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Effects of relocation of sedentary time and physical activity in older adults with diabetes mellitus

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Abstract

Objective: To estimate the hypothetical effects of substituting time spent in moderate-to-vigorous physical activity (MVPA) and time spent in sedentary behavior (SB) and their associations with diabetes.

Methods: A cross-sectional study using exploratory survey methods was performed in Alcobaça city in the state of Bahia, Brazil in the year 2015. A total of 473 older adults (aged ≥60 years) participated in the study. Diabetes mellitus, time MVPA, and SB were assessed in a self-reported manner. The Poisson regression was used to verify the hypothetical effects of the substitution of MVPA with SB on diabetes.

Results: The substitution of the time in MVPA with time in SB showed higher prevalence ratios of diabetes. Conversely, the substitution of the time in SB proved to be a protective factor, with risks reduced by between 4% and 19%.

Discussion: The substitution of the time spent in MVPA with the same amount of time spent on SB can lead to an increase in the probability of diabetes, and a longer reallocation time corresponded to a greater risk.

KEYWORDS
health, motor activity, public health

1 | INTRODUCTION

The number of individuals with chronic noncommunicable diseases has increased substantially in recent decades.[1] Among these diseases, diabetes mellitus is unique in exhibiting an exponential increase mainly in low- and middle-income countries,[1] including in Brazil, with a prevalence of 40.3% in individuals aged 55 years and over.[2] This disease is more frequently observed in women than in men (7.8% vs. 7.1%, respectively). Furthermore, diabetes has been associated with reduced life expectancy and an increased risk of mortality[2] and is identified as being the seventh leading cause of death in the world.[3]

Studies have been developed to investigate the factors that collaborate in reducing the incidence of diabetes mellitus in the population.[4-7] Among the most discussed modifiable factors are physical activity (PA), which is defined as any movement produced by the skeletal muscle that results in energy expenditure.[8] Physical activity is associated with reductions in the risk of diabetes mellitus.[5-7] Another factor influencing diabetes is sedentary behavior (SB), which consists of activities performed in the sitting, lying, and reclining position with energy expenditure ≤1.5 metabolic equivalents (METs).[9] Sedentary behavior is associated with risk factors, which often occur regardless of the time spent in moderate-to-vigorous physical activity (MVPA).[5]

Current recommendations of physical activity for the older adult population are 150–300 weekly minutes of moderate-intensity PA or 75–150 weekly minutes of vigorous-intensity PA, as well as combinations of both recommendations, including muscle strengthening and balance and aerobic exercises, in addition to a reduction in the time of exposure to SB.[10] However, neither the World Health Organization global recommendations nor the recently published PA guide for the Brazilian population specify the precise physical activity times for patients with diabetes.[10,11] Furthermore, people with diabetes mellitus tend to not comply with these recommendations and spend a large part of their day in sedentary activities.[4,7]

The total time of PA has been associated with reductions in the risk of developing diabetes mellitus in the population,[5-7] as demonstrated in a study with more than 400,000 participants, wherein a reduction in the risk of diabetes proportional to the time spent in total PA was observed.[5] Conversely, the time spent in SB is associated with the onset and worsening of the disease; however, other studies did not identify associations with total SB time but only identified associations with the specific domain of screen time,[5-7,12] thus indicating that this domain may represent the greatest association with the onset of diabetes in the population.

Studies on people with diabetes mellitus are important because these patients represent a group at a high risk of mortality, as well as individuals who incur high expenses to the public health budget, who do not comply with daily and weekly recommendations of PA and, on the contrary, who waste their time in sedentary activities. A recent widely used approach in the field of epidemiology employs measures of PA, SB, and isotemporal substitution modeling,[13] taking into account that the daily time is finite and that spending time on one behavior will result in the reduction of time on another behavior.[13,14] With this as a consideration, it is possible to create more specific models, which can help in the creation of more precise recommendations and with a greater potential to be fulfilled by the specific population.

The aim of this study was to estimate the hypothetical effects of replacing the time spent in MVPA and time spent in SB and its associations with diabetes. We hypothesized that the substitution of time in MVPA with the same amount in SB could increase the likelihood of developing diabetes and that inverse substitution when replacing SB with MVPA reduce the chances of developing diabetes.

