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Isotemporal substitution of physical activity patterns and sitting time with obesity indicators among workers in São Paulo

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This study aimed to evaluate the association between substituting 10, 30, and 60 min/day of physical activity and sitting time with obesity indicators among workers. It is a cross-sectional study involving 394 adults (76.6% women) from São Paulo, Brazil. Physical activity and sitting time (min/day) were measured using the short version of the International Physical Activity Questionnaire (IPAQ) to determine physical activity levels. Obesity indicators included body mass index (BMI; kg/m²), waist circumference (cm), and body fat (kg). Isotemporal substitution models were analyzed using multivariate linear regression, adjusted for sociodemographic variables. Participants reported median values of 150.0 min/day (IQR: 60.0–360.0) for walking and 445.7 min/day (IQR: 317.1–565.7) for sitting time. The median values for BMI, waist circumference, and body fat were 27.1 kg/m², 91.0 cm, and 23.5 kg, respectively. Substituting 10 min/day of sitting time for 10 min/day of walking was associated with waist circumference (β: -0.216: 95% CI: -0.041; -0.007). In addition, substituting 60 min/day of sitting time for moderate physical activity (β -0.206; 95% CI: -0.123; -0.008) was negatively associated with body fat. The equivalent substitution of different periods of sitting time for more active behaviors was favorably associated with obesity indicators. These findings suggest that lifestyle interventions based on replacing sitting time with physical activity can reduce the obesity epidemic in adults.

Keywords Sedentary time, Walk, Physical activity, Obesity, Adults

The prevalence of obesity among adults is rising globally[1,2]. By 2030, it is projected that 3 out of every 10 Brazilian adults will be affected by obesity[1]. If this trend continues, it could lead to approximately 808,600 deaths from chronic non-communicable diseases associated with excess weight[3]. Additionally, São Paulo, one of the largest cities in Latin America, has seen a concerning rise in obesity prevalence in recent years[4–7]. The prevalence of obesity (defined as a body mass index [BMI] of ≥30 kg/m^2) increased from 11.1% in 2006 to 19.8% in 2019[6]. Obesity can lead to an increased risk of developing other diseases, including cardiovascular disease[8], type 2 diabetes mellitus[8] and cancer[9].

Non-pharmacological strategies to reduce obesity include engaging in moderate to vigorous physical activity (MVPA) and minimizing sedentary behavior[10]. According to the World Health Organization (WHO), adults should aim for at least 150 min/week of MVPA to achieve significant health benefits[11]. However, global estimates show that physical inactivity (< 150 min/week of MVPA) affects 30.3% of adults[12]. In São Paulo, the prevalence of physical inactivity is even higher, at 38.3%[13] .

Several studies on physical activity and obesity have examined only physical activity or sedentary time to predict obesity outcomes, while adjusting for covariates such as age, gender, smoking, and others[14,15]. However, since a day consists of only 24 h, individuals allocate this time across various behaviors, including sleep, sedentary activities in different contexts (e.g., work, screen time, studying, driving)[16], and physical activities across different domains (e.g., work, leisure, transportation)[17,18] and intensities (e.g., light, moderate, vigorous)[19,20]. Due to the finite nature of the 24-hour day, increasing time spent on one behavior (e.g., screen time) often results in a decrease in time allocated to another behavior (e.g., light-intensity physical activity)[21].

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In this context, isotemporal substitution analysis examines the theoretical effect of "substituting" equal amounts of time spent on one behavior (e.g., 60 min of screen time) with another behavior (e.g., 60 min of light physical activity) on health outcomes[22–24]. Additionally, isotemporal substitution analysis assumes that time-use behaviors, such as sedentary time and physical activity, are interdependent. This approach suggests that reallocating time from one behavior inevitably results in a reduction of another[22–24].

A growing body of evidence shows that replacing various durations of sedentary behavior (10 min/day or 60 min/day) with physical activity is associated with improvements in various health markers[25–32]. For instance, Cao and colleagues demonstrated that substituting 60 min/day of sedentary time with 60 min/day of light or vigorous-intensity physical activity was associated with a reduced risk of COPD, depression, and diabetes[25]. Additionally, another study examining the substitution of 15, 30, 45, and 60 min/day of sedentary time for light and MVPA found negative associations with fat mass (assessed by bioelectrical impedance) and BMI in European adults[33]. However, most of these studies have been conducted in high-income[33–36].

