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ORIGINAL ARTICLE

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The association between patterns of physical activity and sedentary time with frailty in relation to cardiovascular disease

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Abstract

Objective: The associations of moderate-vigorous physical activity (MVPA) bouts and patterns of sedentary time (ST) with frailty according to cardiovascular disease (CVD) status are unknown.

Methods: Accelerometry in adults ≥50 years old from the 2003-2004 and 2005-2006 National Health and Nutrition Examination Survey were used. Bouted and sporadic MVPA in ≥10-minute or <1-minute bouts were assessed based on meeting a percentage of physical activity guidelines of 150 minutes/wk, respectively. ST patterns included: prolonged ST lasting ≥30 minutes, and the frequency, intensity, and duration of breaks from ST. A 46-item frailty index defined *frailty*. Multivariable linear regression was used.

Results: There were 827 and 1490 CVD-free and CVD participants, respectively. Meeting a higher percentage of the physical activity guidelines through bouted MVPA was associated with lower frailty in CVD-only participants ($P < 0.05$ for CVD interaction). Sporadic MVPA was associated with lower frailty levels in both groups. Prolonged ST was associated with worse frailty in CVD ($P > 0.05$ for CVD interaction). Frequency of ST breaks was not associated with frailty. Average ST break intensity was protective in both groups. The duration of breaks in ST was associated with lower frailty in CVD participants only ($P > 0.05$ for CVD interaction).

Conclusion: Insufficient MVPA and prolonged ST are detrimental despite CVD status.

KEYWORDS
cardiovascular diseases, exercise, frail elderly, sedentary behavior

1 | INTRODUCTION

Frailty describes the impaired ability to cope with stressors due to reductions in physiologic reserve. More recently, frailty has emerged as a major health concern in those with cardiovascular disease (CVD).[1,2] Estimates suggest that one-third of patients with CVD are frail, which is significantly higher than the general, non-CVD, community-dwelling population.[3] The presence of both frailty and CVD are likely to arise due to the activation of inflammatory pathways, and it has been suggested that there is a bidirectional relationship between the two.[4,5] As such, it is imperative that these conditions are managed effectively so as to improve patient outcomes.

We and others have shown that movement behaviors, including moderate-vigorous physical activity (MVPA) and sedentary time (ST), are independently associated with lower frailty levels.[6-8] We demonstrated that the total accumulation of MVPA is independently associated with lower frailty levels, which goes against current recommendations from the World Health Organization for accumulated MVPA in at least 10-minutes bouts for health benefits.[6] We also revealed that prolonged sedentary bouts lasting at least 30 minutes were detrimentally associated with frailty independent of total ST. In contrast, breaking up ST with higher-intensity and longer-duration bouts were related to lower frailty levels, while the frequency of these breaks was not. These data suggest that breaking up long bouts of ST with short interruptions of higher intensity physical activity may be related to lower frailty levels.

Here, we expand on this investigation to determine if bouts of MVPA and patterns of ST are associated with frailty according to CVD status. Generating new data concerning CVD-specific associations between different patterns of physical activity and sedentary behaviors with frailty could inform lifestyle therapies and the clinical management of those with and without CVD.[1,9]

2 | METHODS

Data from the 2003-2004 and 2005-2006 National Health and Nutrition Examination Survey (NHANES) were used. NHANES is a nationally representative sample of non-institutionalized Americans aged 3-85 years. Sampling was conducted using a multistage probability sampling approach, and consisted of four stages: (a) primary sampling units were selected by single counties or groups of counties with probability proportional to a measure of size; (b) primary sampling units were divided into segments; (c) households in each segment were randomly selected (oversampling of age, ethnic, and income groups led to higher probability of selection in these groups); and (d) individuals were chosen to participate in NHANES from all persons residing in selected households and were drawn at random within designated age-sex-ethnicity screening sub-domains.

We included ambulatory participants aged at least 50 years old who each wore a uniaxial, hip-mounted accelerometer (Actigraph model 7164) for at least four out of 7 days, 10 hours/d. Individuals were separated according to the presence of CVD, which was defined as self-reporting at least one of the following conditions: high blood pressure, myocardial infarction, heart disease, stroke, angina, or heart failure. Participants were excluded if they did not have sufficient data to assess frailty and were missing covariates. The Institutional Review Board of the Centers for Disease Control and Prevention approved the NHANES study.