2 | METHODS

2.1 | Study design

This investigation is associated with the Longitudinal Study of Older Adults Health in Alcobaça (Estudo Longitudinal de Saúde do Idoso de Alcobaça, BA - ELSIA), which is characterized as an observational, cross-sectional analytical study that uses exploratory methods such as surveys conducted in the municipality of Alcobaça, in the state of Bahia, Brazil.

2.2 | Participants

The details of the study, in conjunction with data collection procedures and inclusion criteria, have been previously described.[15] Briefly, the collection was performed from home visits, with people registered in the city's Family Health Strategy. The Family Health Strategy aims to reorganize primary care in the country, which is regarded as a strategy for the expansion, qualification, and consolidation of primary care, as it favors a reorientation of the work process with a greater potential to enhance the principles, guidelines, and fundamentals of primary care. In this manner, this initiative aims to increase resoluteness and impact on the health situation of people and communities, in addition to providing an important cost-effectiveness relationship with a multidisciplinary team as an important factor.

The exclusion criteria were as follows: individuals who did not present with severe cognitive impairment based on the Mini Mental State Examination (≤11 points), as adapted for the Brazilian population[16]; individuals who did not present with severe impairments in visual and/or hearing acuity; individuals who did not use wheelchairs; individuals who did not present with severe sequelae of cerebrovascular accidents with localized loss of strength; and individuals who were not in end-stage illnesses.

During the data collection, 54 older adults refused to participate in the research, 58 adults were excluded for not meeting the inclusion criteria, and 158 older adults were not located after three attempts. A total of 473 older adults of both sexes aged ≥60 years participated in the study, with a mean age of 70.25 years (±8.25 years), body mass 67.86 kg (±14.13 kg), height 157.73 cm (±14.13 cm), and a body mass index of 27.30 kg/m^2 (±5.39).

2.3 | Diabetes mellitus

Diabetes mellitus was assessed in a self-reported manner based on a list of diseases that were organized according to the International Statistical Classification of Diseases and Related Health Problems (ICD-10).[17] The respondents were asked "Do you have diabetes mellitus?" and had the choice of providing a dichotomous answer (yes or no).

2.4 | Physical activity and sedentary behavior

The level of PA and time exposed to SB were assessed by using the International Physical Activity Questionnaire (IPAQ), which has been validated for Brazilian older adults.[18,19] The PA level was determined from MVPA performed for at least 10 continuous minutes, which was evaluated in the domains of PA at leisure, work, displacement, and at home. For the characterization, the population was dichotomized into sufficiently active (≥150 min/day of moderate-intensity physical activity, 75 min/day

of vigorous-intensity physical activity, or a combination of both) and insufficiently active groups.

The SB was determined by the time spent sitting, which was evaluated from the questions of time exposed to the sitting position. The total time spent sitting in minutes/day was determined from the weighted mean of time sitting on a weekday and a weekend day: ([time sitting on a weekday x 5 + time sitting on a weekend day x 2]/7). SB was considered to be high from the 75th percentile (540 min/day).[20]

2.5 | Sleep assessment

The measurement of nighttime sleep time was performed by using the following specific question from the Pittsburgh Sleep Quality Index, which has been validated for Brazilians (PSQI-BR)[21]: "During the past month, how many hours of actual sleep did you get at night?" The answer to the question was used to compose the total time of activities during the day. To characterize the sample, they were dichotomized into people who slept for <7 h a day and people who slept for ≥7 h a day.[22]

2.6 | Potential confounding factors and covariates

The potential confounding factors that were included in the study were sex (male and female), age, income (the number of minimum wages received during the evaluation, fixed in 'R$ 788,00' and corresponding to 'US$ 299,61' according to exchange of '2015'), family arrangement (with a partner or without a partner), and alcohol consumption (based on the frequency of weekly alcohol consumption).

In addition, the use of medication was continuously evaluated through the question "Do you use medication continuously?" with dichotomous yes or no options. For occupation, the participants were asked "What is your current occupation?" with the following answer options: retired, but working; retired only; housewife; pensioner; and paid work. The answers were grouped into paid work (retired but works and paid work) and without paid work (only retired, housewife, and pensioner); if the older adult had been hospitalized in the last year, the question was "Were you hospitalized in the last 12 months?" with dichotomous yes or no answer options.

Waist and hip circumferences were evaluated by using a flexible and inelastic measuring tape (Lange – TBW, Cambridge, United States) that was 2 meters long, graduated in centimeters, and subdivided into millimeters, and it was used to evaluate the region with the smallest perimeter of the trunk and the area of greatest protuberance measured with the individual placing their feet together.[23] Afterwards, the waist-to-hip ratio (WHR) was calculated by using the waist (cm)/hip (cm) equation.

