ORIGINAL RESEARCH

Patterns of Sedentary Behavior in the First Month After Acute Coronary Syndrome

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***Background*—**Sedentary behavior is a key contributor to cardiovascular disease. Few data exist on the sedentary behavior patterns of patients with acute coronary syndrome.

***Methods and Results*—**We characterized patterns of sedentary time and their correlates in 149 patients with acute coronary syndrome over the first month postdischarge, a critical period when lifestyle behaviors are formed. Sedentary time was measured by accelerometry for 28 days postdischarge. Group-based modeling at the day level was used to characterize sedentary patterns. Participants spent a mean of 9.7±2.0 hours per day sedentary during the 28 days postdischarge, with significant decreases in sedentary time observed in each consecutive week ($P<0.01$ for all). Three distinct sedentary patterns were identified: high (20.6% of participants), moderate (47.9%), and low (31.5%). The high and moderate sedentary groups spent a mean of 12.6±0.8 and 10.0±0.7 hours per day sedentary, respectively, and had only minimal decreases in their sedentary time (<3 minutes per day) over the 28 days. The low sedentary group spent a mean of 7.3±0.8 hours per day sedentary, with a rapid decrease in sedentary time (14 minutes per day) observed during the first week postdischarge followed by a relatively smaller decrease (≈5 minutes per day) that persisted until day 21 postdischarge. Non-Hispanic ethnicity, left ventricular ejection fraction <40%, lower physical health–related quality of life, and not having a partner were associated with an increased likelihood of being in the high sedentary group.

***Conclusions*—**Survivors of acute coronary syndrome accrued high volumes of sedentary time during the first month postdischarge, with most showing little change over time. Interventions targeting reductions in sedentary time among survivors of acute coronary syndrome may be warranted, particularly for those with poor physical health and greater disease severity. **(*J Am Heart Assoc*. 2019;8:e011585. DOI: 10.1161/JAHA.118.011585.)**

Key Words: accelerometry • acute coronary syndrome • sedentary behavior

In the United States, more than 1.1 million patients are hospitalized annually for an acute coronary syndrome (ACS).[1] Despite improvements in acute care, 21% of survivors of ACS will be rehospitalized and ≈1 in 5 patients will die within 1 year following hospitalization.[2] Much of the increased morbidity and mortality risk among survivors of ACS remains unexplained.[3,4] Thus, there is a need to identify novel modifiable risk factors for intervention to increase survival and reduce recurrent events among patients with ACS.

Sedentary behavior (eg, watching TV and computer use) has emerged as a distinct cardiovascular disease (CVD) risk factor that may carry clinical relevance beyond how much one exercises.[5–7] Accumulating evidence from population-based studies indicate that sedentary behavior is associated with CVD morbidity and mortality, and CVD risk factors, such as insulin resistance.[8] Notably, the deleterious effects of sedentary behavior are eliminated only by high levels of moderate to vigorous physical activity (MVPA) (≈60–75 minutes per day), which exceeds physical activity recommendations.[9] Accordingly, the American Heart Association has released a scientific statement on sedentary behavior that endorsed the public health message "sit less, move more."[10] This raises the question as to whether reducing sedentary behavior may represent another therapeutic target for secondary prevention and rehabilitation of ACS survivors, in addition to existing MVPA recommendations.

Despite strong links between sedentary behavior and cardiovascular health, few data exist on the sedentary behavior patterns of survivors of ACS. Furthermore, no

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Accompanying Data S1, Tables S1 through S3, and Figure S1 through S3 are available at https://www.ahajournals.org/doi/suppl/10.1161/JAHA.118.011585

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Clinical Perspective

What Is New?

- Survivors of acute coronary syndrome as a group engaged in high volumes of objectively measured sedentary time over the first month postdischarge.
- Distinct patterns of either gradual or rapid reductions in sedentary behavior emerged over the first month postdischarge, with most showing minimal decreases in their sedentary time (<3 minutes per day) over the 28-day period.
- Greater disease severity, lower physical health–related quality of life, and not having a partner were positively associated with the most hazardous pattern of sedentary behavior.

What Are the Clinical Implications?

- A specific focus on sedentary behavior reduction strategies, in addition to exercise-based strategies, may be needed to mitigate future health risk in survivors of acute coronary syndrome, particularly for those with poor physical health and greater disease severity.
- Although reductions in sedentary behavior were observed over time, most patients still exhibited high volumes of sedentary behavior throughout the first month, which may indicate that intervening at any point during this critical period could yield beneficial reductions in sedentary time and help mitigate future health risk.

studies have examined the change in sedentary behavior over time in survivors of ACS during the period immediately following hospitalization. Characterizing survivors of ACS according to their sedentary behavior as they recuperate from their ACS event may reveal unique patterns and subsets of patients in whom sedentary reduction strategies may be most beneficial. Therefore, the primary aim of the current study was to characterize the amount of sedentary behavior in survivors of ACS and its trajectory of change over the first month postdischarge, a critical period when health behaviors may be influenced and when lifestyle interventions ideally begin (eg, cardiac rehabilitation). Group-based trajectory modeling was utilized to identify and evaluate unique patterns of change in sedentary behavior over the 28-day convalescent period following ACS. A secondary aim was to identify correlates of sedentary behavior patterns in survivors of ACS over the first month postdischarge.

Methods

Study Population

The data that support the findings of this study are available from the corresponding author upon reasonable request. Patients with ACS from a tertiary care academic medical center were enrolled into the PULSE (Prescription Use, Lifestyle, and Stress Evaluation) study, an observational cohort study conducted from February 2009 to September 2012 (N=1087). The PULSE study was designed to examine behavioral and biological pathways that may confer increased risk for recurrent cardiac events.[11] A diagnosis of and hospitalization for ACS was the inclusion criterion, where ACS events were defined according to American Heart Association/American College of Cardiology criteria as either acute myocardial infarction (with or without ST elevation) or unstable angina.[12] Exclusion criteria included individuals younger than 18 years, without English or Spanish proficiency, inability to complete the baseline assessment or to comply with the study protocol, and those who were medically unstable.

This article reports on a substudy whose purpose was to examine physical activity and sedentary behavior as behavioral pathways that may confer increased risk for recurrent cardiac events. Accordingly, physical activity and sedentary behavior were objectively measured for up to 45 days postdischarge via accelerometry among a subsample of the PULSE study cohort from August 2009 to September 2012.[13] Of the 1087 participants enrolled in the PULSE study, 930 were active and eligible to participate in the accelerometer substudy. Of the 930 participants, 620 consented to participate in the accelerometer substudy and were given a device. After excluding participants with lost, defective, or nonworn devices (n=189), noncompliant wear time (n=250; ≥3 days with accelerometer wear ≥10 hours per day each week over the first 28 days postdischarge [weeks 1–4]),[14,15] or who received coronary artery bypass grafting (n=14) and/or were rehospitalized (n=18), a total of 149 participants were available for the current analysis (Figure S1). The PULSE study protocols were approved by the Columbia University Medical Center's institutional review board and written informed consent was obtained from all participants before they were enrolled into the study. Characteristics of the substudy participants and those who were excluded from the current analyses are shown in Table S1.

