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Breaking-up Sedentary Time Is Associated With Physical Function in Older Adults

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Background. Physical function is a key determinant that corresponds to the physiological capacity of older adults to perform normal everyday activities, safely and independently, without undue fatigue. We examined the associations of sedentary behavior (SB), breaks in sedentary time (BST), and moderate-to-vigorous physical activity (MVPA) with physical function in older adults.

Methods. Physical activity and SB were assessed with accelerometers (ActiGraph, GT1M) and physical function with the Senior Fitness Test battery, among 87 males and 128 females aged between 65 and 94 years. A composite *Z*-score was created based on the individual scores for each Senior Fitness Test battery item. Associations of SB, BST, and MVPA with physical function were examined, adjusting for demographic attributes, physical independence, and medical status.

Results. A significant positive association was found between BST and the composite physical function *Z*-score, after adjusting for total SB, MVPA, and potential confounders. MVPA was also positively associated with physical function, after adjusting for SB, BST, and potential confounders. Those with low BST in conjunction with performing less than 30 min/d of MVPA had lower physical function.

Conclusions. Breaking-up sedentary time is associated with better physical function in older adults; and, it may have an important place in future guidelines on preserving older adults' physical function to support activities of daily living.

Key Words: Breaks in sedentary time—Physical activity—Physical fitness—Sedentary behavior.

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PHYSICAL independence in older adults is related to quality of life (1), reduced health care costs (2), and longer survival (3). Prospective observations and interventional studies (4–6) have shown that physical activity (PA) and fitness are related with the physical independence of older adults. Fitness components like aerobic capacity, skeletal muscle performance, flexibility, agility, and dynamic balance are attributes relevant for physical function in elderly (7).

There is a new body of evidence on the negative impact of sedentary behaviors (SB) on physical function in older adults (8–11) which has been associated with the development of functional limitations, independently of PA (4). More recently, awareness has been raised about patterns of SB beyond its duration, particularly the number of daily breaks in sedentary time (BST). In addition to moderate-to-vigorous physical activity (MVPA), BST is a strong predictor of lower extremity function in older adults (9). On the other hand, in high functioning and high active older adults, greater levels of SB and lower BST have been found to be associated with improved lower limb extensor muscle quality (10). These findings highlight the necessity for clarifying the role of breaking-up sedentary time in the physical function of older adults. Overall physical function can be assessed by the Senior Fitness Test (7,12), a battery of tests that includes the assessment of physical function parameters such as strength, endurance, agility, dynamic balance, and flexibility, important determinants of maintaining independence later in life (7).

To address the potential impact of breaking-up sedentary time on older adults' physical function, we examined the associations of objectively assessed PA, SB, and BST with physical function assessed by the Senior Fitness Test scores of adults aged 65 years and older.

Methods

Participants

This study included a sample of noninstitutionalized Portuguese older adults, aged 65–94 years, selected by means of a proportionate stratified random sampling taking into account the number of people by age and sex in each region of mainland Portugal, according to the *NUTS II subregions: Territorial Units for Statistics Portugal*. For sample recruitment, institutions that included senior universities, parish councils, city halls, day care centers, and health promotion fairs organizers were contacted by email and/or formal letter informing about the objectives of our investigation. A total of 402 participants were assessed for PA and physical function. From these, 88 were excluded for not having valid records of PA, 46 did not report educational level or medical status, and 25 did not respond to the physical independence questionnaire. Participants were included based on responses to the 12-item of Composite Physical Functioning Scale (13); only those who responded "can do on own without help" to items (a) and (b) of the CPF scale were included in the analysis (28 participants were excluded). For data analysis, a total of 215 participants were included (87 males and 128 females).

All participants were informed about the possible risks of the investigation before giving their written informed consent to participate. All procedures were approved by the local ethics Committee and were conducted in accordance with the Declaration of Helsinki for human studies.

Physical Activity

PA was assessed by accelerometry (ActiGraph, GT1M, Fort Walton Beach, FL). The accelerometer used is a small device that measures the acceleration of normal human movements, ignoring high frequency vibrations associated with mechanical equipment. All participants were asked to wear the accelerometer on the right hip, near the iliac crest for four consecutive days, including 2 weekdays and 2 weekend days. Participants received a diary to record the time of the day when the accelerometer was placed and removed. The devices were activated on the first morning day and data were recorded in 15-s epochs. However, all analyses were conducted with data transformed into 60-s epochs to allow comparison with other studies. Apart from accelerometer non-wear time (ie, when it was removed for sleeping or water activities), periods of at least 60 consecutive minutes of zero activity intensity counts were also considered as non-wear time. A valid day was defined as having 600 minutes (10 hours) or more of monitor wear, and the study included the results from participants with at least three valid days (including one weekend day).

