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Association between obesity and sedentary behavior in adults

Associação entre a obesidade e o comportamento sedentário em adultos

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Abstract – Although sedentary behavior (SB) is related to the development of metabolic diseases, there is still no consensus in literature about the association between accelerometer-based SB and obesity, especially adjusted for cardiovascular risk factors and level of daily physical activities. The aim was to evaluate the association between obesity and SB adjusted for potential confounders in adults. Data from 780 participants of the Epidemiology and Human Movement (EPIMOV) Study were analyzed. Body weight, body mass index (BMI), and fat body mass as percentage (%FBM) (bioelectrical impedance) were obtained and, then, used to stratify participants. SB was objectively measured using triaxial waist-worn accelerometers placed above the dominant hip during waking hours for at least four consecutive days (4-7 days). SB and its pattern were not significantly different between obesity groups. Although SB presented some significant correlations with obesity, the correlation and determination coefficient indicated weak association between SB and obesity (e.g., BMI and %FBM). Obesity presented little or no association with SB and its pattern after adjustment for potential confounders, especially when SB is measured through accelerometry.

Key words: Body composition; Motor Activity; Obesity; Sedentary Behavior.

Resumo – *Embora o comportamento sedentário (CS) esteja relacionado ao desenvolvimento de doenças metabólicas, ainda não há consenso na literatura sobre a associação entre o CS avaliado diretamente por acelerometria e a obesidade, especialmente quando essa relação é ajustada por fatores de risco cardiovascular e nível de atividade física. Objetivou-se avaliar a associação entre CS e obesidade ajustada por potenciais confundidores em adultos. Foram analisados os dados de 780 participantes do Estudo Epidemiológico sobre o Movimento Humano (EPIMOV). Dados relativos à massa corporal, índice de massa corporal (IMC) e porcentagem de gordura corporal (%GC) (bioimpedância elétrica) foram obtidos e, então, utilizados para estratificar os participantes. O CS foi medido objetivamente por meio de acelerômetros triaxiais colocados sobre o quadril dominante durante as horas de vigília por, pelo menos, quatro dias consecutivos (4-7 dias). O CS e seu padrão não foram significativamente diferentes entre os grupos de obesidade. Embora o CS tenha apresentado algumas correlações significativas com a obesidade, o coeficiente de correlação e determinação indicou uma fraca associação entre o CS e a obesidade (por exemplo, IMC e %GC). A obesidade apresentou pouca ou nenhuma associação com o CS e seu padrão após o ajuste para potenciais fatores de confusão, principalmente quando avaliado com acelerômetro.*

Palavras-chave: *Composição Corporal; Atividade Motora; Obesidade; Comportamento Sedentário.*

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INTRODUCTION

Obesity is a growing worldwide public health problem, which is associated with cardiovascular problems, diabetes, cancer and other diseases[1]. The energy imbalance between calorie consumption and expenditure is the main trigger of obesity[2]. Increased time in sedentary behavior (SB), as well as reduced level of daily physical activities results in decreased total energy expenditure[3].

The benefits of physical activity and its inverse relationship with all-cause mortality are widely described in literature[4]. However, adopting SB (e.g. activities with energy expenditure ≤ 1.5 Metabolic Equivalent of Task (METs) or sitting and lying postures) differs from being physically inactive, both of which may or may not coexist[5]. The English expression "*Active Couch Potato*" refers to the subject who meets the minimum recommended physical activity, but spends much time in SB, which can be equally harmful[5]. Thus, SB should gain attention in public health policies and recommendations on physical inactivity and disease prevention[6] since SB is an independent predictor of premature mortality[7] and has potential for the development of metabolic diseases due to the absence of prolonged muscle contraction[8].

Triaxial accelerometry provides an objective measure of SB and its pattern such as total time, sedentary breaks and bouts, which also influence metabolic health and cardiovascular risk[9,10]. There is still no consensus in literature about the association between accelerometer-based SB and obesity, especially when adjusted for associated comorbidities and level of daily physical activities. Our hypothesis is that obesity is not associated with SB after adjustment for commonly associated comorbidities. Thus, we aimed to evaluate the association between obesity and presence of SB adjusted for potential confounders in adults. Secondarily, the association between obesity and level of daily physical activities was also evaluated.