A 46-item frailty index (FI) was developed to measure frailty based on one that has been previously published within NHANES.[7,10] An FI typically consists of signs, symptoms, chronic conditions, physical and cognitive impairments, self-rated health, and biomarkers.[11] An FI is the ratio of health deficits present. The present study used a 0-100 scale for enhancing interpretability of analyses. Note that CVD-related deficits were included in the FI.

Minute-by-minute accelerometry data were used to assess MVPA and sedentary behaviors. Physical activity intensity cut-points for MVPA were ≥2020 counts/min and time spent in sedentary behaviors had a threshold of 0-100 counts/min based on previously published literature.[12] Accelerometer wear time was determined by subtracting non-wear time from a 24-hours period. Non-wear time was defined as 60 consecutive minutes or longer of 0 intensity counts, with an allowable 2 minutes to reach 1-100 counts/min. Bouted MVPA was defined as any continuous amount of MVPA lasting at least 10 minutes, with two allowable minutes to drop below the moderate-intensity threshold for every 10-minutes block of activity. Sporadic MVPA was defined as any MVPA lasting 1-9 minutes, with no allowable interruption below the moderate-intensity threshold. For bouted and sporadic MVPA, individuals were categorized based on meeting a percentage of the aerobic physical activity component of the World Health Organization physical activity guidelines: 0%, 1%-49%, 50%-99%, and ≥100%. Only four individuals accumulated 4 minutes of sporadic MVPA. Therefore, the 0% sporadic MVPA group represents those who accumulated <1 minutes/d of sporadic MVPA to increase the sample within this group.

Prolonged sedentary bouts, and the frequency, intensity, and duration of breaks from ST were analyzed. A prolonged sedentary bout was defined as ST lasting at least 30 minutes without going above the ST threshold of 0-100 counts/min. A break in ST was defined as an interruption >100 counts/min lasting at least 1 minute. The intensity and duration of breaks in ST were measured in counts/min and minutes, respectively.

2.1 | Statistical analysis

To account for the complex survey design in NHANES, the SAS 9.4 (SAS Institute, Cary, NC, USA) survey procedures were used (proc surveymeans, proc surveyfreq, and proc surveyreg). Mean (SE) and frequencies (%) are provided for continuous and categorical descriptive variables, respectively. Independent *t* tests and chi-square tests were used to compare differences between those with and without CVD for continuous and categorical outcomes, respectively.

Univariable and multivariable linear regression analyses were performed to test the associations between bouted and sporadic MVPA and ST patterns with the FI. All analyses were initially stratified by CVD status, followed by a test for a CVD interaction. Initial CVD-stratified multivariable models adjusted for age, sex, and accelerometer wear time, followed by a fully adjusted model. Fully adjusted models controlled for age, sex, ethnicity, education, income, marital status, smoking status, alcohol consumption, body mass index, total ST, and accelerometer wear time. All physical activity and ST pattern variables were initially analyzed individually using these staged modeling procedures. Subsequent modeling was as follows: (a) for physical activity, bouted and sporadic MVPA were combined into a fully adjusted model; (b) for ST, all ST pattern variables were combined into a fully adjusted model; followed by (c) additional adjustment for bouted MVPA in the fully adjusted ST model. Sporadic MVPA was not added to the final model due to its high correlation ($r > 0.75$) with average break intensity. The analyses in this study excluded light-intensity physical activity as a covariate because it had significant collinearity (variance inflation factor of 18.1) in the linear regression models. A P value of 0.05 was used to determine statistical significance.