In contrast, there is limited evidence on the use of isotemporal substitution for obesity markers in Brazil, with most studies focusing on children and adolescents[37–39]. Furthermore, a study that analyzed isotemporal substitution in obesity among Brazilian adults considered only 10 min/day for the analysis[40]. Therefore, investigating the association between substituting physical activity and sedentary time for different periods could provide further insights into the ideal balance between these behaviors for improving body composition. Thus, the aim of this study was to evaluate the associations between substituting 10, 30 and 60 min/day of physical activity and sitting time with BMI, waist circumference and body fat among workers in São Paulo.

Methods

Study design and sample

This cross-sectional study was conducted among employees of the Regional Health Department (RHD) aged 18 to 73, residing in various regions of the state of São Paulo. Data collection took place between July and September 2018 at each RHD for convenience.

This study is part of the "Agita São Paulo" program, a state initiative aimed at combating sedentary lifestyles and physical inactivity in São Paulo[41]. Details of the "Agita São Paulo" program have been published previously[41–43]. As an extension of the program's efforts, surveys are periodically conducted to assess levels of physical activity, sedentary behavior, and health-related factors (e.g., obesity, hypertension, functionality, and self-perceived health) among the population of São Paulo[44].

The state of São Paulo is divided into 17 RHD, and 15 15 of these departments from different regions participated in the study. A total of 1,056 workers met the eligibility criteria: (a) aged 18 years or older, (b) employed by an RHD, and (c) without clinical or functional limitations. Individuals with missing or inconsistent data on physical activity ($n=176$), sitting time ($n=134$), BMI ($n=74$), waist circumference ($n=70$), body fat ($n=76$), age ($n=14$), socioeconomic status ($n=51$), marital status ($n=36$), and educational level ($n=31$) were excluded from the analysis. The final sample consisted of 394 adults (76.6% women).

Physical activity and sitting time

Participants reported their levels of physical activity and sitting time using the short version of the International Physical Activity Questionnaire (IPAQ), which has been validated in several countries, including Brazil[45,46].

The data collection team instructed participants to report the frequency (days per week) and duration (≥ 10 min performed continuously) of walking, moderate physical activity (MPA), and vigorous physical activity (VPA) performed in the previous week. Average walking time, MPA, and VPA were calculated by multiplying frequency by duration and dividing by 7. IPAQ data were expressed in min/day[25,47]. Additionally, data where the total sum of walking time, MPA, and VPA exceeded 960 min/day were excluded from the analysis. Finally, data with at least 10 min/day of reported activity were considered valid for analysis[48].

Participants also self-reported sitting time spent in various contexts (home, work, free time, studying, lying down watching television) during the last seven days. For the analysis, we used substitutions of 10, 30, and 60 min/day of walking, MPA, VPA, and sitting time. These periods were specifically chosen based on previous studies that have demonstrated significant associations with health outcomes, including type 2 diabetes, metabolic syndrome, glycated hemoglobin, and waist circumference[49,50].

Obesity indicators

BMI, waist circumference, and body fat were used as indicators of obesity. Height (cm) was measured using a Seca 213 portable stadiometer (Seca 213®, Hamburg, Germany) with an accuracy of 0.5 cm. Participants were instructed to stand barefoot in an upright position, aligned with the Frankfurt plane.

Body weight (kg) was measured using a Tanita SC-240 bioelectrical impedance device (TANITA Corporation, Japan), which has a maximum capacity of 200 kg. BMI (kg/m²) was calculated by dividing body weight (kg) by height (m²).

Waist circumference (cm) was measured using an inelastic tape measure (Sanny, São Paulo, Brazil) with an accuracy of 0.1 cm. The tape was placed horizontally at the level of the umbilical scar while the participant stood in an upright position. Three measurements were taken, and the average was calculated.