Height and body mass were measured on a Wiso digital scale (W721) with a capacity of 180 kg and a precision of 0.100 g for body mass and 0.1 cm for height. Subsequently, body mass index (BMI) was calculated based on the equation of body mass/height.[2]

2.7 | Data analysis

The preparation of the database was performed by double typing using Epidata software, version 3.1b (EpiData Association, Odense, DK/Fiónia, Denmark), and the analyses were performed by using SPSS software, version 23.0 (Statistical Package for the Social Sciences, IBM, Chicago, Illinois, United States). Data normality was tested via the Kolmogorov–Smirnov test with the use of descriptive statistics with calculations of dispersion, absolute, and relative frequencies to characterize the sample. Additionally, to compare the presence of diabetes about the descriptive variables, we used the chi-square test (sex, family arrangement, occupation, hospitalization, medication, alcohol consumption, sleep, physical activity, and sedentary behavior) and the Mann-Whitney *U* test (waist circumference, hip circumference, body mass index, and waist-to-hip ratio).

To compare the time averages tested in the isotemporal model according to the presence and absence of diabetes, the Mann-Whitney *U* test was used for physical activity and sleep and the *t* test for independent samples for sedentary behavior.

The isotemporal substitution approach was used to verify the hypothetical effects of the reallocation of time spent in MVPA and SB in the presence of diabetes.[13,14] Isotemporal substitution analyses were performed by estimating the prevalence ratio (PR), with the respective 95% confidence intervals (CIs), as well as from the Poisson regression with robust variance. The effects of replacing the time of 10, 20, 30, 40, 50, and 60 min for the variables of MVPA and SB time were verified, whereas the sleep time remained constant in the model. The models were adjusted for sex, age, income, family arrangement, and alcohol consumption. A significance level of 5% was adopted.

3 | RESULTS

Of the total participants, 91 (19.3%) participants reported having diabetes mellitus, and the mean time of physical activity and sleep was longer in people who did not have the disease, with 55.20 min/day versus 38.54 min/day of physical activity ($P = 0.217$) and 437.89 min/day versus 426.61 min/day of sleep ($P = 0.531$), whereas SB was higher in people with the disease, with 426.62 min/day versus 460.95 min/day ($P = 0.076$). Table 1 shows the characteristics of the participants regarding the presence of diabetes. On average, those individuals with diabetes were female, lived without a partner, were hospitalized in the last year, and continuously used medication.

The isotemporal substitution model is shown in Table 2. In the 10-, 20-, 30-, 40-, 50- and 60-min models that were tested, the substitution of the MVPA time by time in SB demonstrated higher diabetes prevalence ratios, with values varying between 3% ($P = 0.035$), 7% ($P = 0.035$), 10% ($P = 0.035$), 14%, 18% ($P = 0.035$) and 22% ($P = 0.035$), respectively. Conversely, the substitution of the SB time proved to be a protective factor, with risks reduced by 4% ($P = 0.035$), 7% ($P = 0.035$), 10% ($P = 0.035$), 13% ($P = 0.035$), 16% ($P = 0.035$) and 19% ($P = 0.035$), respectively, in times from

TABLE 1 Characteristics of participants.