Each minute during which the accelerometer counts were below 100 counts/min was considered SB; total sedentary time was the sum of sedentary minutes while the accelerometer was worn. A BST was considered as any interruption in sedentary time in which the accelerometer count rose up to or above 100 counts/min. SB and BST were adjusted for register time by regressing these variables on register time and residuals from the models represented adjusted variables.

Accelerometer counts more than or equal to 100 counts/min were classified as PA (14,15), with further differentiation (15) to identify separately moderate-to-vigorous intensity PA (≥2,020 counts/min) and light-intensity PA (100–2,019 counts/min). Data treatment was performed using the Actilife software (version 6.0, ActiGraph, Fort Walton Beach, FL). To analyze the adherence to PA recommendations for public health, the accumulation of at least 30 min/d of MVPA was assessed (16).

Physical Function

Physical function was assessed with the Senior Fitness Test (7,12). Physical fitness parameters selected as indicators of physical function included lower and upper body strength, lower and upper body flexibility, agility/dynamic balance, and aerobic endurance. The items were evaluated, respectively, by the following tests: chair stand (repetitions/30 s), arm curl: women 5 lb; men 8 lb (repetitions/30 s), chair sit-and-reach (cm), back scratch (cm), 8-foot up-and-go (s), 6minute walk test (m). The result of each test was standardized (*Z*-score) by sex. The *Z*-score is the number of standard deviations a specific value differs from the sample mean (*Z*-score = [observed − sample mean]/sample *SD*). The sum of the six *Z*-scores was used to compute an overall continuous measure of physical function.

Covariates

Participants were weighed to the nearest 0.1 kg wearing minimal clothes and without shoes. Height was measured to the nearest 0.1 cm. Body mass index was calculated as weight (kg) divided by the square of the height (m). Self-reported educational and medical covariates were assessed via interviewer-administered questionnaires. Educational attainment was categorized as: (a) no formal education, (b) 4 years of education, (c) 9 years of education, (d) 12 years of education, and (e) higher education.

Medical history for hypertension, elevated cholesterol and glycemia, current medication, and the presence of any long-standing condition such as diabetes, asthma, cancer, or cardiac disease and current smoking status were also reported and classified in two categories (no or yes). Physical independence was assessed using the 12-item Composite Physical Function (CPF) Scale (13) and categorized as: high functioning (score = 24), moderate functioning (score 14–23), and low functioning (score < 14) (7).

Statistical Analysis

All analyses were performed with SPSS Statistics version 22.0, 2013 (SPSS Inc., Chicago, IL). Descriptive statistics (mean ± *SD*) were calculated for all outcome measurements. Normality was verified using the Kolmogorov–Smirnov test. One-way analysis of variance was used to compare differences when more than two groups were considered using the Dunnett's T3 adjustment.

Multiple regression analyses were performed to test the associations of MVPA, SB, and BST with the composite

Z-score for physical function. Analyses were also performed separately for each fitness test. Age, sex, body mass index, education (dummy variable), and physical independence (dummy variable) were included as covariates in all regression models, and additional models were developed also adjusting for medical status. Normality and homoscedasticity of the residuals were tested during models development. Since the residuals were not normal in one model (8-foot up-and-go test), the dependent variable was transformed using a rational function [$f(y) = 1/y$]. This brought the model into compliance with the assumptions of multiple linear regression. Significance was set at p less than .05 for all tests.

Results

A total of 215 participants aged 65–94 years (73.3 ± 5.9 years), including 87 males and 128 females, participated in the study. Participants' characteristics are summarized in Table 1.

Figure 1 shows the histogram for PA intensity, as expressed by the counts per minute measured by the accelerometer. PA intensity shows a right-skewed distribution.

Multiple regression analyses were performed to identify the association of BST with each physical function component and for the overall physical capacities (Table 2). BST was significantly associated with the arm curl and the chair stand test, even when adjusting for MVPA and SB. We additionally found a positive association between BST and the physical function composite *Z*-score ($\beta = .169$; 95% CI: 0.042, 0.295).

Associations of different components of sedentary and active time, particularly, BST, SB, and MVPA with overall physical function (composite *Z*-score), are summarized in Table 3.