METHODS

Study design and participants

This is a cross-sectional study with 780 participants aged ≥ 20 years (297 men and 493 women) selected from the Epidemiological and Human Movement Study (EPIMOV), approved by the local university ethics and research committee, No. 186.796. The EPIMOV Study is a population-based epidemiological study whose main objective is to evaluate the association between SB and physical inactivity and the development of hypokinetic chronic diseases.

The sample was selected for convenience and recruited through folders and social media. All participants were informed about the risks and discomforts related to the research protocol and signed the Informed Consent Form.

Participants with previous diagnosis of heart or lung disease and/or with difficulties to perform physical activity due to osteoarticular, neurological or musculoskeletal problems were excluded.

Measures

- **Clinical and sociodemographic assessment**

Anamnesis about regular medication use and health problems was conducted. In addition, all participants answered the previously validated physical activity readiness questionnaire (PAR-Q)[11]. The following cardiovascular risk factors were considered: Family history of cardiovascular diseases (incidence of acute myocardial infarction in first-degree relatives), arterial hypertension, hyperglycemia or diabetes, already installed hypercholesterolemia or dyslipidemia, smoking (self-reported current smoking or having smoked at least 100 cigarettes during life), overweight or obesity and level of physical activity as recommended[12], which were adapted for direct evaluation by triaxial accelerometry in this study.

- **Anthropometric evaluation and body composition**

Body mass and height were obtained using stadiometer (TOLEDO, São Paulo, Brasil). Then, body mass index (BMI) was calculated[13]. Waist, hip and neck circumferences were also measured, as previously recommended[13].

Body composition was assessed using tetrapolar electrical bioimpedance (310e, BIODYNAMICS, Detroit, USA). All prior determinant procedures for non-compromise and test accuracy were followed, which include not using diuretic drugs for 7 days, fasting for at least 4 hours, do not drink alcohol 48 hours prior to test, urinate at least 30 minutes before test and remain 10 minutes in supine position prior to test[14].

Two electrodes were applied on the dorsal region of the dominant hand and other two on the dominant foot. Participants were evaluated in supine position with arms and legs abducted at 30º and 45º respectively. All procedures followed manufacturer's manual instructions. Resistance and reactance were obtained. Lean body mass and fat body mass as total and percentage were calculated by means of previously validated specific equation[15].

Participants were stratified according to fat body mass as percentage (%FBM) as follows: mild obesity was considered from 25 to 29.9%, moderate from 30 to 34.9%, high from 35 to 39.9% and morbid above 40% for women. For men, mild obesity was considered from 15 to 19.9% of FBM, moderate from 20 to 24.9%, high from 25 to 29.9 and morbid above 30%[14].

- **Accelerometer-based sedentary behavior and physical activity**

Previously validated triaxial accelerometer (GT3X+, Actigraph, Pensacola, FL, EUA) was used to assess SB and daily physical activity [16,17].

Participants were instructed to use the device in the dominant hip for 7 consecutive days during waking hours without removing it, except for water-related activities or during night sleep.

Data from participants who used the device for at least four days for 12 consecutive hours per day were considered valid [17]. As recommended, participants who presented less than 150 minutes of moderate-to-vigorous physical activity (MVPA) during weekdays were considered physically inactive[12]. SB and its pattern were obtained as previously described[9, 17-19].

Briefly, SB was considered as activities with less than 100 counts per minute (cpm) and sedentary bouts as activities that remain at least 5 minutes. For sedentary breaks, activities with more than 100 cpm (transitions from sedentary to active phase) were considered. Accelerometer non-use time was defined as at least 60 minutes of zero counts, e.g. between 0 and 100 cpm. SB and its pattern were calculated as minutes or minutes/week, and as absolute values and percentages of the total time. The total duration of sedentary series (min) was corrected for total accelerometer use time[17-19].

Physical activity intensity thresholds were as follows: light (≤ 3.00 METs or <1952 counts), moderate (3.00-5.99 METs or between 1952-5724), vigorous (6.00-8.99 METs or between 5725-9498 counts) and very vigorous physical activity (9.00 METs or >9498 counts)[19]. Daily .physical activity was calculated as minutes, hours and percentages of the total time.

Energy expenditure was also obtained in METs and Kcal from counts using Freedson's equation through the physical activity intensity [18].