Body fat (kg) was measured using bioelectrical impedance with the Tanita SC-240 portable body composition analyzer (TANITA Corporation, Japan). The analyzer uses four electrodes placed on the feet, with a frequency of 50 kHz and an electric current of 90 milliamps. Participants' height, age, and gender were entered into the scale's software before measurement. Once the information was input, participants were instructed to stand straight in the Frankfurt plane. Bioelectrical impedance analysis has demonstrated acceptable validity and reproducibility in adults when compared to dual-energy X-ray absorptiometry[51].

Correlates

A standardized questionnaire was used across all departments during the interviews to collect sociodemographic data. Participants were categorized by age (< 65 and ≥ 65 years), sex (male and female), and marital status (single, married, divorced, and widowed). In addition, participants were classified by socioeconomic status (low, medium, and high) according to the Brazilian income classification index[52]. Educational level was categorized as low (up to elementary school), medium (completed elementary school), and high (university degree, master's degree, PhD, or post-doctorate).

Statistical analyses

The Kolmogorov-Smirnov test was used to assess the normality of the data distribution. Frequency and percentage (%) were used to describe categorical variables. Given the non-normal distribution of data on physical activity, sitting time, and obesity indicators, continuous variables were reported as medians and interquartile ranges (25th and 75th percentiles).

Multivariate linear regression analysis (β coefficient) and 95% confidence intervals (95% CI) were used to assess the associations between different durations (10, 30, and 60 min/day) of sitting time, walking, MPA, and VPA with obesity indicators (BMI, waist circumference, and body fat). Due to the non-parametric distribution of sitting time, physical activity variables, and obesity indicators, we transformed the non-parametric data using a log10 transformation.

Linear models for single activities, partitioning, and isotemporal substitution were employed, following the method proposed by Merkay and colleagues[22]. The single-activity model assessed the associations of each behavior independently, adjusting for covariates, without including other behaviors in the statistical model. In contrast, the partition model considers all activities that contribute to the total time spent and evaluates the effect of each time-use behavior on the outcome variable independently. However, the partition model is not isotemporal, as it does not include the total time variable (the sum of sitting time, walking, MPA, and VPA) in the analysis.

The isotemporal model, however, assumes the effect of substituting one specific behavior for another within the same time period. For instance, when analyzing the effect of substituting 60 min/day of sitting time with 60 mi/day of walking or VPA on BMI, sitting time is excluded from the analysis. The coefficients generated for walking and VPA represent the effect of replacing sitting time with these activities, while keeping covariates and total time within the analysis.

The single-activity, partition, and isotemporal models were applied to the periods of 10, 30, and 60 min per day of sitting time and physical activity to assess obesity outcomes. All analyses were adjusted for age, sex, marital status, socioeconomic status, and educational level. A significance level of $p < 0.05$ was considered, and analyses were conducted using SPSS, version 24 (SPSS Inc., IBM Corp., Armonk, Nova York, NY, EUA).

Ethics approval and consent to participate

All aspects of the study were in accordance with the Declaration of Helsinki. The study was approved by the Ethics Committee of Universidade Municipal de São Caetano do Sul under protocol number 2.531.002. All participants provided written informed consent or assent before participating in the study. To ensure confidentiality, participants' data was anonymized using numeric identification codes instead of names.

Results

The characteristics of the participants are summarized in Table 1. Overall, the sample was predominantly female (76.6%), with a medium socioeconomic level (59.1%), married (52.5%), and highly educated (63.2%). Participants self-reported a median of 150 min/day of walking (IQR: 60.0 – 360.0), 180 min/day of MPA (IQR: 78.7 – 450.0), and 60 min/day of VPA (IQR: 0.0 – 240.0). In contrast, the median sitting time was 445.7 min/day (IQR: 317.1 – 565.7).

Table 2 presents the results of the single and partial activity analyses examining the associations between different patterns of physical activity and sitting time with obesity indicators. In the single activity models, both 10 and 60 min/day of walking were negatively associated with waist circumference (β: -0.125; 95% CI: -0.025; -0.004; β: -0.135; 95% CI: -0.026; -0.005, respectively) and body fat (β: -0.101; 95% CI: -0.067; -0.001; β: -0.111; 95% CI: -0.068; -0.003, respectively). No significant associations were found between 30 min/day of physical activity or sitting time and obesity indicators. In the partitioned model, only 10 min/day of walking was negatively associated with waist circumference (β: -0.129; 95% CI: -0.028; -0.001).