More BST were associated with improved physical function, after controlling for covariates (sex, age, body mass index, education, physical independence, and medical status) and time spent in SB and MVPA (Models 4, 6, and 7). Also, MVPA had a positive association with the physical function composite *Z*-score, independent of both daily BST and time spent in SB (Model 4). Additionally, SB was a significant predictor of physical function composite *Z*-score, independently of BST and MVPA (Model 4).

We further analyzed the impact of being less sedentary and having more BST (Figure 2A), and being sufficiently active and having more BST (Figure 2B) on overall physical function. Figure 2 shows that participants spending more time in SB and making fewer interruptions in this behavior presented a significantly lower physical function than all of the other groups, after adjusting for age, sex, education, and body mass index, and physical independence. Similarly, older adults who did not meet the 30 min/d of MVPA recommendation and who fell into the half bottom of the BST group had a lower mean physical function composite *Z*-score compared to their counterparts, although the differences did not remain significant after adjusting for the covariates.

Discussion

The main findings of our study showed that breaking-up time in SB was positively associated with physical function

Table 1. Participants' Characteristics, PA and SB Patterns, Physical Function Tests, Physical Independence, and Health Status

Variables	Total (n = 215)	Male (n = 87)	Female (n = 128)
Age (years)	73.3 ± 5.9	73.7 ± 6.2	73.0 ± 5.7
Body mass (kg)	69.8 ± 11.0	75.5 ± 10.6	66.0 ± 9.5
Height (m)	1.59 ± 0.08	1.66 ± 0.06	1.54 ± 0.05
BMI (kg/m^2)	27.6 ± 3.5	27.3 ± 3.3	27.8 ± 3.6
SB (min/d)	513.2 ± 113.1	529.7 ± 107.7	502.0 ± 115.7
LIPA (min/d)	295.7 ± 111.0	275.8 ± 106.8	309.2 ± 112.2
MVPA (min/d)	19.5 ± 23.1	24.5 ± 27.5	16.1 ± 19.0
Sufficiently active (%)	21.9	28.7	17.2
BST (number/d)	78.9 ± 16.0	71.7 ± 15.5	83.7 ± 14.5
Wear time (min/d)	829.9 ± 94.5	836.8 ± 91.0	825.2 ± 96.8
6MWT (m)	470.2 ± 133.4	495.5 ± 147.5	453.0 ± 120.5
8-foot up-and-go (s)	7.7 ± 4.7	7.5 ± 4.9	7.8 ± 4.6
Chair Stand (repetitions/30 s)	14.4 ± 4.5	14.6 ± 4.5	14.3 ± 4.5
Arm curl (repetitions/30 s)	16.9 ± 5.2	17.8 ± 5.5	16.3 ± 5.0
Chair sit-and-reach (cm)	−1.4 ± 10.6	−3.6 ± 11.8	0.1 ± 9.5
Independent functioning (%)			
Low/moderate/high	6.0/54.4/39.5	3.4/37.9/58.6	7.8/65.6/26.6
Hypertensive (%)	48.4	42.5	52.8
Hypercholesterolemia or glycemia (%)	40.7	34.9	44.5
Medical history for chronic disease	30.7	29.9	31.3
Take medication (%)	89.3	87.4	91.3
Current smokers (%)	2.8	1.6	4.7

Note: 6MWT = 6-min walking test; BMI = body mass index; BST = breaks in sedentary time (adjusted for register time); LIPA = low-intensity physical activity; MVPA = moderate-to-vigorous physical activity; PA = physical activity; SB = sedentary behavior (adjusted for register time).

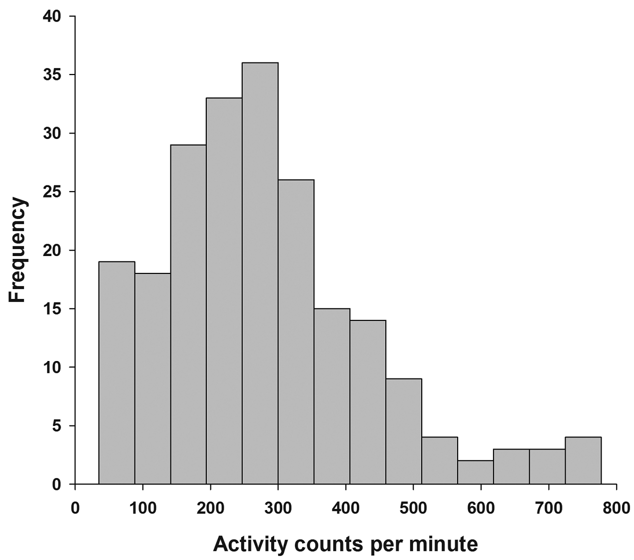

Figure 1. Histogram depicting the distribution of the activity counts per minute.

in older adults. This positive role of daily BST was observed after controlling for overall time in MVPA and SB.