Statistical analysis

Statistical analysis was performed using SPSS® version 23 (IBM SPSS Corp., Armonk, NY, USA). Data were descriptively analyzed and presented as mean ± standard deviation or as median (interquartile range) according to the Kolmogorov-Smirnov test. Categorical variables were described as frequency and percentages.

Sample size was calculated based on the number of independent variables of interest for inclusion in the multiple regression model, which indicates at least 135 subjects for the present study. Sex, age (years), hypertension, dyslipidemia, diabetes, %FBM and current smoking were included in multivariate models.

At first, correlations between physical activity and SB and the other variables under study were analyzed using Pearson's or Spearman's correlation coefficients and simple linear regression.

The sample was stratified according to %FBM. ANOVA was used for comparison of physical activity and SB between groups. The analysis was adjusted for age (years), sex and main confounders (e.g., cardiovascular risk factors). For comparison of categorical variables, the χ^2 test was used.

A 3-step hierarchical regression analysis was performed to investigate the association between %FBM or BMI and physical activity or SB. In Step 1, only %FBM or BMI was used to obtain unadjusted coefficients. Step 2 contained Step 1 plus age and sex. Finally, Step 3 used Step 2 plus arterial hypertension, diabetes, dyslipidemia and current smoking. The α error probability was set at 5% for aforementioned tests.

RESULTS

The sample was mainly composed of middle-aged women. Eutrophic participants were younger when compared to obese groups. The prevalence of diabetes was higher in morbid obesity in comparison to the other groups. The same was observed for prevalence of hypertension in high and morbid obesity and for prevalence of dyslipidemia in moderate, high and morbid obesity (Table 1).

Table 1. Sample characteristics (n = 780).

	Obesity stratified according to Fat Body Mass (%)				
	Eutrophic (n=74)	Mild obesity (n=114)	Moderate obesity (n=198)	High obesity (n=153)	Morbid obesity (n=241)
Age (yr)	30 ± 9	36 ± 13	43 ± 13	48 ± 12	49 ±13
Male	31 (41.9)	44 (38.6)	55 (27.8)	57 (37.3)	110 (41.5)†
Female	43 (58.1)	70 (61.4)	143 (72.2)#	96 (62.7)	141 (58.5)
Hypertension	2 (2.7)	6 (5.3)	25 (12.6)	36 (23.5)*‡	70 (29)*‡†
Diabetes	0 (0)	5 (4.4)	16 (8.1)	19 (12.4)	43 (17.8)‡†
Dyslipidemia	3 (4.1)	12 (10.5)	52 (26.3)*‡	54 (35.3)*‡	91 (37.5)*‡
Smoking	6 (8.1)	12 (10.5)	26 (13.1)	19 (12.4)	27 (11.2)
BMI (kg/m²)	22 ± 2	23 ± 2	26 ± 4	29 ± 3	33 ± 6
Waist circumference (cm)	73 ± 8	77 ± 8	84 ± 11	94 ± 8	102 ± 14
Waist-to-hip ratio	0.7 ± 0.05	0.8 ± 0.08	0.8 ± 0.07	0.9 ± 0.08	0.8 ± 0.07

Note. Data were expressed as mean ± standard deviation and frequency (%). BMI: body mass index. *: ($p \leq 0.05$) vs. eutrophic; ‡: ($p \leq 0.05$) vs. mild obesity; †: ($p \leq 0.05$) vs. moderate obesity; €: ($p \leq 0.05$) vs. high obesity; #: ($p \leq 0.05$) vs. morbid obesity.

The proportion of physically inactive participants was 23% for the eutrophic group, 26% for the mild obesity, 25% for the moderate obesity group, 35% for the high obesity group and 38% for the morbid obesity group (Table 1).

SB pattern was similar for all groups, except for sitting time (%) in the high obesity group when compared to the eutrophic group, and standing time (%) in all groups when compared to the morbid obesity group (Table 2).

Regarding physical activity, there was a downward trend of decrease in all measurements as adiposity increases, especially in very vigorous physical activity, MVPA (%), and MVPA per day. The eutrophic group showed higher physical activity when compared to the other groups (Table 2).

The number of steps per minute was higher in all groups compared to morbid obesity. High total number of steps in eutrophic, mild and moderate obesity groups was also found. The average duration of sedentary bouts, standing time (%) and sitting time (%) correlated with %FBM and BMI ($p \leq 0.01$) (Table 3).