No statistically significant association was found between substituting 10 min/day of physical activity or sitting time with BMI (Table 3). On the other hand, substituting 10 min/day of MPA and 10 min/day of VPA for 10 min/day of walking (β: -0.176; 95% CI: -0.037; -0.002; β: -0.183; 95% CI: -0.037; -0.004) was associated with waist circumference. Additionally, substituting 10 min/day of sitting time for 10 min/day of walking (β: -0.216; 95% CI: -0.041; -0.007) was negatively associated with waist circumference. Similarly, substituting 10 min/day of VPA with 10 min/day of walking (β: -0.172; 95% CI: -0.106; -0.005) was associated with a decrease in body fat. Furthermore, substituting 10 min/day of sitting time for 10 min/day of walking (β: -0.203; 95% CI: -0.119; -0.012) or MPA (β: -0.208; 95% CI: -0.127; -0.008) was negatively associated with body fat (Table 3).

No associations were found between substituting 30 min/day of physical activity or sitting time with BMI, waist circumference, or body fat (Table 4).

Table 5 shows the associations between the substitution of 60 min/day of physical activity and sitting time with indicators of obesity. Substituting 60 min/day of VPA for 60 min/day of walking (β: -0.151; 95% CI: -0.033; -0.001) was negatively associated with waist circumference. In addition, substituting 60 min/day of sitting time for MPA (β: -0.206; 95% CI: -0.123; -0.008) was negatively associated with body fat.

Characteristics	Median (P25-P75) or *n* (%)
Age (years)	51.0 (41.0–56.0)
Age categorical	
<65 years	380 (96.4)
≥65 years	14 (3.6)
Sex	
Male	92 (23.4)
Female	302 (76.6)
Socio-economic level	
Low	153 (38.8)
Medium	233 (59.1)
High	8 (2.0)
Marital status	
Single	111 (28.2)
Married	207 (52.5)
Divorced	60 (15.2)
Widowed	16 (4.1)
Educational level	
Low	16 (4.1)
Medium	129 (32.7)
High	249 (63.2)
Walking (min/day)	150.0 (60.0-360.0)
MPA (min/day)	180.0 (78.7–450.0)
VPA (min/day)	60.0 (0.0-240.0)
ST (min/day)	445.7 (317.1-565.7)
BMI (kg/m^2)	27.1 (24.1–30.3)
BMI Categorical	
Underweight	0 (0)
Eutrophic	122 (31.0)
Overweight	166 (42.1)
Obese	106 (26.9)
Waist circumference (cm)	91.0 (83.0–99.0)
Body fat (kg)	23.5 (18.2–30.9)

Table 1. Descriptive characteristics of the participants (median [P25-P75] or n [%]). MPA moderate physical activity, VPA vigorous physical activity, ST sitting time.

Discussion

The present study examined the associations between substituting 10, 30 and 60 min/day of physical activity and sitting time with BMI, waist circumference and body fat among workers in São Paulo. Overall, the results of this study suggest that substituting different patterns of sitting time with various forms of physical activity may be associated with a reduction in obesity indicators in São Paulo workers.

Both 10 min/day and 60 min/day of walking were associated with lower waist circumference and body fat in the single and partition models, but no associations were found with higher-intensity activities. These findings are consistent with studies in high- and middle-income countries[33,40,53,54], which have shown that light-intensity physical activity (10 and 60 min/day), as measured by accelerometry and self-report, is negatively associated with BMI, body fat, and waist circumference. Walking, in particular, can be a more accessible form of physical activity, as it requires no prior experience and involves no financial cost[55]. Furthermore, the potential benefits of light physical activity on obesity and cardiovascular risk, as well as its significance for public health, have already been well established[19,56].