Accelerometer Protocol

Participants were fitted at or soon after hospital discharge with an Actical accelerometer (Philips Respironics) on their nondominant wrist, and were asked to wear the device for 45 days postdischarge, and then to return the device via mail at the end of the monitoring period. Participants were instructed to remove the device when bathing and during sleep. The Actical is an omnidirectional accelerometer that can detect acceleration in all directions (up, forward, and sideways) and has been validated for the measurement of

physical activity when worn on the wrist.[16,17] Activity counts were collected in 1-minute epochs.

Accelerometer Processing

Nonwear time was determined using the Choi algorithm, defined as at least 90 consecutive minutes of zero counts, with allowance of 1 or 2 minutes of nonzero counts as long as no counts were detected in the 30-minute windows at the start or end of the 90-minute (or longer) period.[18] Epochs with <100 counts per minute (cpm) and ≥1065 cpm were classified as sedentary behavior and MVPA, respectively.[19,20] Time spent in sedentary behavior was determined by summing the number of minutes in a day when the activity counts met these criteria. Some physical activity recommendations endorse bouts of ≥10 minutes of MVPA as a health-enhancing bout of physical activity. Accordingly, we defined an MVPA bout as any period of ≥10 minutes for which each consecutive 10-minute window contained ≤2 minutes for which the activity count was below threshold (1065 cpm).[21,22] For each compliant day (≥10 hours of wear), the total number of sedentary minutes and the total time spent in MVPA bouts were calculated.

Presently, there are no validated cut points to classify sedentary behavior using the Actical device when worn on the wrist. We selected a sedentary cut point of 100 cpm based on findings and methods defined in the DHS (Dallas Heart Study), a longitudinal, multiethnic population-based probability sample of Dallas County residents.[20] The DHS assessed sedentary time with a wrist-worn Actical accelerometer and classified sedentary time as <100 cpm. Findings from the DHS demonstrated that objectively measured sedentary time was associated with subclinical atherosclerosis[20] and myocardial injury.[23] Given that sedentary time classified as <100 cpm was associated with meaningful cardiovascular health indices in a large, representative sample, we chose to incorporate the same cut point for our analyses.

Because of a high correlation between sedentary time and wear time (r=0.78), we corrected for the influence of variation in wear time by standardizing sedentary time using the residuals obtained when regressing sedentary time on wear time at the group level.[24–26] As a result, sedentary time is expressed as the predicted sedentary time for that day, had the participant worn the device for 16 hours.

Potential Correlates of Sedentary Behavior

Sociodemographic factors (age, sex, race, ethnicity, education, partner status, Medicaid), hospitalization characteristics/procedures (ACS type, length of hospital stay, percutaneous coronary intervention), measures of health status/disease severity (body mass index, left ventricular ejection fraction [LVEF], CVD history, Charlson Comorbidity Index,[27,28] Global Registry of Acute Coronary Events [GRACE] risk score,[29] depression, physical- and mental health–related quality of life), exercise history, cardiac rehabilitation participation, and sleep quality were examined as potential correlates of objectively measured sedentary behavior trajectory group. Details on all potential correlates are available in Data S1.

Statistical Analysis

Descriptive statistics, including frequencies and means±SDs, were computed to characterize the sociodemographic and health characteristics as well as the patterns of sedentary behavior during weeks 1, 2, 3, and 4 and the whole month. Multilevel growth curve models were then used to examine and compare the pattern of time spent in sedentary behavior each week.[30]

Classes or natural groupings of participants who tended to exhibit similar patterns of sedentary behavior over the 28 days postdischarge were identified and characterized using group-based trajectory modeling.[31] Using this approach, each individual is presumed to belong to only 1 group, and each group is assumed to have its own distinct trajectory.[31,32] Quadratic trajectories and a normal probability distribution for the estimated sedentary time, given a wear time of 16 hours per day, were used to compare 1-, 2-, 3-, 4-, 5-, and 6-group solutions to identify the model that best characterized sedentary patterns among survivors of ACS over the first 28 days postdischarge without overfitting the data. The best fit model was selected using the Bayesian information criterion, subject to the condition that each group contained at least 10% of participants.[31] All analyses were performed using SAS software version 9.4 (SAS Institute Inc) and the PROC TRAJ macro.[33] Based on the Bayesian information criterion, a 3-group model was selected as the final model. Next, the model was adjusted to ensure that the highest order parameter was significant for each group, resulting in a linear function in time for groups 2 (moderate) and 3 (high) and a quadratic function in time for group 1 (low).

Multilevel growth curve models were then used to examine time effects within each trajectory group. The estimated time effects within group 2 (moderate) and group 3 (high) were based on a linear time function over the first 28 days postdischarge, where the slope constituted an estimate of the average daily rate of change. For group 1 (low), the daily rate of change changed over the 28-day period, as represented by the quadratic function, and therefore the estimated rates of change were reported on day 1, day 14, and day 28 as the slope of the tangent of the curve on these days.

Logistic regression models were conducted to examine correlates of membership in the most sedentary trajectory

group. All correlates were initially examined, one at a time, in separate models that included age, sex, race, and ethnicity as covariates (model 1). In order to identify the strongest correlates of the most sedentary trajectory group, we then conducted a backwards elimination regression analysis that included all correlates to arrive at a parsimonious model that retained only those potential predictors that were statistically significant at the α=0.05 level; age, sex, race, and ethnicity were again included as covariates in the model (model 2). Because a validated wrist-based Actical cut point has not been established, a sensitivity analysis was conducted with all analyses repeated after defining sedentary behavior as epochs with <200 cpm. Additionally, to exclude any effect of possible accelerometer wear during sleep, a sensitivity analysis was conducted restricting the accelerometer analysis period to 8 AM to 8 PM.

Results

Table 1 presents the sociodemographic and health characteristics of the 149 participants who comprised the analytic sample. Participants were predominantly men, and racially and ethnically diverse. The mean (±SD) of age and body mass index was 62.8±11.2 and 28.6±5.0, respectively. The majority presented with unstable angina (n=78; 52.3%), received percutaneous coronary intervention during hospitalization (n=128; 85.9%), and did not attend cardiac rehabilitation post-hospitalization (n=132; 88.6%). Additionally, the majority of participants had a partner/spouse (n=90; 60.4%) and almost half reported regular participation in exercise before their ACS event (n=68; 45.6%).