Physical activity variables correlated with %FBM and BMI, except for light physical activity. The average daily total energy expenditure was significant only when correlated with BMI (Table 3).

After adjustment, accelerometer-based SB variables were less associated with %FBM than self-reported SB variables (Table 4).

Table 2. Results for accelerometer-based sedentary behavior and accelerometer-based physical activity

	Obesity stratified according to Fat Body Mass (%)				
	Eutrophic (n=74)	Mild obesity (n=114)	Moderate obesity (n=198)	High obesity (n=153)	Morbid obesity (n=241)
Sedentary behavior					
Total number of sedentary bouts	66 (28)	66 (30)	58 (28)	66 (32)	61 (32)
Total time of sedentary bouts (min)	1,228.3 (571.7)	1,277.9 (653.0)	1,112.8(601.7)	1,303.9 (704.3)	1,219.9 (712.4)
Average duration of each sedentary bouts (min)	18.3 (-2.6)	18.8 (-2.2)	18.8 (2.5)	19.2 (-2.7)	19.3 (-2.7)
Daily average duration of sedentary bouts (min)	221.6 (-78.6)	226.9 (-96.8)	207.4(-86.6)	229.7 (-99.3)	223.3 (-98.1)
Total number of sedentary breaks	65 (28)	65 (30)	57 (28)	65 (32)	60 (32)
Total duration of sedentary breaks (min)	7,348.9 (2,679.5)	7,013.7 (1,877.7)	7,058.4 (1,990.9)	6,991.9 (-2,409.9)	7,306.7 (2,586.3)
Average duration of each sedentary break (min)	131.4 (-71.7)	137.7(-94.5)	165.4 (-162.9)	135.0 (-89.2)	174.1 (-207.2)
Average duration of sedentary breaks (min)	1,379.9 (488.4)	1,299.1 (376.9)	1,391.1 (479.9)	1.,292.4 (499.7)	1,453.2 (638.5)
Average time in sedentary behavior (% total)	74.0 (-6.1)	74.1 (-6.2)	72.0 (-7.2)	73.1 (-7.6)	73.8 (-6.5)
Standing time (% total)	24.0 (-8.2)†€#	24.2 (7.2)€#	21.4 (7.5)#	20.5 (6.9)#	17.5 (-7.4)
Sitting time (% total)	22 (8)	23 (7)	24.1 (-8.1)	26.0 (-7.6)*	24.7 (-8.3)
Sitting time during weekdays (min) ¥	305.3 (-189.0)	315.9 (-202.3)	298.5 (-220.5)	294.5 (-198.5)	338.6 (-222.5)
Sitting time during weekend (min) ¥	249.5 (-181.0)	272.2 (-206.9)	246.6 (-193.2)	266.5 (-172.6)	318.1 (-200.8)†
Physical activity level					
Average energy expenditure (Kcal)	2.102 (1.224)	2.034 (1.213)	2.278 (1.291)	2.625 (1.560)‡	2.627 (1.533)‡
Average energy expenditure/day (Kcal)	379 (204)	373 (208)	427 (200)	480 (256)*‡	492 (240)*‡
Average energy expenditure (METs)	1.2 (0.1)	1.2 (0.1)	1.2 (0.1)	1.2 (0.1)	1.2(0.1)
Physical activity					
Light (% total)	20.1 (5.1)	20.5 (5.8)	22.6 (6.2)*	21.7 (6.1)	21.7 (5.4)
Moderate (% total)	5.1 (2.1)	4.8 (2.5)	4.9 (2.4)	4.8 (3.1)	4.2 (2.4)
Vigorous (% total)	0.4 (0.7)#	0.4 (0.9)€#	0.2 (0.7)	0.2 (0.6)	0.1 (0.4)
Very vigorous (% total)	0.1 (0.3)‡†€#	0.0 (0.0)	0.0 (0.1)	0.0 (-0.2)	0.0 (-0.1)
Moderate-to-vigorous (% total)	5.7 (2.5)#	5.3 (2.9)	5.3 (2.6)#	5.1 (3.3)	4.4 (2.5)
Average MVPA/day (min)	50.6 (203.9)#	48.3(28.1)#	47.0 (23.1)#	45.4 (29.3)	38.8 (23.7)
Number of steps/min	10.2 (3.3)#	9.7 (3.6)#	9.7 (3.4)#	9.2 (4.0)#	7.9 (3.0)
Total number of steps	8.021(3.959-16.278)#	7.732(4.747-16.318)#	8.124(4.360-13.647)#	7.453(3.185-14.279)	6.634(3.338-12.205)