In the isotemporal substitution model, beneficial associations were found when substituting at least 10 min/day of sitting time with 10 min/day of walking and 10 min/day of MPA, which were linked to lower waist circumference and body fat, respectively. A study by Gonze and colleagues[40], conducted with 780 Brazilian adults (493 women), found that substituting 10 min/day of sedentary time with 10 min/day of light physical activity or MVPA was associated with reductions in BMI (β = -0.104) and fat percentage (β = -0.383). Sitting time, a form of sedentary behavior, is strongly associated with an increase in waist circumference, visceral adipose tissue, and body fat, which in turn are linked to the development of certain cancers (including digestive system and colorectal cancers) and all-cause mortality[14,57,58]. Our findings suggest that reducing sitting time and increasing physical activity levels can positively impact obesity indicators and may help reduce the risk of adverse health outcomes.

Variables	Walking 10 min β (95% CI)	MPA 10 min β (95% CI)	VPA 10 min β (95% CI)	ST 10 min β (95% CI)
Single activity model				
BMI	− 0.085 (-0.028; 0.002)	0.007 (− 0.017; 0.015)	0.021 (− 0.014; 0.019)	0.027 (− 0.021; 0.036)
Waist circumference	− 0.125 (− 0.025; − 0.004)*	− 0.022 (− 0.014; 0.009)	0.003 (− 0.011; 0.012)	0.058 (− 0.008; 0.033)
Body fat	− 0.101 (− 0.067; − 0.001)*	− 0.029 (− 0.044; 0.025)	0.004 (− 0.035; 0.037)	0.075 (− 0.016; 0.108)
Partition mode				
BMI	− 0.056 (− 0.028; 0.012)	− 0.031 (− 0.026; 0.017)	0.063 (− 0.010; 0.027)	0.030 (− 0.031; 0.050)
Waist circumference	− 0.129 (− 0.028; − 0.001)*	− 0.010 (− 0.016; 0.014)	0.058 (− 0.007; 0.019)	0.027 (− 0.022; 0.034)
Body fat	− 0.066 (− 0.066; 0.023)	− 0.048 (− 0.062; 0.031)	0.055 (− 0.024; 0.057)	0.050 (− 0.054; 0.124)
	Walking 30 min	**MPA 30 min**	**VPA 30 min**	**ST 30 min**
Single activity model				
BMI	− 0.057 (− 0.024; 0.007)	0.019 (− 0.013; 0.018)	− 0.044 (− 0.018; 0.007)	0.041 (− 0.017; 0.041)
Waist circumference	− 0.087 (− 0.021; 0.000)	0.002 (− 0.011; 0.011)	− 0.086 (− 0.017; 0.000)	0.065 (− 0.006; 0.035)
Body fat	− 0.070 (− 0.057; 0.010)	− 0.007 (− 0.036; 0.031)	− 0.082 (− 0.050; 0.004)	0.087 (− 0.009; 0.117)
Partition model				
BMI	− 0.048 (− 0.024; 0.010)	0.049 (− 0.010; 0.025)	− 0.031 (− 0.019; 0.011)	0.038 (− 0.020; 0.042)
Waist circumference	− 0.081 (− 0.021; 0.003)	0.055 (− 0.006; 0.018)	− 0.059 (− 0.016; 0.005)	0.063 (− 0.008; 0.035)
Body fat	− 0.056 (− 0.055; 0.019)	0.040 (− 0.025; 0.050)	− 0.066 (− 0.049; 0.014)	0.071 (− 0.023; 0.110)
	Walking 60 min	**MPA 60 min**	**VPA 60 min**	**ST 60 min**
Single activity model				
BMI	− 0.096 (− 0.029; 0.001)	− 0.007 (− 0.016; 0.014)	0.004 (− 0.015; 0.016)	0.034 (− 0.018; 0.037)
Waist circumference	− 0.135 (− 0.026; − 0.005)*	− 0.034 (− 0.014; 0.007)	− 0.023 (− 0.014; 0.009)	0.064 (− 0.006; 0.033)
Body fat	− 0.111 (− 0.068; − 0.003)*	− 0.020 (− 0.039; 0.026)	− 0.021 (− 0.041; 0.028)	0.080 (− 0.013; 0.108)
Partition model				
BMI	− 0.050 (− 0.026; 0.011)	− 0.093 (− 0.033; 0.007)	0.068 (− 0.010; 0.028)	0.051 (− 0.020; 0.047)
Waist circumference	− 0.085 (− 0.023; 0.004)	− 0.073 (− 0.023; 0.006)	0.047 (− 0.009; 0.019)	0.045 (− 0.014; 0.034)
Body fat	− 0.048 (− 0.057; 0.026)	− 0.111 (− 0.080; 0.009)	0.051 (− 0.026; 0.057)	0.083 (− 0.023; 0.125)