Over the first month postdischarge, on average, sedentary behavior accounted for 60.6% of wear time over a 16-hour waking day, equivalent to a mean (SD) of 9.7±2.0 hours per day. The mean (SD) sedentary time was 10.3±2.0, 9.8±2.1, 9.4±2.2, and 9.3±2.2 hours per day over a 16-hour waking day in weeks 1, 2, 3, and 4 postdischarge, respectively. Sedentary time declined over the first month postdischarge ($F_{3,\ 592}$=25.53, P<0.001 for overall time effect), with decreases in sedentary time observed in each consecutive week (P<0.01 for weeks 1 versus 2, 2 versus 3, and 3 versus 4).

The Figure shows the 3-group sedentary trajectories determined by the group-based trajectory modeling. Low, moderate, and high sedentary time trajectory groups were identified, which comprised 31.5%, 47.9%, and 20.6% of the analytic sample, respectively. Characteristics of the 3 sedentary trajectory groups are shown in Table S2. The mean±SD of total sedentary time for the low, moderate, and high trajectory groups was 7.3±0.8, 10.0±0.7, and 12.6±0.8 hours per day, respectively. Each sedentary trajectory group had a significant change in day-level sedentary time over the 28-day post-hospitalization period (P<0.05 for all). The high and moderate groups decreased their sedentary time at a rate of 1.9 (P=0.003) and 2.9 (P<0.001) minutes per day, respectively. The low sedentary trajectory group decreased their sedentary time at a rate of 14.0 minutes per day immediately

Table 1. Characteristics of Survivors of ACS

Participant Characteristics	Overall (N=149)
Sociodemographics	
Age, y	62.8 (11.2)
Men, %	69.8 (n=104)
Black race, %	17.4 (n=26)
Hispanic ethnicity, %	38.3 (n=57)
Education ≤high school graduation, %	43.0 (n=64)
Partner/spouse, %	60.4 (n=90)
Medicaid, %	34.0 (n=50)
Hospitalization	
ACS type	
Unstable angina, %	52.3 (n=78)
NSTEMI, %	31.5 (n=47)
STEMI, %	16.1 (n=24)
Length of hospital stay >4 d, %	23.5 (n=35)
Percutaneous coronary intervention, %	85.9 (n=128)
Physical and psychosocial	
Exercise participation pre-ACS event, %	45.6 (n=68)
Cardiac rehabilitation post-ACS event, %	11.4 (n=17)
Body mass index, kg/m^2	28.6 (5.0)
LVEF <40% (%)	14.1 (n=21)
CVD history, %	33.6 (n=50)
Charlson Comorbidity Index	1.5 (1.6)
GRACE risk score	87.8 (28.3)
Depression, %*	30.9 (n=46)
Physical health composite score	40.0 (10.9)
Mental health composite score	53.0 (10.7)
Sleep quality	5.2 (4)
Accelerometer characteristics	
Wear time, min/d	1219.0 (224.1)
Valid wear days	25.7 (2.8)
Total sedentary time, min/d	581.4 (121.6)
MVPA bout minutes, min/d	22.7 (37.6)

Values presented as mean (SD) or percentage. ACS indicates acute coronary syndrome; CVD, cardiovascular disease; GRACE, Global Registry of Acute Coronary Events; LVEF, left ventricular ejection fraction; MVPA, moderate to vigorous physical activity; NSTEMI, non–ST-segment–elevation myocardial infarction; STEMI, ST-segment–elevation myocardial infarction.
*Depression=Beck Depression Inventory score >10.

postdischarge ($P<0.001$). After 2 weeks post-hospitalization, the rate in which sedentary time decreased reduced to 4.8 minutes per day and bottomed out at day 21 and thereafter increased to a rate of 4.8 minutes per day at day 28. The low trajectory group had a significantly greater rate of change in sedentary time compared with the high and moderate groups over the 28-day postdischarge period ($<P=0.01$ for both). The difference in the rate of change in sedentary time between the high and moderate trajectory groups was not statistically significant (1.9 versus 2.9 minutes per day; $P=0.22$). In sensitivity analyses, similar 3-group trajectories were observed when using a cut point for sedentary behavior of 200 cpm (Figure S2) and when restricting the accelerometer analysis period to 8 AM to 8 PM (Figure S3). Furthermore, there is high agreement between the assignment of participants to trajectory groups for each of these sensitivity analyses with that for the primary analysis; both weighted kappas were >0.70 (Table S3).

Multivariable models examining the correlates of the high sedentary trajectory group are shown in Table 2. The final parsimonious model identified Hispanic ethnicity, having a partner, LVEF <40%, history of CVD, body mass index, GRACE risk score, and perceived physical health as significant bivariate correlates of the high sedentary trajectory group, controlling for age, sex, black race, and ethnicity. Survivors of ACS with Hispanic ethnicity, a partner/spouse, history of CVD, and higher body mass index were less likely to be in the high total sedentary trajectory group. On the other hand, those with an LVEF <40%, higher GRACE risk score, or lower physical health–related quality of life were more likely to be in the high total sedentary time group.

Discussion

The current study found that survivors of ACS spent, on average, more than 9 hours of a 16-hour waking day engaged in sedentary behavior over the first month immediately following hospitalization. Sedentary time was greatest during the first week and decreased in subsequent weeks as survivors of ACS assimilated back into everyday life after discharge. Our analysis suggests the presence of 3 distinct patterns of change. Two of these patterns, comprising ≈70% of study participants, exhibited small but statistically significant rates of decline in sedentary time over the first month after discharge. Over the same period, those in the third pattern exhibited less sedentary behavior initially, with declines in sedentary time during weeks 1 to 3 before leveling off at about 6.75 hours per day of sedentary time. Several factors, including greater disease severity, lower physical health–related quality of life, and not having a partner were positively associated with the most hazardous post-hospital trajectory of sedentary time (ie, high volume of sedentary time with only a modest improvement over time).