Note. Data were expressed as median (95% interval confidence). *: (p ≤ 0.05) vs. eutrophic; ‡: (p ≤ 0.05) vs. mild obesity; †: (p ≤ 0.05) vs. moderate obesity; €: (p ≤ 0.05) vs. high obesity; #: (p ≤ 0.05) vs. morbid obesity. ¥: self-reported.

Table 3. Results for bivariate analysis between obesity and sedentary behavior or physical activity.

	%FBM	BMI
	r	r
Sedentary behavior		
Total number of sedentary bouts	-0.01	-0.04
Total time of sedentary bouts (min)	0.01	0
Average time of sedentary bouts (min)	0.11**	0.10**
Maximal time of sedentary bouts (min)	0.08*	0.07*
Minimal time of sedentary bouts (min)	-0.01	0.01
Daily mean of sedentary bouts (min)	0.01	0
Total number of sedentary breaks	-0.01	-0.04
Total time of sedentary breaks (min)	0.01	0.02
Average time of sedentary breaks (min)	0.03	0.05
Maximal time of sedentary breaks (min)	0	0.05
Minimal time of sedentary breaks (min)	0.01	-0.02
Daily mean of sedentary breaks (min)	0	0.06
Average time in sedentary behavior (h)	0	-0.05
Average time in sedentary behavior (% total)	-0.01	-0.03
Standing time (% total)	-0.02**	-0.34**
Sitting time (% total)	0.12**	0.11**
Sitting time during weekdays (min) ¥	-0.01	0.05
Sitting time during weekend (min) ¥	0.05	0.10**
Physical activity		
Average energy expenditure (Kcal)	0	0.23**
Average energy expenditure/day (Kcal)	0	0.30**
Average energy expenditure (METs)	-0.17**	0.23**
Light physical activity (h)	0.08*	0.30**
Moderate physical activity (h)	-0.13**	0.02
Vigorous physical activity (h)	-0.23**	0.03
Very vigorous physical activity (h)	-0.17**	-0.12**
Light physical activity (% total)	0.12**	-0.16**
Moderate physical activity (% total)	-0.15**	-0.11**
Vigorous physical activity (% total)	-0.24**	0.12**
Very vigorous physical activity (% total)	-0.17**	-0.11**
Average moderate-to-vigorous physical activity (h/total)	-0.18**	-0.16**
Average moderate-to-vigorous physical activity (% total)	-0.21**	-0.11**
Average moderate-to-vigorous physical activity/day (min)	-0.20**	-0.15**
Number of steps/min	-0.23**	-0.15**
Total number of steps	-0.18**	-0.15**

Note. BMI: body mass index. FBM: fat body mass. ¥: self-reported; **: $p < 0.01$; *: $p < 0.05$.

Table 4. Results for multivariate analysis.

Outcomes	Predictors			
	Fat Body Mass (%)		Body Mass Index	
	Unadjusted coefficient	Adjusted coefficient	Unadjusted coefficient	Adjusted coefficient
Average duration of sedentary bouts (min)	0.033*	0.005	-0.042*	0.005
Standing time (% total)	-0.256*	-0.426*	-0.470*	-0.575*
Sitting time (% total)	0.122*	0.061	0.156	0.053
Sitting time during weekdays (min) ¥	-0.406	4.176*	1.859	-0.052*
Sitting time during weekend (min) ¥	1.222	3.874*	3.007*	4.570*
Average moderate-to-vigorous physical activity (% total)	-0.064*	-0.055*	-0.064*	3.800*
Average number of steps	-0.015*	-0.019*	-0.022*	-0.023*

Note. ¥: self-reported; **: p < 0.01; *: p < 0.05.

Subsequently, in hierarchical regression, the %FBM coefficient remained significant in relation to accelerometer-based variables, except for average duration of sedentary bouts. However, the %FBM coefficient became significant when controlled for age, sex (Step 2) and cardiovascular risk factors (Step 3) to both self-reported sitting time during weekdays and weekend (Table 5).