Table 2. Single and partition analysis of the association between patterns (10, 30, 60 min/day) of physical activity and sitting time with obesity indicators in workers. Models adjusted for age, sex, marital status, socioeconomic level, and educational level. Beta coefficient and confidence interval. *Statistical significance ($p < 0.05$). CI confidence interval, MPA moderate physical activity, VPA vigorous physical activity, ST sitting time, BMI body mass index.

Curiously, our results showed that substituting 10 min/day of MPA and VPA with 10 min/day of walking was associated with a reduction in obesity indicators (waist circumference and body fat). These findings are not consistent with the WHO's recommendation of at least 60 min/day of MVPA[11]. This discrepancy may be due to the discomfort higher-intensity activities may cause compared to light physical activity[59,60]. Additionally, walking is a natural activity that helps break sedentary behavior, improves lipid metabolism, and can be sustained for long periods[61–63]. However, it is important to highlight the potential benefits of higher-intensity activities, such as greater energy expenditure and improved health markers, which have been widely demonstrated in the literature[34,39,64,65].

We found no association between substituting 30 min/day of physical activity and sitting time with obesity indicators. These results contrast with existing literature[49,50,66,67]. Additionally, a systematic review study[49] examining the effect of isotemporal substitution on various obesity indicators found that some studies included in the review analyzed the effects of 30 min/day and reported associations with different obesity indicators, such as BMI, waist circumference, and body fat percentage. We hypothesize that methodological differences between our study and the cited studies may explain the discrepancies. For example, the sample size in our study was smaller than in other studies[50,66]. Additionally, objective methods, such as accelerometry, were used to measure physical activity in these studies[50,67], which was not feasible in our study. While questionnaires are commonly used in large-scale studies due to their practicality, accelerometry helps reduce memory bias by directly measuring physical activity and sedentary time without relying on self-reports[68,69]. Finally, the studies mentioned above[50] estimated body composition objectively, which was not possible in our study. These differences in measurement methods could lead to variations in body composition estimates and impact the analysis[70].

Finally, a previous population-based study found that substituting 60 min/day of MVPA for sedentary time (assessed using accelerometry) was negatively associated with fat mass and body fat, as measured by bioelectrical impedance[33]. Similarly, Wang and colleagues observed beneficial effects on overweight and obesity when

Variables	Walking	MPA	VPA	ST
	β (95% CI)	β (95% CI)	β (95% CI)	β (95% CI)
BMI				
to substitute for walking	Dropped	− 0.069 (− 0.038; 0.017)	0.034 (− 0.018; 0.027)	0.040 (− 0.029; 0.055)
to substitute for MPA	− 0.075 (− 0.036; 0.015)	Dropped	0.009 (− 0.021; 0.024)	0.023 (− 0.034; 0.048)
to substitute for VPA	− 0.116 (− 0.041; 0.006)	0.007 (− 0.024; 0.026)	Dropped	0.007 (− 0.036; 0.040)
to substitute for TS	− 0.127 (− 0.043; 0.006)	− 0.112 (− 0.044; 0.011)	− 0.001 (− 0.022; 0.023)	Dropped
Waist circumference				
to substitute for walking	Dropped	− 0.042 (− 0.024; 0.015)	0.031 (− 0.012; 0.019)	0.050 (− 0.018; 0.041)
to substitute for MPA	− 0.176 (− 0.037; − 0.002)*	Dropped	− 0.023 (− 0.018; 0.013)	0.007 (− 0.027; 0.030)
to substitute for VPA	− 0.183 (− 0.037; − 0.004)*	0.003 (− 0.017; 0.017)	Dropped	0.021 (− 0.021; 0.031)
to substitute for ST	− 0.216 (− 0.041; − 0.007)*	− 0.111 (− 0.031; 0.007)	− 0.021 (− 0.018; 0.013)	Dropped
Body fat				
to substitute for walking	Dropped	− 0.139 (− 0.107; 0.014)	− 0.018 (− 0.054; 0.044)	0.046 (− 0.060; 0.124)
to substitute for MPA	− 0.132 (− 0.100; 0.013)	Dropped	− 0.053 (− 0.065; 0.033)	0.037 (− 0.065; 0.116)
to substitute for VPA	− 0.172 (− 0.106; − 0.005)*	− 0.042 (− 0.067; 0.029)	Dropped	0.016 (− 0.071; 0.091)
to substitute for ST	− 0.203 (− 0.119; − 0.012)*	− 0.208 (− 0.127; − 0.008)*	− 0.067 (− 0.069; 0.029)	Dropped