Physical inactivity plays a major role in the secondary aging of many essential physiological functions, and this aging can be prevented through a lifetime of PA (17). Engaging in MVPA has been found to be associated with better functionality at older ages (4,8,18–20) but only more recently has the role of SB in physical function been identified (4,8,9,11). However, only one of these studies (9) examined BST using accelerometers and BST was only associated with lower extremity function. In our investigation, we observed a relationship with overall physical function, assessed by a validated battery of tests (7,12). Our results confirm and extend those of Davis and coworkers (9), but we also verified that BST predicted overall physical function and was also associated with higher scores in specific fitness parameters like upper and lower body strength. In contrast with our findings, Chastin and coworkers (10) observed that higher SB and lower BST were associated with an improved muscle quality. The differences from our

Table 2. Standardized Regression Coefficients of Sedentary Daily Breaks With Physical Function Tests

	Model 1†	Model 2‡	Model 3§
Dependent Variables	β (95% CI)	β (95% CI)	β (95% CI)
6-min walk test	.078 (−0.062, 0.218)	.111 (−0.025, 0.246)	−0.043 (−0.187, 0.101)
8-foot up-and-go‖	0.125 (−0.010, 0.260)	0.132 (−0004, 0.268)	−0.081 (−0.224, 0.060)
Chair stand	0.181* (0.045, 0.318)	0.197* (0.060, 0.333)	−0.141 (−0.286, 0.004)
Arm curl	0.180* (0.039, 0.322)	0.179* (0.037, 0.322)	−0.185 (−0.258, 0.050)
Chair sit-and-reach	−0.021 (−0.172, 0.130)	−0.012 (−0.164, 0.140)	−0.259* (−0.422, 0.596)
Back scratch	0.084 (−0.063, 0.231)	0.098 (−0.050, 0.246)	0.018 (−0.141, 0.177)
Composite *Z*-score	0.154* (0.027, 0.280)	0.169* (0.042, 0.295)	0.180* (0.052, 0.310)

Notes: *Significant at $p < .05$.

†Model 1, adjusted for age, sex, education, body mass index (BMI), physical independence, and sedentary time.

‡Model 2, adjusted for age, sex, education, BMI, physical independence, sedentary time, and moderate-to-vigorous physical activity (MVPA).

§Model 3, adjusted for age, sex, education, BMI, physical independence, sedentary time, MVPA, medical history for chronic disease, hypertension, and elevated cholesterol or glycemia, and current medication status.

‖8-foot up-and-go was transformed using a rational function [$f(y) = 1/y$].

Table 3. Linear Regression Analysis for the Associations of MVPA Sedentary Time and BST as Independent Variables With the Physical Function Composite *Z*-Score

	MVPA	SB	BST	
Independent Variables	β (95% CI)	β (95% CI)	β (95% CI)	Adjusted R^2
Model 1†			.222* (0.101,0.343)	.347
Model 2†	.174* (0.052, 0.343)		.224* (0.105,0.343)	.369
Model 3†		−.198* (−0.325,−0.071)	.154* (0.027,0.280)	.373
Model 4†	.130* (0.003,0.256)	−.158* (−0.290,−0.026)	.169* (0.042,0.295)	.383
Model 5†	.110 (−0.018,0.238)	−.222* (−0.347,−0.098)		.365
Model 6†,‡	.131* (0.005,0.258)	−.154* (−0.287,−0.022)	.170* (0.042,0.300)	.398
Model 7†,‡,§	.134* (0.007,0.259)	−.165* (−0.298,−0.033)	.180* (0.052,0.310)	.405

Notes: BST = breaks in sedentary time (adjusted for register time); MVPA = moderate-to-vigorous physical activity; SB = sedentary behavior (adjusted for register time).

*Significant at $p < .05$.

†Adjusted for sex, age, body mass index, education, and physical independence.

‡Adjusted for medical history for chronic disease, hypertension, and elevated cholesterol or glycemia.

§Adjusted for current medication status.

