer bouts of ST and lower number of breaks can be associated with an increase in low-grade inflammation as demonstrated by increased levels of markers such as interleukin-6 and C-reactive protein, especially among inactive people,[15,33] which can be consequently associated with higher depressive symptoms.[34]

The interaction of sedentary behavior patterns with physical activity among men has important implications, as people exposed to extensive periods of ST without recommended levels of physical activity can derive benefit (for depressive symptoms) from breaking up their ST with light physical activity. The lack of association between patterns of ST and depressive symptoms among participants with adequate levels of physical activity can be because the practice of MVPA already confers the adaptations of breaking ST, as reduction of low-grade inflammation,[35] improvements in cerebral blood flow[36] and cognition.[37]

We presented data on device-based ST patterns and depressive symptoms using a representative sample of adults, and we consider this our main strength. However, our results should be interpreted in light of potential limitations. Given the cross-sectional design, it is not possible to infer causality. Therefore, it is plausible that higher depressive symptoms can also cause longer sedentary bouts, fewer sedentary breaks, and higher bout length. In addition, we were unable to adjust the analyses for important confounders, such as previous diagnosis of any mental disorder or family history of depression. The sample size was also small after stratifying by groups of physical activity, which may have decreased the statistical power.

Our findings suggest that the number of longer sedentary bouts, longer mean sedentary bout length, and a lower number of sedentary breaks are associated with higher depressive symptoms, but only in inactive men. Interventions to encourage breaking up ST should be helpful among inactive people. Future studies should investigate the prospective association of ST patterns and depressive symptoms, with an emphasis on the role of physical activity, as well as explore potential mediators.

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Disclosure

The authors report no conflicts of interest. BS is an unsalaried advisor to FitXR on matters unrelated to this work; has spoken (noncommercially) about the topic at a range of events on exercise and mental health, and donates 100% of any fees to charity; and has received honoraria from co-editing a book on exercise and mental illness and from unrelated advisory work for ASICS Europe. This paper presents independent research. The views expressed in this publication are those of the authors and not necessarily those of the acknowledged institutions.

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