Table 3. Isotemporal substitution for 10 min/day activities and obesity indicators in workers. Models adjusted for age, sex, marital status, socioeconomic level, and educational level. *Statistical significance ($p < 0.05$). CI confidence interval, MPA moderate physical activity, VPA vigorous physical activity, ST sitting time, BMI body mass index.

Variables	Walking	MPA	VPA	ST
	β (95% CI)	β (95% CI)	β (95% CI)	β (95% CI)
BMI				
to substitute for walking	Dropped	0.067 (− 0.013; 0.032)	− 0.018 (− 0.021; 0.016)	0.065 (− 0.017; 0.054)
to substitute for MPA	− 0.042 (− 0.027; 0.014)	Dropped	− 0.031 (− 0.022; 0.014)	0.044 (− 0.021; 0.047)
to substitute for VPA	− 0.032 (− 0.026; 0.016)	0.062 (− 0.014; 0.032)	Dropped	0.060 (− 0.018; 0.052)
to substitute for ST	− 0.059 (− 0.029; 0.011)	0.034 (− 0.017; 0.027)	− 0.048 (− 0.023; 0.012)	Dropped
Waist circumference				
to substitute for walking	Dropped	0.068 (− 0.008; 0.023)	− 0.053 (− 0.018; 0.008)	0.092 (− 0.005; 0.044)
to substitute for MPA	− 0.077 (− 0.023; 0.005)	Dropped	− 0.086 (− 0.021; 0.004)	0.050 (− 0.013; 0.035)
to substitute for VPA	− 0.073 (− 0.023; 0.006)	0.058 (− 0.009; 0.022)	Dropped	0.083 (− 0.007; 0.042)
to substitute for ST	− 0.113 (− 0.026; 0.001)	0.017 (− 0.013; 0.017)	− 0.096 (− 0.021; 0.003)	Dropped
Body fat				
to substitute for walking	Dropped	0.018 (− 0.042; 0.054)	− 0.090 (− 0.064; 0.015)	0.074 (− 0.030; 0.121)
to substitute for MPA	− 0.080 (− 0.071; 0.007)	Dropped	− 0.114 (− 0.071; 0.007)	0.057 (− 0.038; 0.109)
to substitute for VPA	− 0.071 (− 0.068; 0.022)	0.013 (− 0.045; 0.053)	Dropped	0.076 (− 0.030; 0.123)
to substitute for ST	− 0.112 (− 0.078; 0.006)	− 0.027 (− 0.055; 0.038)	− 0.128 (− 0.072; 0.003)	Dropped

Table 4. Isotemporal substitution for 30 min/day activities and obesity indicators in workers. Models adjusted for age, sex, marital status, socioeconomic level, and educational level. *Statistical significance ($p < 0.05$). CI confidence interval, MPA moderate physical activity, VPA vigorous physical activity, ST sitting time, BMI body mass index.

sedentary time was replaced with MVPA, as assessed by the IPAQ[34]. These findings support our results and emphasize the need for effective strategies to encourage reallocating sedentary time to more active behaviors.

Educating the public about the distribution of time spent on various behaviors can have positive implications for public health[71]. Given the challenges middle-aged and older adults face in performing VPA for extended periods[72,73], replacing sedentary time with at least 10 min/day of light physical activity could be a useful starting point for reducing overweight and obesity.