3 | RESULTS

3.1 | Descriptive statistics

From 3177 participants who were aged at least 50 years or older with valid data from accelerometry, no missing covariates, and missing <20% FI variables,[11] there were 1490 individuals defined as having CVD and 827 without CVD with complete data (Table 1). Compared to participants without CVD, those with CVD were older, had a higher FI, had a higher body mass index, were more likely to be non-Hispanic Black, generally had a lower education and income, and were current smokers. Those with CVD were less active than those without CVD, as they accumulated about half the amount of bouted (22 vs 42 minutes/wk) and less sporadic (45 vs 66 minutes/wk) MVPA than those without CVD. People without CVD were more likely to meet the physical activity guidelines through bouted (4.6% vs 7.9%) or sporadic (4.8% vs 10.6%) MVPA. In general, CVD participants had a higher amount of total ST, accumulated more prolonged bouts of ST, and had a lower frequency, intensity, and duration of breaks in ST than CVD-free participants.

3.2 | MVPA-frailty relationship

Univariate analyses demonstrated that, in both groups, achieving a higher amount of bouted and sporadic MVPA as assessed by meeting a percentage of the physical activity guidelines was associated with reduced frailty (Table 2). Meeting 1%-49% of the guidelines through bouted MVPA was not associated with a lower FI in those without CVD. A significant CVD interaction was found for bouted and sporadic MVPA in separate models, with the strength of association with frailty being higher in those with CVD. Results were similar for the age, sex, and accelerometer wear time models, although the strength of associations were slightly attenuated. For the fully adjusted models examining the individual and independent associations of bouted MVPA and sporadic MVPA (Table 2), achieving a higher percentage of bouted MVPA was significantly associated with lower frailty levels in participants with CVD, but not in those without CVD ($P < 0.05$ for interaction). Sporadic MVPA was associated with a lower frailty score in both groups.

Multivariable linear regression models combining bouted and sporadic MVPA into a fully adjusted model are provided in Table 3. This model showed a protective association with achieving a higher percentage of physical activity guidelines with bouted MVPA for CVD participants only (Model 1, $P < 0.05$ for interaction). There was a peak in the strength of association at meeting 50%-99% of the guidelines through bouted MVPA. A similar relationship between bouted MVPA and frailty was revealed when a model added prolonged sedentary bouts, and the frequency, intensity, and duration of breaks in ST (Table 3). Meeting a higher percentage of the guidelines through sporadic MVPA was associated with a lower FI to a similar extent in both groups when bouted MVPA was added to the model (Table 3).

3.3 | Sedentary behavior patterns and frailty

In the univariate models examining sedentary pattern variables individually, prolonged ST was associated with worse frailty in both groups (Table 2). The frequency of breaks from ST was associated with a lower FI score in those with CVD only ($P > 0.05$ for interaction). Both the intensity and duration of breaks from ST were associated with a lower FI in both groups. There was a statistically significant CVD interaction found for both variables, with a stronger protective relationship from a more severe frailty state in those with CVD. The age-, sex-, and accelerometer-wear-time-adjusted models revealed similar results. However, the frequency of breaking up ST was no longer associated with lower frailty levels in those with CVD.

Fully adjusted stratified models examining the individual and independent associations between individual ST pattern variables with frailty are found in Table 2. Prolonged sedentary bouts were associated with worse frailty levels in CVD participants only ($P > 0.05$ for interaction). Total breaks in ST were not associated with frailty in either of the groups. The intensity of breaks from ST was associated with a lower FI in both groups. A significant CVD interaction was found; the CVD group's average break intensity was more strongly associated with lower frailty levels. The durations of breaks from ST were associated with lower frailty levels in those with CVD, but not in those without CVD ($P < 0.05$ for interaction).

Fully adjusted linear regression models combining the sedentary bout patterns are described in Table 3. Prolonged bouts of ST were significantly associated with worse frailty in CVD participants only ($P > 0.05$ for interaction) after adjustment for the other ST pattern variables (Model 2). Total breaks in ST were not associated with frailty in either group. The intensity of breaks in ST had a protective association with frailty in both groups. However, there was a stronger association amongst those with CVD ($P < 0.05$ for interaction). The durations of breaks from ST were associated with lower frailty levels in CVD participants only ($P > 0.05$ for interaction).