We previously reported in this cohort of survivors of ACS that only ≈16% met MVPA guidelines and, strikingly, ≈40% of patients did not engage in a single day of health-enhancing physical activity akin to exercise (eg, ≥30 MVPA bout minutes).[34] Collectively, the present and previous studies

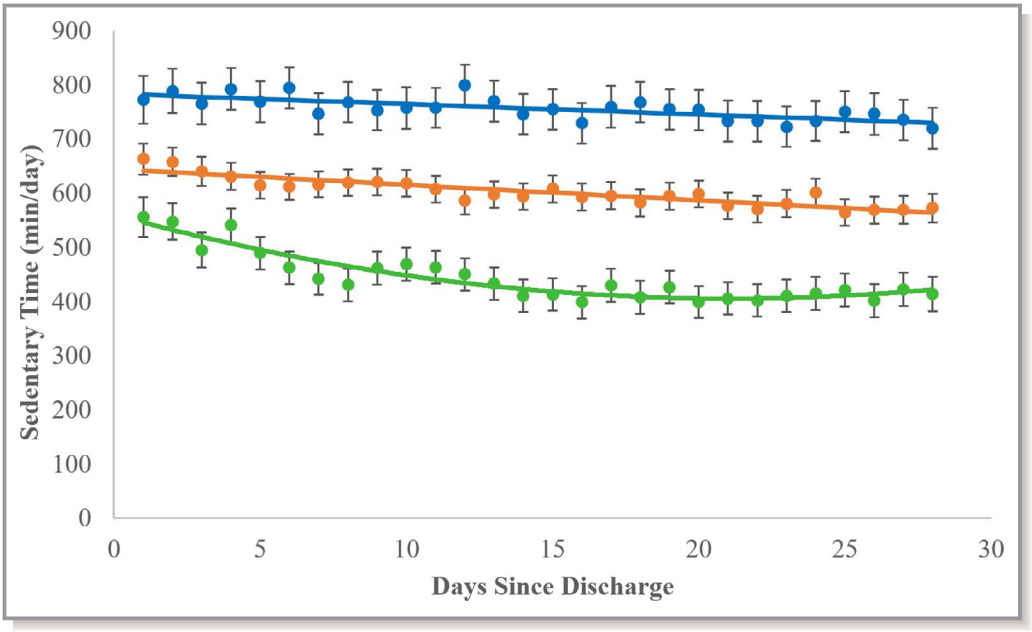

Figure. Sedentary time over the 28-day postdischarge period among low, moderate, and high trajectory groups of survivors of acute coronary syndrome. Data are presented as mean±1 standard error for each day, by sedentary trajectory group.

Table 2. Correlates of Being in the High Sedentary Behavior Trajectory (vs Either of the Other 2 Sedentary Behavior Trajectories)

	Model 1*		Model 2†	
Variables	OR (95% CI)‡	*P* Value	OR (95% CI)‡	*P* Value
Sociodemographic				
Age	1.06 (1.02–1.11)	0.01	0.97 (0.89–1.06)	0.46
Male	1.48 (0.56–3.90)	0.43	2.32 (0.52–10.31)	0.27
Black race	1.63 (0.50–5.30)	0.42	0.70 (0.16–3.11)	0.64
Hispanic ethnicity	1.33 (0.53–3.32)	0.54	0.20 (0.06–0.74)	0.02
≤High school education	0.71 (0.27–1.84)	0.48	. . .	. . .
Partner/spouse	0.40 (0.15–1.08)	0.07	0.28 (0.08–0.97)	0.04
Medicaid	5.56 (1.45–21.36)	0.01	. . .	. . .
Hospitalization				
STEMI (reference=UA/NSTEMI)	2.11 (0.75–5.96)	0.16	. . .	. . .
Length of hospital stay >4 d	4.51 (1.75–11.62)	<0.01	. . .	. . .
Percutaneous coronary intervention	0.50 (0.16–1.53)	0.22	. . .	. . .
Physical and psychosocial				
Exercise participation before event	0.87 (0.37–2.05)	0.76	. . .	. . .
Cardiac rehabilitation after event	2.29 (0.67–7.87)	0.19	. . .	. . .
Body mass index	0.93 (0.84–1.02)	0.13	0.87 (0.77–0.99)	0.04
LVEF <40%	11.22 (3.67–34.3)	<0.01	9.24 (2.03–42.00)	<0.01
CVD history	0.98 (0.40–2.37)	0.96	0.17 (0.05–0.68)	0.01
Charlson Comorbidity Index	1.08 (0.83–1.41)	0.55	. . .	. . .
GRACE risk score	1.04 (1.02–1.07)	<0.01	1.05 (1.01–1.09)	<0.01
Depression§	1.30 (0.51–3.28)	0.58	. . .	. . .
Physical health composite score	0.96 (0.92–1.00)	0.06	0.94 (0.89–0.99)	0.02
Mental health composite score	0.95 (0.92–0.99)	0.03	. . .	. . .
Sleep quality	1.00 (0.9–1.12)	0.98	. . .	. . .

CVD indicates cardiovascular disease; GRACE, Global Registry of Acute Coronary Events; LVEF, left ventricular ejection fraction; NSTEMI, non–ST-segment–elevation myocardial infarction; STEMI, ST-segment–elevation myocardial infarction; UA, unstable angina.

*Separate logistic regression models for each correlate adjusted for age, sex, black race, and Hispanic ethnicity.

†Parsimonious backward elimination regression model after including all correlates and adjusting for age, sex, black race, and Hispanic ethnicity.

‡Odds ratio (OR) for high sedentary group membership. Low and moderate groups were combined and set as the reference group.

§Depression=Beck Depression Inventory score >10.

provide a comprehensive description of the physical activity and sedentary behavior profile of survivors of ACS in the first month after hospitalization. Our results suggest that few survivors of ACS engage in sufficient levels of MVPA, and many adopt a sedentary lifestyle immediately upon returning home, with most participants exhibiting relatively little change thereafter. These findings highlight a need to develop strategies for promoting movement in this vulnerable population. While cardiac rehabilitation is a cornerstone of secondary prevention, only 11.4% of our participants attended a cardiac rehabilitation program. This is not surprising, as low cardiac rehabilitation referral rates and poor adherence to exercise-based programs are well established among cardiac patients.[35,36] Furthermore, recent evidence has demonstrated that exercise-based cardiac rehabilitation programs do not yield reductions in sedentary time (since one can exercise for 30 minutes and be sedentary the rest of the day).[37–39] Thus, a specific focus on sedentary behavior reduction strategies, in addition to exercise-based strategies, may be needed to promote greater activity in survivors of ACS.

The total volume of sedentary behavior detected among survivors of ACS in the current study is lower than that observed in other clinical populations (eg, stroke and chronic obstructive pulmonary disease).[40,41] However, between-study differences in accelerometer protocols and processing (eg, device, wear

location, epoch length, sedentary count threshold, and nonwear threshold duration) make it difficult, and potentially problematic, to compare our results with those reported in other clinical conditions.[42–44] A similar study suitable for comparing our results is the DHS, a longitudinal, multiethnic population-based probability sample of 2031 Dallas County adults without CVD. Using a wrist-worn Actical accelerometer and a 100 cpm threshold to define sedentary behavior (identical to the present study), sedentary time accounted for a mean of 5.1 hours per day over a 12-hour period from 8 AM to 8 PM in the DHS. Similarly, when we restricted the analytic period to 8 AM to 8 PM, we observed that survivors of ACS spent a mean of 5.4 hours per day sedentary. The similar total volume of sedentary time observed between our study sample and that of the DHS may be attributed to the high percentage of patients with unstable angina in our study sample (≈52%), as these patients are more likely to typically have preserved cardiac function and return to work soon after hospitalization compared with those with myocardial infarction.[45,46] Future research may be needed to elucidate whether survivors of ACS are prone to higher volumes of sedentary behavior relative to their healthier peers.