This study has several limitations. Due to its cross-sectional design, we cannot establish causal relationships. Additionally, our results may not be generalizable to other populations, as the sample consisted mainly of Brazilian workers with a high socioeconomic status and education level. We also could not assess the amount of sleep as part of the full 24-hour movement cycle. While the IPAQ's validity has been established, memory bias may have led participants to over report physical activity levels and underreport sedentary time[74]. Body fat was measured indirectly using bioelectrical impedance, so the estimates are prone to error[75,76]. Finally, we

Variables	Walking	MPA	VPA	ST
	β (95% CI)	β (95% CI)	β (95% CI)	β (95% CI)
BMI				
to substitute for walking	Dropped	− 0.043 (− 0.031; 0.019)	0.056 (− 0.014; 0.029)	0.072 (− 0.015; 0.055)
to substitute for MPA	− 0.007 (− 0.025; 0.023)	Dropped	0.088 (− 0.011; 0.035)	0.082 (− 0.016; 0.061)
to substitute for VPA	− 0.086 (− 0.035; 0.010)	0.015 (− 0.022; 0.026)	Dropped	0.029 (− 0.016; 0.061)
to substitute for ST	− 0.071 (− 0.033; 0.013)	− 0.105 (− 0.041; 0.011)	0.057 (− 0.014; 0.030)	Dropped
Waist circumference				
to substitute for walking	Dropped	− 0.038 (− 0.022; 0.014)	0.028 (− 0.012; 0.018)	0.069 (− 0.011; 0.040)
to substitute for MPA	− 0.086 (− 0.028; 0.008)	Dropped	0.028 (− 0.014; 0.020)	0.048 (− 0.018; 0.038)
to substitute for VPA	− 0.151 (− 0.033; − 0.001)*	− 0.029 (− 0.020; 0.014)	Dropped	0.034 (− 0.018; 0.032)
to substitute for ST	− 0.137 (− 0.032; 0.001)	− 0.124 (− 0.033; 0.005)	0.009 (− 0.015; 0.017)	Dropped
Body fat				
to substitute for walking	Dropped	− 0.112 (− 0.092; 0.020)	0.001 (− 0.047; 0.047)	0.081 (− 0.028; 0.128)
to substitute for MPA	− 0.060 (− 0.074; 0.035)	Dropped	0.012 (− 0.047; 0.055)	0.085 (− 0.037; 0.136)
to substitute for VPA	− 0.137 (− 0.094; 0.006)	− 0.046 (− 0.067; 0.037)	Dropped	0.042 (− 0.053; 0.102)
to substitute for ST	− 0.145 (− 0.098; 0.004)	− 0.206 (− 0.123; − 0.008)*	− 0.020 (− 0.054; 0.042)	Dropped

Table 5. Isotemporal substitution for 60 min/day activities and obesity indicators in workers. Models adjusted for age, sex, marital status, socioeconomic level, and educational level. *Statistical significance ($p < 0.05$). CI confidence interval, MPA moderate physical activity, VPA vigorous physical activity, ST sitting time, BMI body mass index.

were unable to account for other potential confounders, such as race/ethnicity, household income, energy consumption, and the built environment.

Conclusion

The results of this study suggest that substituting 10 min/day and 60 min/day of sitting time for 60 min/day of walking or MPA is beneficial for reducing waist circumference and body fat. These findings align with existing literature on the positive effects of walking on body composition and support lifestyle interventions that promote replacing sitting time with physical activity to reduce and prevent obesity. Furthermore, our results underscore the need for longitudinal studies to evaluate the long-term effects of these time-use behavior substitutions on obesity indicators.

Data availability

The datasets generated and/or analyzed during the current study are not publicly available due the terms of consent/assent to which the participants agreed but are available from the corresponding author on reasonable request. Please contact the corresponding author to discuss availability of data and materials.

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Author contributions
JPSJ, RRB and AS carried out the study, collected and interpreted the data. DS, GF, JPSJ, RRB, PPOM, AS and MS helped to write and revise the manuscript; VM was responsible for coordinating the overall study and contributed to the intellectual content. All the authors contributed to the study design, critically reviewed the manuscript and approved the final version.

Declarations

Competing interests
The authors declare no competing interests.

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