The fully adjusted model with bouted MVPA added to the ST pattern variables showed that prolonged sedentary bouts were associated with higher FI scores in those with CVD, but not in those without CVD (Model 3, Table 3). No significant interaction was found. Total sedentary breaks were not associated with the FI for

TABLE 1 Characteristics of included sample according to CVD status

Variable	No CVD n = 827 Mean (SE) or n and frequency (%)	CVD n = 1490 Mean (SE) or n and frequency (%)	P value
Age (years)	65.85 (0.51)	68.34 (0.31)	<0.0001
Sex (% female)	411 (49.7%)	732 (49.1%)	0.7925
Frailty index	0.16 (0.003)	0.25 (0.005)	<0.0001
Weight (kg)	75.56 (0.73)	82.73 (0.59)	<0.0001
Body mass index (kg/m^2)	26.85 (0.26)	29.60 (0.19)	<0.0001
Race/ethnicity			
Mexican American	175(21.2%)	249 (16.7%)	<0.0001
Other Hispanic	15 (1.8%)	24 (1.6%)	
Non-Hispanic white	514 (62.2%)	894 (60.0%)	
Non-Hispanic black	96 (11.6%)	289 (19.4%)	
Other	27 (3.3%)	34 (2.3%)	
Education			
<12th grade	271 (32.8%)	533 (35.8%)	0.0001
High school/GED equivalent	199 (24.1%)	385 (25.8%)	
Some college	174 (21.0%)	354 (23.8%)	
College graduate or higher	183 (22.1%)	218 (14.6%)	
Marital status			
Married/common law	521 (63.0%)	921 (61.8%)	0.6814
Widowed	165 (20.0%)	312 (20.9%)	
Divorced/separated	106 (12.8%)	205 (13.8%)	
Never married	35 (4.2%)	52 (3.5%)	
Annual household income			
<$20 000	215 (26.0%)	480 (32.2%)	0.0339
$20 000-$34 999	238 (28.8%)	402 (27.0%)	
$35 000-$54 999	175 (21.2%)	292 (19.6%)	
$55 000-$74 999	73 (8.8%)	124 (8.3%)	
≥$75 000	126 (15.2%)	192 (12.9%)	
Alcohol intake			
Does not drink	686 (83.0%)	1216 (81.6%)	0.0734
<1 drink/d	76 (9.2%)	182 (12.2%)	
1-2 drinks/d	30 (3.6%)	46 (3.1%)	
>2 drinks/d	35 (4.2%)	46 (3.1%)	
Smoking status			
Non-smoker	368 (44.5%)	653 (43.8%)	0.0174
Previous smoker	322 (38.9%)	647 (43.4%)	
Current smoker	137 (9.2%)	190 (12.8%)	
Bouted MVPA (min/wk)	41.76 (3.00)	22.47 (2.40)	<0.0001
Sporadic MVPA (min/wk)	65.83 (3.83)	44.70 (2.18)	<0.0001
Meeting guidelines of 150 min/wk with bouted MVPA			
Meeting ≥100% of guidelines	65 (7.9%)	69 (4.6%)	<0.0001
Meeting 50%-99% of guidelines	78 (9.4%)	68 (4.8%)	
Meeting 1%-49% of guidelines	176 (21.3%)	230 (15.4%)	
Meeting 0% of guidelines	508 (61.4%)	1123 (75.4%)	

(Continues)

TABLE 1 (Continued)

Variable	No CVD *n* = 827 Mean (SE) or *n* and frequency (%)	CVD *n* = 1490 Mean (SE) or *n* and frequency (%)	*P* value
Meeting guidelines of 150 min/wk with sporadic MVPA			
Meeting ≥100% of guidelines	88 (10.6%)	71 (4.8%)	<0.0001
Meeting 50%-99% of guidelines	147 (17.8%)	178 (11.9%)	
Meeting 1%-49% of guidelines	526 (63.6%)	1038 (69.7%)	
Meeting 0% of guidelines	66 (8.0%)	203 (13.6%)	
Total sedentary time (h/d)	8.54 (0.08)	8.91 (0.05)	0.0007
Sedentary bouts lasting 30 min or longer (per day)	3.31 (0.08)	3.77 (0.05)	<0.0001
Number of breaks in sedentary time (per day)	89.81 (0.84)	86.35 (0.60)	0.0003
Average intensity of breaks from sedentary time (counts/min)	433.07 (3.96)	402.52 (3.19)	<0.0001
Average duration of breaks from sedentary time (min)	3.97 (0.07)	3.54 (0.04)	<0.0001

CVD, cardiovascular disease; GED, General Education Diploma; MVPA, moderate-vigorous physical activity.

either of the groups. Average break intensity was associated with a lower FI in both groups, but no interaction between groups was found. For participants with CVD, the duration of breaks from ST was significantly associated with lower frailty levels, but this was not the case for those without CVD ($P > 0.05$ for interaction).