A unique contribution of the present study is the application of group-based trajectory modeling techniques to identify distinct patterns of change in sedentary behavior in a post-hospitalization patient group. The first month after hospital discharge was studied under the premise that this is a critical period when survivors of ACS recuperate from their event and wherein different trajectories might be observed. Although significant decreases in sedentary time from one week to the next were observed for the full sample, different patterns of change emerged that were gradual in some cases and more rapid in others. Regardless of the change observed over time, most patients still exhibited high volumes of sedentary behavior throughout the first month, which may indicate that intervening at any point during this critical period could yield beneficial reductions in sedentary time and help mitigate future health risk.

Understanding the factors that influence the amount of time survivors of ACS spend sedentary may help to inform the development of effective interventions in this population. Unsurprisingly, we observed that sicker patients with poorer physical function were more likely to accrue higher volumes of sedentary time. Specifically, indices of greater disease severity (ie, LVEF <40% and GRACE risk score) and lower physical health–related quality of life were among the factors associated with being classified in the most sedentary trajectory group (ie, high volume and minimal improvement over time). In light of the fact that such patients are likely to have difficulty in attaining MVPA recommendations,[47–49] the replacement of sedentary time with even light-intensity activities of daily living may be beneficial. For example, in a general population–based study, theoretical estimates via isotemporal substitution have suggested that replacing 30 minutes of sedentary time with light physical activity could reduce all-cause mortality risk by 18% among adults with low activity levels.[50]

Partner status was also a significant correlate, such that those without a partner or spouse were more likely to engage in hazardous amounts of sedentary time. Broadly, partner support is linked to a wide range of positive health behaviors and health outcomes.[51,52] Partners often attempt to directly influence each other's health behaviors,[53] and partners may even engage in activities with patients as an effective strategy for illness management.[54] Theorists have highlighted the importance of communal coping (ie, appraising an illness as relevant for the couple and engaging collaboratively to manage patient illness) in promoting positive behavioral and health outcomes.[55–57] In sum, our findings suggest that greater disease severity, lower physical health–related quality of life, and not having a partner may be important factors to consider when approaching the development and implementation of sedentary behavior reduction strategies for patients who recently experienced an ACS event. However, caution is warranted when interpreting these findings as causality cannot be inferred based on the cross-sectional observational nature of the current study.

Study Strengths and Limitations

A strength of our study is the objective measurement of sedentary behavior via accelerometry over 28 consecutive days immediately post-hospital discharge, which is a critical period when patients recover from their event and secondary prevention interventions ideally begin. Conventional accelerometer protocols often entail 7-day monitoring periods; thus, the present study represents one of the longest accelerometer protocols conducted in patients with ACS. These findings, however, should be interpreted in the context of several limitations. First, the Actical accelerometer cannot distinguish between different postures (eg, sitting and standing); thus, we used an intensity-only definition of sedentary.[58] Second, wrist-worn accelerometers lack validated wrist-based cut points and have been shown to be less accurate than hip/thigh accelerometers for estimating sedentary time, as they tend to underestimate daily sedentary time as a result of greater movement of the upper extremities during everyday activities.[59] Despite existing limitations, wrist-worn accelerometers have been adopted by many population-based studies to increase wear compliance by alleviating the discomfort or inconvenience of hip-worn devices.[60] Therefore, because of its tolerability, use of a wrist-worn accelerometer in the present study permitted the evaluation of sedentary behavior over a far longer period (28 days) relative to conventional hip-based accelerometer protocols (≈7 days);

thus, allowing us to explore important post-hospital trajectories. Third, information about participants' return to work after hospitalization was not collected. Return to work represents a critical indicator of recovery from illness.[61,62] Furthermore, prior studies have demonstrated that occupation can largely influence daily physical activity levels.[63] Thus, return to work (or lack thereof) could have influenced the observed findings. Last, this is a small, single-center study in an urban academic medical center, which may limit the generalizability of our findings. Most participants presented with unstable angina (≈52%), which may limit applicability of the results for patients with myocardial infarction. Further, compliance to the accelerometer protocol was relatively low (≈45%). Participants excluded from the current analyses differed in several ways from those included. For example, excluded participants were more likely to have a length of hospital stay >4 days and lower physical health–related quality of life and were less likely to receive percutaneous coronary intervention. Thus, our findings may not be generalizable to the full PULSE study cohort.

Conclusions

This study demonstrated that patients with ACS as a group engaged in high volumes of objectively measured sedentary time, with patients exhibiting different patterns over the first month postdischarge, which involved either gradual or rapid reductions in sedentary behavior. Several measures of disease severity and physical health (LVEF <40%, GRACE risk score, and physical health–related quality of life), as well as partner status, were associated with the most hazardous pattern of sedentary behavior. These findings provide a foundation for characterizing different patterns of sedentary behavior as patients assimilate back into their daily life and routine over the first month after discharge. Future research is needed to determine whether these patterns of sedentary behavior are linked to the risk of adverse events after an ACS and to inform whether, among the multitude of secondary prevention strategies recommended for survivors of ACS, sedentary behavior should also be targeted.

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Disclosures

None.

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SUPPLEMENTAL MATERIAL

Data S1.

Supplemental Methods

Socio-demographic factors (age, sex, race, ethnicity, education, partner status, Medicaid), hospitalization characteristics/procedures (ACS type, length of hospital stay, percutaneous coronary intervention [PCI]), measures of health status/disease severity (body mass index [BMI], left ventricular ejection fraction [LVEF], CVD history, Charlson Comorbidity Index, GRACE risk score, physical and mental health-related quality of life), prior exercise history, cardiac rehabilitation participation, depression, and sleep quality were examined as potential correlates of objectively-measured sedentary behavior trajectory group.

Sociodemographic factors and prior exercise participation were determined by patient interview at baseline using standard questionnaires. Medicaid is a state-administered federal assistance program designed to provide health coverage for low-income people under the age of 65 years who cannot finance their own medical expenses or have qualifying comorbid conditions[1]. As such, Medicaid is considered a proxy for low socioeconomic status.