Unlike %FBM, the BMI coefficient remained significant for standing time and sitting time during weekend. Regarding the average duration of sedentary bouts, MVPA and sitting time (%) became non-significant. Finally, the BMI coefficient remained significant in relation to sitting time during weekdays (Table 5).

Table 5. Results for hierarchical regression analysis with %FBM or BMI as predictors.

Outcomes	Variables entered								
	Step 1			Step 2			Step 3		
	β	R^2	ΔR^2	β	R^2	ΔR^2	β	R^2	ΔR^2
%FBM									
Average duration of sedentary bouts (min)	0.143**	0.021	-	0.128*	0.042	0.021	0.121	0.044	0.003
Standing time (% total)	-0.298**	0.089	-	-0.546**	0.140	0.051	-0.557**	0.150	0.010
Sitting time (% total)	0.148**	0.022	-	0.165*	0.038	0.016	0.173*	0.042	0.004
Sitting time during weekdays (min) ¥	-0.019	0.000	-	0.235**	0.062	0.061	0.223**	0.069	0.007
Sitting time during weekend (min) ¥	0.068	0.005	-	0.242**	0.028	0.023	0.219**	0.040	0.012
Average moderate-to-vigorous physical activity (% total)	-0.250**	0.062	-	-0.259**	0.063	0.001	-0.248**	0.077	0.014
Average number of steps	-0.277**	0.077	-	-0.467**	0.103	0.026	-0.457**	0.114	0.011
BMI									
Average duration of sedentary bouts (min)	0.122**	0.015	-	0.061	0.039	0.024	0.047	0.043	0.004
Standing time (% total)	-0.346**	0.120	-	-0.371**	0.125	0.006	-0.392**	0.139	0.014
Sitting time (% total)	0.114**	0.013	-	0.060	0.037	0.024	0.062	0.042	0.004
Sitting time during weekdays (min) ¥	0.062	0.004	-	0.163**	0.067	0.063	0.162**	0.072	0.005
Sitting time during weekend (min) ¥	0.112**	0.013	-	0.172**	0.035	0.022	0.161**	0.045	0.010
Average moderate-to-vigorous physical activity (% total)	-0.209**	0.044	-	-0.154**	0.163	0.119	-0.125	0.171	0.009
Average number of steps	-0.279**	0.078	-	-0.283**	0.127	0.049	-0.246**	0.141	0.014

Note. Variables entered: %FBM (Step 1); %FBM, Age and Sex (Step 2); %FBM, Age, Sex, Hypertension, Diabetes, Dyslipidemia and Current smoking (Step 3). **: p < 0.01; *: p < 0.05. ¥: self-reported.

DISCUSSION

The present study investigated the association between SB and obesity categorized by %FBM free from confounding effect of cardiovascular risk factors in adults. To our knowledge, the association related to %FBM instead of BMI is still scarce, especially when SB is measured through accelerometry. After adjustment, accelerometer-based SB variables were less associated with %FBM than self-reported SB variables, which may be linked to the low self-report accuracy. As expected, obesity was more significantly associated with level of physical activity than SB. Thus, obesity has little or no association with SB after adjustment for main confounders.

Our sample was mainly composed of middle-aged women. The presence of cardiovascular risk factors was similar to those presented by the Brazilian population for current smoking-related prevalence in all groups, but low prevalence of arterial hypertension and diabetes, except for high and morbid obesity[20].

The association between SB, physical activity and obesity has recently been the focus of several studies. Although obesity was associated with average duration of sedentary bouts objectively measured, our results showed no significant differences of accelerometer-based SB between obesity groups, as previously described for BMI, which only correlated with self-reported TV time[21]. In a review study, Carneiro et al.[22] suggested that the obese population has higher daily and total energy expenditure. However, when considering body composition (fat-free mass), there are no differences between obese and non-obese subjects, which may occur due to the presence of unhealthy behaviors such as low physical activity and high fat intake[22].

It was observed that high BMI, but not high %FBM, was also related to long duration of sedentary bouts[23], which reinforces what literature has yet to clarify. Our results shows that sitting time correlates with increased obesity level, which differs from a recent study suggesting that sitting time was not significantly associated with obesity[5].

As expected, vigorous and very vigorous physical activity, as well as number of steps, was lower in high and morbid obesity groups. These findings agree with literature, since MVPA is associated with low BMI, subcutaneous and visceral adipose tissue[24].