4 | DISCUSSION

The present study demonstrates that patterns of MVPA and ST are differentially associated with frailty according to CVD status. A key finding of the present study was that MVPA accumulated in at least 10-minute bouts had a protective association with frailty in those with CVD only. Meanwhile, sporadic MVPA accumulated in <10-minute bouts was similarly associated with frailty despite CVD status, and appeared to have a stronger protective association compared to bouted MVPA. Prolonged sedentary bouts were associated with worse frailty in participants with CVD, but not in those who were CVD-free. Despite CVD status, the average intensity at which breaks from ST were performed was associated with lower frailty levels despite being active, although this association was stronger in those with CVD. Overall, these findings extend our understanding of the benefits of physical activity and the consequences of ST with frailty according to CVD status.

The World Health Organization physical activity guidelines recommend that adults accumulate at least 150 minutes/wk of MVPA in 10-minutes bouts or longer for health benefits.[13] Similar recommendations are provided to adults with CVD, although they are silent on the way in which MVPA should be accumulated.[14] The present study provides evidence that bouted MVPA is strongly associated with lower frailty levels in participants with CVD, whereas there was no significant association found in those without CVD. It is unclear why bouted MVPA was only significantly associated with frailty in those with CVD, but there is likely a mechanistic link between longer physical activity duration with cardiovascular health. We speculate that in patients with CVD, longer-duration MVPA is protective from further damage to the endothelium and improves overall vascular function.[15] However, further evidence is needed to clarify this hypothesis.

The present study demonstrates that regardless of how MVPA is accumulated, it is significantly associated with lower frailty levels despite CVD status. This confirms the findings from a comprehensive review of interventional studies as well as previous epidemiological studies comparing the link between shorter versus longer bouts of physical activity on cardiovascular health.[16-18] Interestingly, we demonstrate that meeting less than half of the physical activity guidelines through sporadic MVPA is clinically meaningful. Specifically, a β-coefficient of ±2.17 represents a one-FI deficit difference in the present study. Therefore, participants with CVD who met 1%-49% of the physical activity guidelines through sporadic MVPA had approximately one fewer deficits than those who met 0% of the guidelines. These data suggest that current physical activity recommendations should include sporadic MVPA for health benefits, and that lower amounts of MVPA below the currently recommended 150 minutes/wk may reduce frailty; this recommendation is supported by others.[19]

The findings here extend our previous investigation with regards to the relationship between patterns of sedentary behaviors with frailty.[6,8] We demonstrate that prolonged ST is associated with a higher accumulation of deficits in those with CVD independent of bouted MVPA and total ST (i.e. any duration of ST). This finding is novel and could inform health recommendations for individuals with and without CVD. To date, there are no guideline recommendations for adults to reduce the time spent in sedentary behaviors in North America. Sedentary behavior guidelines in Australia and the UK are broad in scope and suggest that adults should minimize time spent

TABLE 2 Multivariable linear regression models examining individual and independent associations of MVPA and sedentary pattern variables stratified by CVD status