Prior exercise participation was assessed by the single item, "In the three months prior to this hospitalization, were you exercising regularly?" with "yes" and "no" response options. Cardiac rehabilitation participation was ascertained at 1-month post-hospitalization with a one item question "Since the last study visit, have you participated in cardiac rehabilitation?" that had a "yes" or "no" response format. Cardiac rehabilitation participation was determined by patient interview at one-month post hospitalization. LVEF, prior CVD, length of hospital stay, in-hospital cardiovascular procedures (PCI), and ACS type (unstable angina, non-ST-segment elevation MI, ST-segment elevation MI) were ascertained by medical record chart review. LVEF and length of hospital stay were expressed categorically (LVEF: <40% vs. ≥40%; length

of stay: <4 days vs. ≥4 days) [2,3]. The 6-month post-ACS mortality risk was assessed using the Global Registry of Acute Coronary Events (GRACE) index. The GRACE index tabulates scores related to clinical health measures (age, heart rate, systolic blood pressure, serum creatinine, congestive heart failure Killip class, presence of cardiac arrest at admission, ST segment deviation, and elevated cardiac enzymes or biomarkers) and has a range of 1 to 263 points, with higher scores indicating greater mortality risk [4]. To assess the severity of comorbidities the Charlson comorbidity (CCI) index was used. The CCI takes into account 17 categories of comorbidity (such as diabetes, dyslipidemia and hypertension), weighting each category by its mortality risk, sums the weighted scores and subgroups these into four categories [5]. Numerous studies have supported the consistency and predictive validity of the CCI [6].

Physical and mental health-related quality of life was assessed in-hospital by the Short Form 12 Health Survey (SF-12), a 12-item multi-purpose measure of health-related quality of life, which is based on eight health-related concepts, adapted from the longer SF-36 [7]. The SF-12 subscales include physical functioning, role-physical (e.g., how physical problems affect daily life), and social functioning, mental health, role-emotional (e.g., how emotional problems affect daily life), bodily pain, vitality, and general health. Composite scores of physical and mental health-related quality of life are derived from a combination of the eight sub-scales, and these are reported in this study.

Depressive symptoms were measured in-hospital by the 21-item Beck Depression Inventory [8]. Participants rated on a 4-point scale the extent to which various depression symptoms (21-items describing cognitive, affective, and somatic symptoms) had been present or absent for the previous week. Ratings were summed, and higher levels indicated greater symptom severity. Sleep quality was measured at 1-month follow-up by the Pittsburgh Sleep

Quality Index, a 19-item self-rated questionnaire that assesses sleep quality and disturbances [9]. Because sleep disturbance has been well documented among hospitalized patients [10], we elected to assess sleep quality at 1-month follow-up instead of in-hospital.

Table S1. Characteristics of participants who consented to participate in the accelerometer sub-study by inclusion vs. exclusion from the present analyses.

Participant Characteristics	Included (n=149)	Excluded-Participated in sub-study* (n=471)	Excluded-Did not Participate in sub-study† (n=467)	*P1*‡	*P2*§
Sociodemographic					
Age (yrs)	62.8 (11.2)	63.4 (11.7)	64.7 (11.6)	0.58	0.09
Male (%)	69.8	64.5	66.0	0.24	0.39
Black Race (%)	17.5	23.7	16.8	0.11	0.85
Hispanic Ethnicity (%)	38.3	36.7	29.1	0.74	0.04
Education ≤ High School (%)	43.0	50.7	40.7	0.10	0.62
Partner/Spouse (%)	60.4	55.1	61.5	0.26	0.82
Medicaid (%)	34.0	32.0	23.8	0.65	0.02
Hospitalization					
ACS Type				0.44	0.07
Unstable Angina (%)	52.4	54.4	58.5		
NSTEMI (%)	31.5	32.1	32.1		
STEMI (%)	16.1	13.6	9.4		
Length of Hospital Stay > 4 days (%)	23.5	40.8	42.0	<0.01	<0.01
Percutaneous Coronary Intervention (%)	85.9	76.0	74.1	0.01	<0.01
Physical & Psychosocial					
Exercise Participation Pre-ACS event (%)	45.6	44.0	45.2	0.69	0.23
Cardiac Rehabilitation Post-ACS event (%)	11.4	12.5	12.6	0.72	0.69
Body Mass Index (kg/m^2)	28.6 (5.0)	29.2 (5.9)	28.9 (5.4)	0.22	0.54
Left Ventricular Ejection Fraction < 40% (%)	14.1	13.6	13.9	0.88	0.96
CVD History (%)	33.6	32.2	29.5	0.78	0.33
Charlson Comorbidity Index	1.5 (1.6)	1.7 (1.7)	1.6 (1.7)	0.29	0.43
GRACE Risk Score	87.8 (28.3)	91.7 (30.5)	95.2 (31.0)	0.16	<0.01
Depression* (%)	30.9	33.6	33.0	0.55	0.63
Physical Health Composite Score	40.0 (10.9)	37.8 (11.0)	38.5 (11.7)	0.03	0.18
Mental Health Composite Score	53.0 (10.7)	54.0 (10.7)	53.9 (11.3)	0.35	0.39
Sleep Quality	5.2 (4)	5.6 (4.2)	5.4 (4.2)	0.38	0.65

Values presented as mean (SD) or %. NSTEMI (non-ST segment elevation myocardial infarction), STEMI (ST segment elevation myocardial infarction), CVD (cardiovascular disease). Depression= Beck Depression Inventory score > 10.

[*]Includes participants who consented to participate in the accelerometer sub-study but were excluded due to lost, defective, or non-worn devices (n=189), non-compliant wear-time (n=250), received a coronary artery bypass grafting and/or were re-hospitalized (n=32).

[†]Includes participants who declined participation in the accelerometer sub-study (n=264), were unable to be scheduled (n=46) or were enrolled in the parent study prior to the accelerometer sub-study start date (n=157).

[‡]P-Value comparing Included vs. Excluded-Participated in sub-study.

[§]P-Value comparing Included vs. Excluded-Did not Particpate in sub-study.

Table S2. Characteristics of Acute Coronary Syndrome survivors stratified by total sedentary time trajectory groups.