Our results showed that the average daily energy expenditure was higher, the higher the obesity level. DeLany[25] recently discussed these findings and suggested that they may be explained not by increased metabolic efficiency, but by the high energy expenditure to perform activities due to high body mass. The author also pointed out that these points could mask the lower levels of physical activity performed by these subjects.

Although SB correlates with %FBM, it does not seem to be sufficient to determine obesity, unlike physical activity, especially MVPA. A large NHANES study including more than 5,000 participants found that slight differences in daily MVPA (e.g., 6 minutes) between groups had significant impact on the risk of obesity, which did not occur with the total time spent on SB or watching TV [26].

In contrast to our results, Werneck et al.[27] concluded that sedentary bouts no longer than 4 minutes and high sedentary behavior breaks are associated with adiposity, thus contributing with obesity in adolescents [27]. However, the sample was composed of 389 adolescents (10-14 years), mainly male, using skinfold thickness, waist circumference and BMI to characterized adiposity. In addition, sedentary bouts were divided into 3 main groups: 1-4mins, 5-14mins, ≥15mins, whereas we obtained more time in SB and the average duration of SB were greater than the last interval. Although SB as % was similar to ours, the sample presented major differences in comparison to the sample of this study, as well as methods, which explains the opposite results. Similar to our study, Myers et al.[28] observed negative correlation between physical activity and all body composition measurements (body mass, FBM, and waist circumference and BMI). The authors showed that the correlation between adiposity and SB was attenuated when adjusted for MVPA. Thus, that the MVPA is more important than SB in adiposity, which reinforce our results.

In our study, SB was associated with obesity stratified by %FBM. However, it is possible to observe that SB presented little or no influence on obesity when examining correlation and determination coefficients and comparing adjusted and unadjusted coefficients. Although significant correlations between SB (e.g., standing time, sitting time and average duration of sedentary bouts) and obesity were found, the association was weak, especially when compared to those observed for physical activity. Our results are in agreement with the systematic review and meta-analysis of prospective studies carried out by Campbell et al.[29], who concluded that the association between SB and body weight and obesity is weak, inconsistent and lacking in significance. Thus, our study reinforces that obesity has more consistent association with physical activity than SB, which corroborates previous findings[29].

According to Curry and Thompson[30], both self-reported physical activity and sedentary time are underestimated when compared to accelerometer-based measurements. This may be due to the lack of physical activity participation cultural context and terminology, the difficult of measuring how much physical activity is compatible with a given intensity, the struggle to remind the amount of time-spent sitting, and the limited knowledge about moderate-to-vigorous daily-living activities. Therefore, our findings showed conflicting and inconsistent adjusted and unadjusted coefficients, especially self-reported SB, which may be attributed to the main limitations of the use of questionnaires to inquire the amount of activities of the daily living.

Some limitations and strengths of the present study should be considered. The convenience sample may explain the higher proportion of women. Moreover, the study design does not allow cause and effect interference. Therefore, how much SB is a cause or consequence of obesity needs further clarification by longitudinal studies. However, SB and physical activity were objectively evaluated using triaxial accelerometer. Taking to account BMI limitations, we choose to use FBM to stratify our sample, which is one of the main strengths of our study.

CONCLUSIONS

Sedentary behavior and its pattern were not significantly different between obesity groups. Although SB presented some significant correlations with obesity, correlation and determination coefficient indicated weak association between SB and obesity (e.g., BMI and %FBM). Obesity presents little or no association with SB and its pattern after adjustment for potential confounders, especially when measured through accelerometry. Finally, obesity has more important association with level of physical activity than with SB.

COMPLIANCE WITH ETHICAL STANDARDS

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Ethical approval

Ethical approval was obtained from the Federal University of São Paulo Human Research Ethics Committee – No. 186.796/2013 and the protocol was written in accordance with standards set by the Declaration of Helsinki.

Conflict of interest statement

The authors have no conflict of interests to declare.

Author Contributions

Conception and design of the experiment: VZD. Conduction of experiments: BBG, TLVPO, EFS. Data analysis: VZD. Contribution with reagents/research materials/analysis tools: RLA, ARTG, MR. Article Writing: BBG, TLVDPO, VZD. All authors read and approved the final version of the manuscript.

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