	Model 1: Univariate				Model 2: Age and accelerometer wear time adjusted				Model 3: Fully adjusted examining MVPA and ST pattern variables individually			
	CVD		No CVD		CVD		No CVD		CVD		No CVD	
Variables	β-coefficient	SE	β-coefficient	SE	β-coefficient	SE	β-coefficient	SE	β-coefficient	SE	β-coefficient	SE
Physical activity variables												
Meeting guidelines of 150 min/wk with bouted MVPA												
≥100% guidelines	**−9.081**	**1.384**	**−4.525**	**1.325**[a]	**−8.522**	**1.407**	**−4.024**	**1.250**[a]	**−5.405**	**1.361**	−1.944	1.276[a]
50%-99% guidelines	**−10.915**	**1.162**	**−3.283**	**0.916**	**−9.252**	**1.130**	**−2.434**	**1.119**	**−5.615**	**1.177**	−1.417	1.100
1%-49% guidelines	**−7.191**	**0.880**	**−2.240**	**1.326**	**−5.696**	**0.904**	−1.655	1.117	**−3.626**	**0.836**	−0.211	1.041
0% guidelines	Reference				Reference				Reference			
Meeting guidelines of 150 min/wk with sporadic MVPA												
≥100% guidelines	**−13.972**	**1.287**	**−9.771**	**1.948**[a]	**−12.059**	**1.662**	**−9.612**	**1.892**[a]	**−5.936**	**1.707**	**−6.167**	**1.857**[a]
50%-99% guidelines	**−12.047**	**1.237**	**−9.122**	**1.387**	**−9.775**	**1.503**	**−8.900**	**1.667**	**−4.808**	**1.507**	**−6.110**	**1.591**
1%-49% guidelines	**−5.659**	**1.012**	**−6.018**	**1.485**	**−4.949**	**1.084**	**−5.963**	**1.494**	**−2.640**	**1.080**	**−4.789**	**1.413**
0% guidelines	Reference				Reference				Reference			
SB/break from SB variables												
SBs lasting ≥30 min (per day)	**1.396**	**0.252**	**1.007**	**0.290**	**1.632**	**0.208**	**1.254**	**0.286**	**0.767**	**0.307**	0.335	0.377
Breaks from SB (every 10 per day)	**−0.857**	**0.223**	−0.500	0.288	−0.414	0.271	−0.005	0.310	−0.189	0.245	−0.015	0.281
Average break intensity (per 100 counts/min)	**−4.505**	**0.295**	**−2.422**	**0.427**[a]	**−4.627**	**0.465**	**−2.783**	**0.457**[a]	**−2.619**	**0.494**	**−1.672**	**0.540**[a]
Average break duration (min)	**−3.812**	**0.350**	**−1.521**	**0.304**[a]	**−3.397**	**0.361**	**−1.469**	**0.300**[a]	**−2.034**	**0.490**	−0.667	0.390[a]

CVD, cardiovascular disease; MVPA, moderate-vigorous physical activity; SB, sedentary bout; ST, sedentary time.
Estimates of the regression coefficient are provided, with SEs.
Model 1: No adjustment.
Model 2: Adjusted for age and accelerometer wear time.
Model 3: Adjusted for age, ethnicity, education, annual household income, marital status, smoking status, alcohol consumption, body mass index, total ST, and accelerometer wear time.
Bold indicates *P*-values < 0.05.
[a]Indicates statistically significant CVD interaction ($P < 0.05$).

TABLE 3 Multivariable linear regression models combining MVPA and ST variables stratified by CVD status

Variables	Model 1 (bouted + sporadic MVPA adjusted model)				Model 2 (prolonged ST, and frequency, intensity, and duration of ST-break adjusted model)				Model 3 (ST pattern + bouted MVPA adjusted model)			
	CVD		No CVD		CVD		No CVD		CVD		No CVD	
	β-coefficient	SE	β-coefficient	SE	β-coefficient	SE	β-coefficient	SE	β-coefficient	SE	β-coefficient	SE
Physical activity variables												
Meeting guidelines of 150 min/wk with bouted MVPA												
≥100% guidelines	**−5.018**	**1.360**	−1.391	1.298[a]	—	—	—	—	**−3.489**	**1.431**	−0.616	1.324[a]
50%-99% guidelines	**−5.349**	**1.187**	−1.003	1.114	—	—	—	—	**−4.966**	**1.195**	−0.607	1.139
1%-49% guidelines	**−3.285**	**0.843**	0.277	1.060	—	—	—	—	**−3.011**	**0.820**	0.559	1.032
0% guidelines	Reference				—	—	—	—	Reference			
Meeting guidelines of 150 min/wk with sporadic MVPA												
≥100% guidelines	**−4.885**	**1.727**	**−5.994**	**1.911**	—	—	—	—	—	—	—	—
50%-99% guidelines	**−3.739**	**1.510**	**−5.905**	**1.605**	—	—	—	—	—	—	—	—
1%-49% guidelines	**−2.296**	**1.067**	**−4.740**	**1.419**	—	—	—	—	—	—	—	—
0% guidelines	Reference				—	—	—	—	—	—	—	—
SB/break from SB variables												
SBs lasting ≥30 min (per day)	—	—	—	—	**1.370**	**0.429**	0.528	0.490	**1.413**	**0.428**	0.533	0.494
Breaks from SB (every 10 per day)	—	—	—	—	0.018	0.336	−0.148	0.405	0.033	0.331	−0.147	0.404
Average break intensity (per 100 counts/min)	—	—	—	—	**−2.212**	**0.540**	**−1.611**	**0.574**[a]	**−1.721**	**0.540**	**−1.563**	**0.583**
Average break duration (min)	—	—	—	—	**−1.632**	**0.531**	−0.489	0.461	**−1.593**	**0.526**	−0.504	0.462