	All	Absence	Presence	
	n (%)	*n* (%)	*n* (%)	*P*
Sex				
Male	117 (37.4)	153 (86.4)	24 (13.6)	0.015
Female	296 (62.6)	229 (77.4)	67 (22.6)	
Family arrangement				
Lives alone	255 (54.0)	197 (77.3)	58 (22.7)	0.039
Accompanied	217 (46.0)	184 (84.8)	33 (15.2)	
Occupation				
Paid work	109 (23.0)	94 (86.2)	15 (13.8)	0.098
No paid work	364 (77.0)	288 (79.1)	76 (20.9)	
Hospitalization				
No	393 (83.1)	325 (82.7)	68 (17.3)	0.018
Yes	80 (16.9)	57 (71.3)	23 (28.7)	
Medicament				
No	99 (20.9)	96 (97.0)	3 (3.0)	<0.001
Yes	374 (79.1)	286 (76.5)	88 (23.5)	
Alcohol consumption				
No	247 (52.2)	199 (80.6)	48 (19.4)	0.911
Yes	226 (47.8)	183 (81.0)	43 (19.0)	
Sleep				
≥7 h/day	235 (49.7)	191 (81.3)	44 (18.7)	0.777
>7 /day	238 (50.3)	191 (80.3)	47 (19.7)	
Physical activity level				
≥150 min/week	249 (52.6)	204 (81.9)	45 (18.1)	0.497
<150 min/week	224 (47.4)	178 (79.5)	46 (20.5)	
Sedentary behavior				
<540 min/day	354 (74.8)	290 (81.9)	64 (18.1)	0.270
≥540 min/day	119 (25.2)	92 (77.3)	27 (22.7)	
		Median (IQR)	Median (IQR)	*P*
Waist circumference	-	95.55 (15.7)	101.70 (13.7)	<0.001
Hip circumference	-	96.75 (12.2)	100.00 (6.84)	0.028
Body mass index	-	26.26 (6.84)	28.91 (6.68)	0.001
Waist-to-hip ratio	-	0.97 (0.09)	1.00 (0.09)	0.003

Note: PR adjusted for gender, age, income, family arrangement, and alcohol consumption.
Abbreviations: CI, confidence interval; IQR, interquartile range. MVPA, moderate-to-vigorous physical activity; PR, prevalence ratio; SB, sedentary behavior.

10 min to 60 min. The time spent in sleep was not included in the behavioral reallocations and was kept constant in the model.

4 | DISCUSSION

This study aimed to examine the hypothetical effects of the reallocation of time spent in MVPA and SB and their associations with diabetes mellitus in older adults. The substitutions of time from SB to MVPA demonstrated lower prevalence ratios for diabetes in the older adults, and these associations increased as the time tested progressed. Correspondingly, the replacement of MVPA for time spent in SB proved to be a risk factor for diabetes mellitus.

Our findings demonstrated that PA is a protective factor for the onset of diabetes mellitus, which is in agreement with other studies.[5–7] In a Chinese study of more than 400,000 participants with a mean age of 51 years (± 10.6 years), researchers observed reduced risks of diabetes mellitus according to the level of total PA, and these risks were reduced as the level of PA increased among the participants.[5]

Despite the current recommendations of PA for the older adult population,[24] studies have observed beneficial results for health associated with intensity and times lower than the recommendations.[25]

TABLE 2 Isotemporal substitution model of the association of time reallocation in sedentary behavior and moderate-to-vigorous physical activity in the prevalence ratio of diabetes in older adults.

	PR (95% CI)	PR (95% CI)
Substitution models	**MVPA**	**SB**
10 min		
Replacement of MVPA	-	1.035 (1.002–1.068)*
Replacement of SB	0.967 (0.936–0.998)*	-
20 min		
Replacement of MVPA	-	1.070 (1.005–1.140)*
Replacement of SB	0.934 (0.877–0.995)*	-
30 min		
Replacement of MVPA	-	1.108 (1.007–1.218)*
Replacement of SB	0.902 (0.822–0.991)*	-
40 min		
Replacement of MVPA	-	1.146 (1.009–1.300)*
Replacement of SB	0.873 (0.769–0.990)*	-
50 min		
Replacement of MVPA	-	1.186 (1.012–1.389)*
Replacement of SB	0.843 (0.720–0.988)*	-
60 min		
Replacement of MVPA	-	1.227 (1.014.485)*
Replacement of SB	0.815 (0.674–0.986)	-

Note: PR adjusted for gender, age, income, family arrangement, and alcohol consumption.

Abbreviations: CI, confidence interval; MVPA, moderate-to-vigorous physical activity; PR, prevalence ratio; SB, sedentary behavior.

*$P < 0.05$.

This was illustrated by researchers in a study performed with 435 people with a mean age of 66.8 years who used isotemporal substitution analysis and found positive results regarding insulin sensitivity when substituting small amounts of time sitting with time spent standing or walking.[6]

Furthermore, studies with patients with diabetes have become even more relevant, as this population tends to have a low level of PA.[4,7] As observed in a study by Balducci et al.,[4] patients with diabetes mellitus had low PA levels and high SB times, and they found very strong correlations between mild PA and time spent in sedentary behavior. Additionally, insufficient PA levels may be linked to risks of diabetes mellitus and metabolic syndrome.[26]