Participant Characteristics	Total Sedentary Time Trajectory Groups Low (n=47)	 Moderate (n=72)	 High (n=30)
Sociodemographic			
Age (yrs)	58.5 (10.7)	63.7 (10.8)	67.6 (11.0)
Male (%)	70.2	68.1	73.3
Black Race (%)	21.3	15.3	16.7
Hispanic Ethnicity (%)	42.6	38.9	30.0
Education ≤ High School (%)	48.9	41.7	36.7
Partner/Spouse (%)	55.3	68.1	50.0
Medicaid (%)	29.8	32.9	43.3
Hospitalization			
ACS Type			
Unstable Angina (%)	57.4	54.2	40.0
NSTEMI (%)	36.2	26.4	36.7
STEMI (%)	6.4	19.4	23.3
Length of Hospital Stay > 4 days (%)	17.0	18.1	46.7
Percutaneous Coronary Intervention (%)	93.6	83.3	80.0
Physical & Psychosocial			
Exercise Participation Pre-ACS event (%)	48.9	44.4	43.3
Cardiac Rehabilitation Post-ACS event (%)	10.6	9.7	16.7
Body Mass Index (kg/m^2)	28.8 (5.4)	29.2 (4.9)	27 (4.5)
Left Ventricular Ejection Fraction < 40% (%)	4.3	9.7	40.0
CVD History (%)	31.9	33.3	36.7
Charlson Comorbidity Index	1.3 (1.4)	1.4 (1.7)	1.9 (1.6)
GRACE Risk Score	77.2 (23.5)	86.4 (23.9)	107.4 (35)
Depression* (%)	29.8	29.2	36.7
Physical Health Composite Score	41.3 (10.6)	40.6 (11.1)	36.6 (10.5)
Mental Health Composite Score	55.1 (8.5)	53 (11.3)	49.9 (11.7)
Sleep Quality	5.6 (4.4)	5 (3.9)	5.2 (3.5)
Accelerometer Characteristics			
Wear Time (mins/day)	1251.1 (219.8)	1173.4 (240.3)	1278.1 (166.9)
Valid Wear Days	26 (2.6)	25.1 (3.1)	26.4 (2.6)
Total Sedentary Time (mins/day)	440.3 (50.2)	601.1 (44.1)	755.4 (46.5)
MVPA Bout Minutes (mins/day)	42.3 (56.8)	16.6 (20.7)	6.6 (8.6)

Values presented as mean (SD) or %. CVD (cardiovascular disease), MVPA (moderate-to-vigorous physical activity), NSTEMI (non-ST segment elevation myocardial infarction), STEMI (ST segment elevation myocardial infarction).

*Depression= Beck Depression Inventory score > 10.

Table S3. The assignment of participants to trajectory groups when using: 1) a sedentary cut-point of 200 counts per minute (cpm; left panel); and 2) when restricting wear time from 8:00 AM to 8:00 PM (right panel) compared with that for the primary analysis.

	Using 200 cpm Threshold			Wear Time 8:00 AM to 8:00 PM		
Primary Analysis Trajectory Groups	Low (n=49)	Moderate (n=88)	High (n=12)	Low (n=41)	Moderate (n=65)	High (n=43)
Low (n=47)	43	4	0	39	8	0
Moderate (n=72)	6	66	0	2	56	14
High (n=30)	0	18	12	0	1	29
	Weighted $\kappa = 0.73$			Weighted $\kappa = 0.79$		

Figure S1. Consort of Accelerometer Device Return.