MVPA, moderate-vigorous physical activity; SB, sedentary bout; ST, sedentary time.
Estimates of the regression coefficient are provided, with SEs.
All models are adjusted for age, ethnicity, education, annual household income, marital status, smoking status, alcohol consumption, body mass index, total ST, and accelerometer wear time. Models are also adjusted for variables within the specific models presented.
Model 1: All physical activity and SB/break variables.
Model 2: Sex comparison of estimates with all physical activity and SB/break variables.
Model 3: Sex comparison of estimates with bouted physical activity and all SB/break variables.
Bold indicates *P*-values < 0.05.
[a]Indicates statistically significant CVD interaction ($P < 0.05$).

in sedentary pursuits for extended periods.[20,21] Scientific entities, such as the American Heart Association and the Sedentary Behavior Research Network, are calling for more research concerning the link between sedentary behaviors and health outcomes, along with potential mechanisms.[22,23]

The present study provides insight into the potential and differential associations between different patterns of ST with frailty by CVD status. Further research is needed to understand and explain these relationships, and to determine if the implementation of a targeted approach to reduce prolonged ST leads to better health outcomes. For example, a prolonged ST reduction strategy could be implemented into the current standard of care for patients who have experienced a cardiovascular event (e.g. cardiac rehabilitation). Evidence to inform such a strategy comes from Bond and colleagues, who found that 3-minute breaks every 30 minutes is superior to reducing ST compared to 12-minute sedentary breaks every 60 minutes in overweight and obese adults (47 vs 26 minutes/d).[24] To complement that evidence, it should be determined if more intense breaks of longer duration can support reductions in ST, along with deriving significant health outcomes as was found in the present study.

4.1 | Limitations

There are limitations to consider with the use of an accelerometer to classify intensity of physical activity and sedentary behaviors. Specifically, the accelerometer cut-points used may not be appropriate for the cohort studied, leading to potential inaccurate estimates of MVPA and ST. Standard accelerometer cut-points typically used in NHANES were chosen because to date there is no consensus on appropriate cut-points to use in an older population.[25] The accelerometers used in NHANES may not accurately capture all movements of activities of daily living, possibly underestimating physical activities and their associations with frailty in the present study.[26] With regards to CVD, there was no standard definition in NHANES to separate groups by CVD status. Also, this cross-sectional study could not determine if higher frailty was a consequence of CVD, or vice versa. Given the bidirectional relationship between CVD and frailty, a larger prospective study is needed.[5]

5 | CONCLUSIONS

These data suggest that sporadic MVPA is equally important to reducing frailty despite CVD status, while bouted MVPA was associated with lower frailty levels in CVD patients only. Breaking up ST with light-vigorous intensity breaks resulted in significant associated reductions in frailty in those with and without CVD, which may help inform the development of CVD-specific and general public health sedentary behavior guideline recommendations.

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CONFLICT OF INTEREST

R.C.A. holds an unrestricted educational grant from Pfizer Canada Inc. and honoraria from Mallinckrodt Pharmaceuticals. These potential competing interests are unrelated to the present study.

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