With this reduction in PA time due to the diabetic condition, individuals tend to accumulate more time in other behaviors, including sedentary time, as demonstrated by Falconer et al.,[7] wherein people with a recent diagnosis of diabetes spent approximately 65% of the day in SB, of which 46% was accumulated for periods greater than 30 min/day and MVPA represented only 4% of the hours of the day. These behaviors tended to be a risk factor not only for the onset but also for the progression of the disease.[5,6]

Studies have shown that, in addition to total sedentary time, the manner in which this time is accumulated is an important risk factor for diabetes mellitus.[5,6] Edwardson et al.[6] used the same isotemporal substitution analysis and observed beneficial results in relation to insulin sensitivity by reducing sitting time for long periods of time (≥30 min) for short periods (<30 min). This time prolonged in sedentary episodes is indicated as being harmful to metabolic health indicators, such as BMI and waist circumference, and the performance of MVPA on a regular basis can be beneficial in preventing changes in these indicators,[7] in addition to eliciting lower levels of diastolic blood pressure and triglycerides, as well as high levels of high density lipoprotein-cholesterol (HDL-C).[26]

Some researchers have also observed associations between diabetes and different domains of sedentary behavior.[5,12] Hsueh et al. investigated the associations between the sedentary domains and diabetes mellitus in more than a thousand individuals and only observed associations with sedentary time watching television, wherein watching television for more than 2 h was positively associated with the risk of diabetes mellitus; however, the authors found no association with total sedentary time, which is a fact that may be linked to television viewing, low energy expenditure,[27] high alcohol consumption, and being unhealthy.[28] This time spent watching television can elicit a higher cardio-metabolic risk even when substituted by domains of sedentary behavior on the computer, reading, on the telephone, or in a car.[12]

Additionally, Bennett et al.[5] observed a risk of diabetes hazard ratio (HR) = 1.13 in individuals who spent their leisure time in sedentary activities; however, this risk was reduced by 60% (HR = 1.05) by adding the adjustment for BMI levels.

This mechanism for reducing glucose intolerance by reducing sedentary time through MVPA is linked to increased glucose transport capacity stimulated by insulin release and contraction, the product of which is an increase in skeletal muscle glucose transporter expression (GLUT4).[29]

The present study had limitations to be highlighted. The design did not allow for the determination of cause, and subjective measures of the level of PA and SB, which tended to be overestimated and underestimated, respectively, were used in the study, in addition to the impossibility of evaluating measures of mild PA. Another limitation was the self-reported measure of the presence of diabetes in the population. Finally, other comorbidities may have acted as confounding variables. Despite the advantages of using the isotemporal model, the modeling estimates are based on statistical modeling and not on real behavioral changes. The strengths of the study include the poorly studied population and

the different time stratification in the isotemporal substitution model.

The results suggest that the isotemporal substitution model indicates that small changes, such as the reallocation of 10 min of time exposed to SB to MVPA, are capable of reducing diabetes mellitus rates by up to 4%, whereas the reallocation of time spent in MVPA to SB increases the rate of diabetes. Additionally, a longer reallocation time corresponded to greater observed effects.

AUTHOR CONTRIBUTIONS

Galvão LL: conceptualization (equal), data curation (equal), formal analysis (equal), investigation (equal), methodology (equal), supervision (equal), writing-original draft (equal), and writing-review and editing (equal); Silva RR: investigation (equal), methodology (equal), writing-original draft (equal), and writing-review and editing (equal); Costa DJ: conceptualization (equal), investigation (equal), writing-original draft (equal), and writing-review and editing (equal); Tribess S: investigation (equal), methodology (equal), project administration (equal), visualization (equal), writing-original draft (equal), and writing-review and editing (equal); Santos DAT: investigation (equal), methodology (equal), supervision (equal), visualization (equal), writing-original draft (equal), and writing-review and editing (equal); and Virtuoso Júnior JS: conceptualization (equal), funding acquisition (equal), investigation (equal), methodology (equal), project administration (equal), supervision (equal), writing-original draft (equal), and writing-review and editing (equal). All authors critically revised the intellectual content of the manuscript and approved the final version as submitted.

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CONFLICT OF INTEREST STATEMENT

The authors declare that there is no conflict of interest.

ETHICS STATEMENT

The study protocol and procedures were performed in accordance with the Declaration of Helsinki and were previously approved by the Human Research Ethics Committee of the Universidade Federal do Triângulo Mineiro (UFTM) (Ordinance number 966.983; dated: February 27, 2015).

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