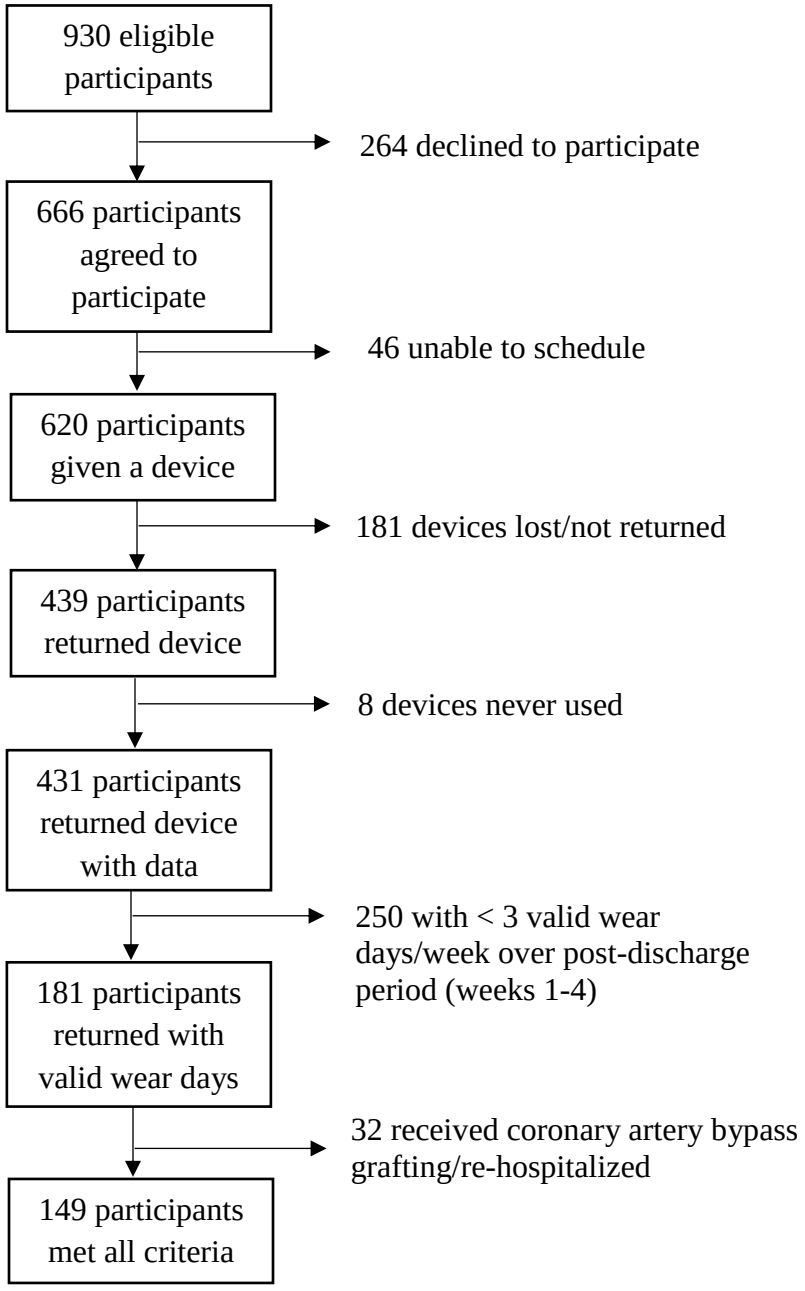
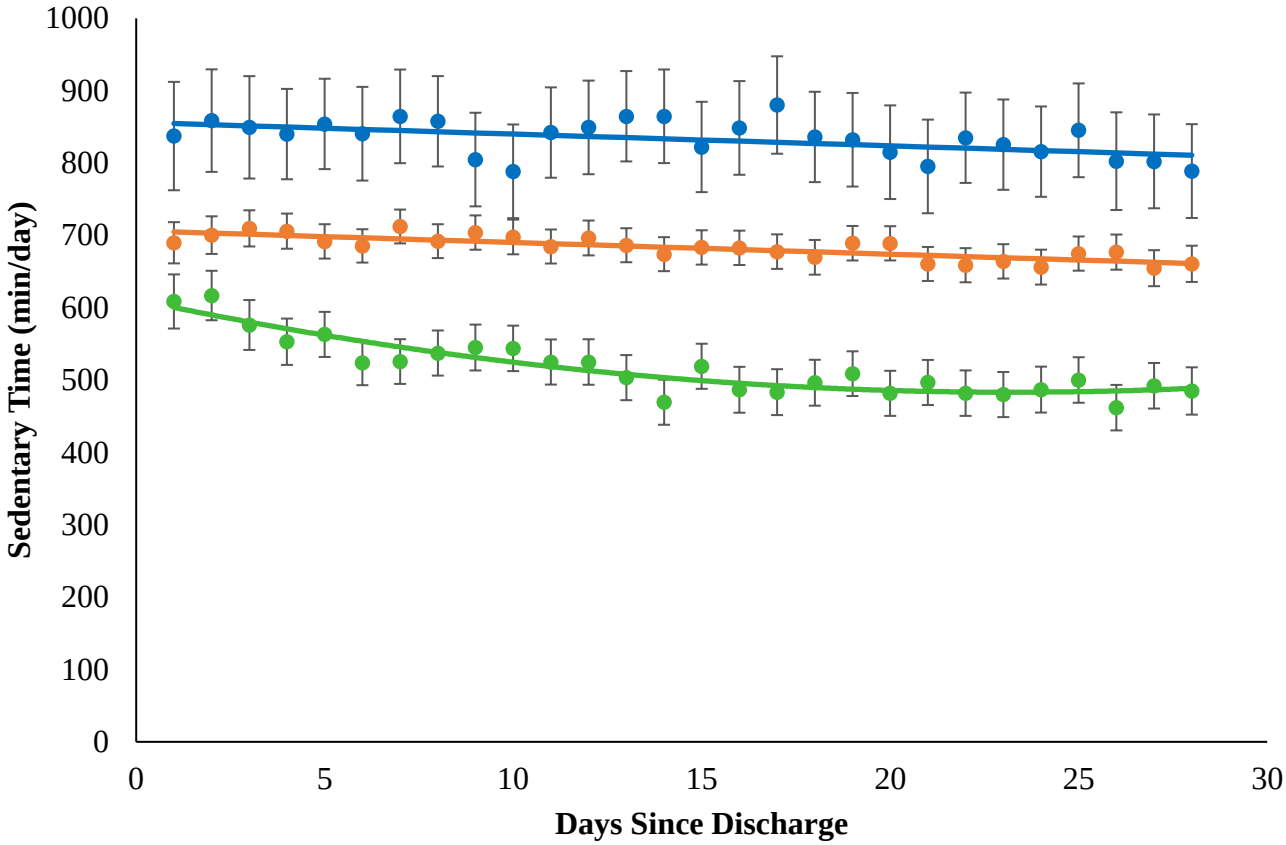
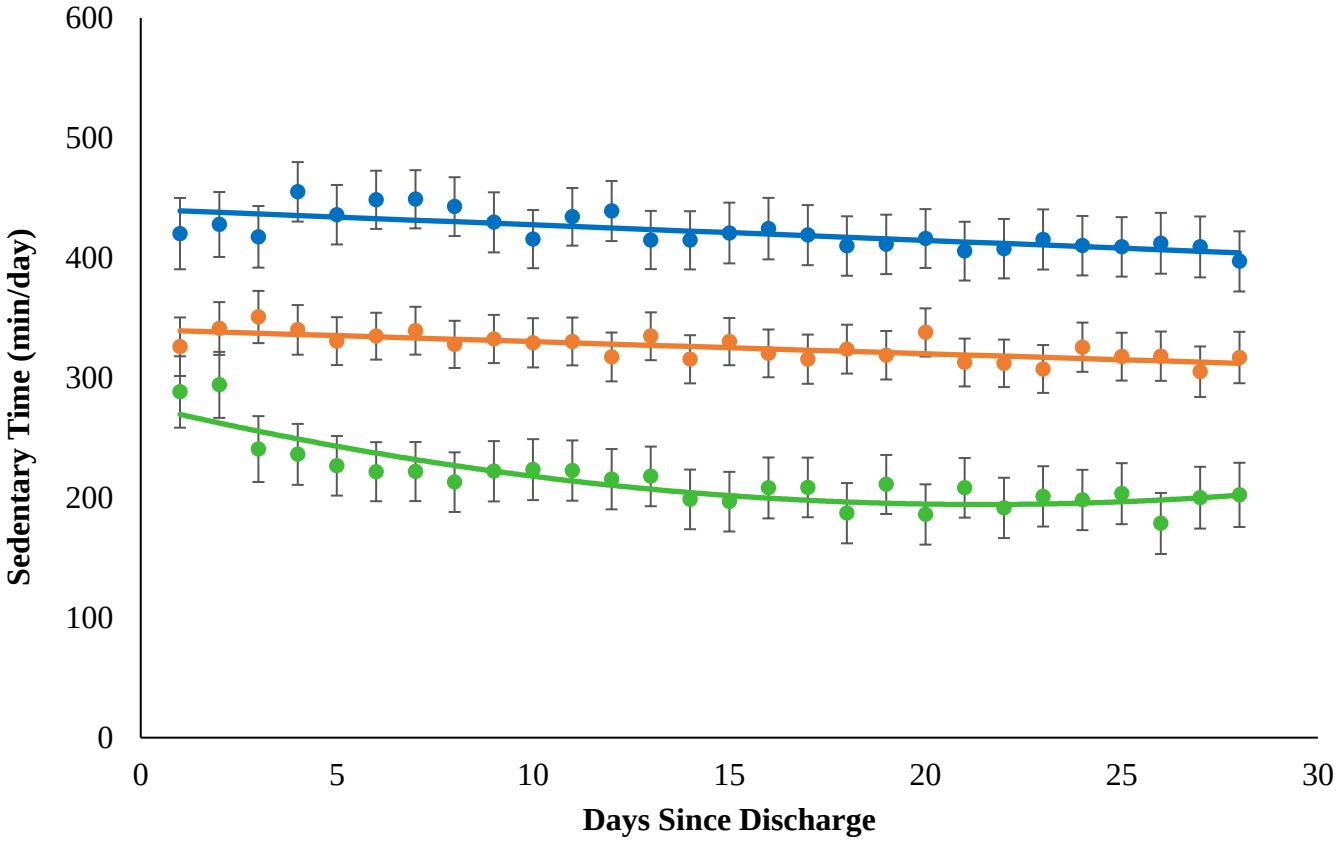


Figure S2. Sedentary time over the 28 days post-discharge period among low, moderate and high trajectory groups of Acute Coronary Syndrome survivors using a 200 counts per minute threshold.



Data are presented as mean ± 1 standard error for each day, by sedentary trajectory group.

Figure S3. Sedentary time over the 28 days post-discharge period among low, moderate and high trajectory groups of Acute Coronary Syndrome survivors when restricting wear time from 8:00 AM to 8:00 PM.



Data are presented as mean ± 1 standard error for each day, by sedentary trajectory group.

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