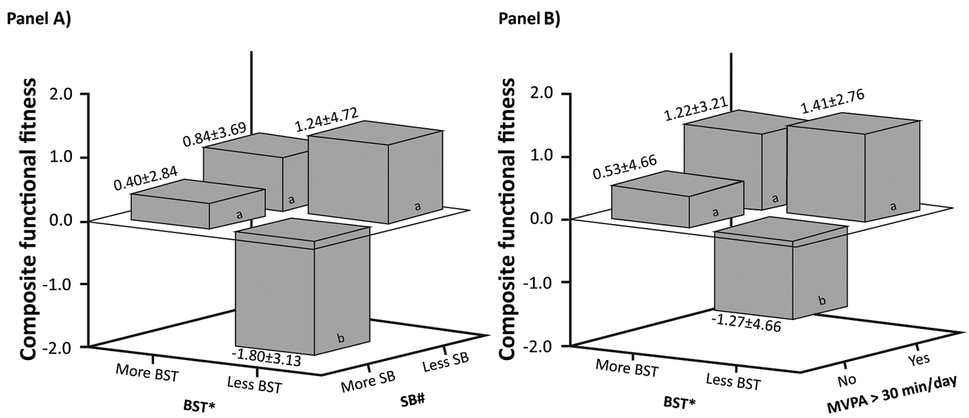

Figure 2. Physical function composite Z-score in different groups. (**A**) BST and SB groups and (**B**) BST and compliance with MVPA guidelines. BST = breaks in sedentary time; MVPA = moderate-to-vigorous physical activity; SB = sedentary behavior. *More BST: ≥P50; less BST: <P50 (P50 = 80.4 BST/d); #More SB: ≥P50; Less SB: <P50 (P50 = 518 min/d). Significant differences between (a) and (b), $p < .05$

own findings may be attributable, at least in part, to the different participant study samples examined. Indeed, the sample used by Chastin and coworkers (10) consisted of high functioning older adults, who spent on average over an hour a day walking. Given that SB was associated with adiposity, Chastin and coworkers (10) suggested that carrying more body fat associated with longer sedentary time may provide a training stimulus for muscle and hence help to maintain leg power. It was further suggested by these authors that PA strategies to conserve energy also may induce different patterns of SB.

When a person engages in SB, the work performed by the large skeletal muscles required for upright movement comes to a halt. Infrequently interrupting SB would thus result in the loss of opportunities for potentially thousands of muscular contractions throughout the day (21). These opportunities, which are associated with light energy expenditure, may provide important functional adaptations that can ultimately reduce mortality rates (22). Therefore, it seems evident that older adults that break-up SB more often may have benefits in their physical function that are associated with these additional muscle contractions, not necessarily associated with MVPA and not requiring prolonged periods of active time. This is in accordance to our findings, as we observed that breaking-up sedentary time was positively associated with physical function.

From a public health perspective, a reduction in SB may pose less challenges than those of increasing MVPA, given that there may be fewer practical limitations in doing so, and that reducing SB may be attained with relatively modest burden to a person's time or financial resources (23). In older adults, this is particularly important as recruitment into PA programs can be difficult (24).

Current PA guidelines focus mainly on MVPA (16). However, the deleterious consequences for the human body during prolonged SB are not necessarily simply the absence of health enhancing benefits from regular PA (21). In the future, and as further evidence accumulates, health guidelines may focus on limiting SB and promoting regular interruptions of sitting time. Regular nonexercise activities for the elderly should act to ameliorate the deleterious impact of prolonged SB on physical function. However, it is not our intention to undervalue the importance of engaging in 30 min/d of MVPA, indeed we verified that MVPA was an independent predictor of physical function. Therefore, PA guidelines for older adults might emphasize more strongly these two distinct behaviors to be considered together, such that even if a person were to comply with 30 min/d of MVPA, they should avoid too much sitting for the rest of the day. Periodic and small interruptions to SB are likely to be of importance in preventing a decline in physical function.

Further research should extend these novel findings using longitudinal approaches, particularly by using randomized controlled trials. We observed that BST and MVPA were positively and independently associated with overall physical function. However, the design of our investigation ultimately does not allow conclusions on the direction of these associations and it is possible that a lower physical capacity in some participants may be a limiting factor to perform MVPA and may also be a limiting factor to more BST. However, in our study, we only included participants if they had an independent physical functioning and additionally adjusted the analysis for the level of physical independence, which attenuates this limitation.

In conclusion, physical function at older ages may be enhanced by breaking-up SB more often, in addition to engaging in MVPA. The amount of daily BST was positively associated with physical function, independently of total SB, MVPA, and other covariates. Regular interruptions in sedentary time in addition to regular levels of PA may help older adults in improving physical function, but further analysis are necessary to understand the prospective associations of patterns of PA and SB on physical function.

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Conflict of Interest

The authors report no conflict of interest.

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