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Accelerometer-measured hospital physical activity and hospital-acquired disability in older adults

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Abstract

Background: Hospital-acquired disability (HAD) is common and often related to low physical activity while in the hospital.

Objective: To examine whether wearable hospital activity trackers can be used to predict HAD.

Design: A prospective observational study between January 2016- March 2017.

Setting: An academic medical center.

Participants: Community-dwelling older adults aged ≥ 60 years, enrolled within 24 hours of admission to general medicine (n=46).

Main Measures: Primary outcome was HAD, defined as having one or more new ADL deficits, decline of 4 or greater on the Late-Life Function and Disability Instrument (calculated between baseline and discharge), or discharge to skilled nursing facility (SNF). Hospital activity (mean active time; mean sedentary time; mean step counts per day) was measured using ankle-mounted accelerometers. The association of the literature-based threshold of 900 steps/day with HAD was also evaluated.

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Conflict of Interests: The authors have no conflicts.

Key Results: Mean age was 73.2 years (SD 9.5), 48% were male, 76% were Caucasian. Median length of stay was 4 days (IQR 2.0, 6.0); 61% (n=28) reported being able to walk without assistance of another person or walking aid at baseline. Median daily activity time and step counts were 1.1 hrs/day (IQR 0.7, 1.7); 1455.7 steps/day (IQR 908.5, 2643), respectively. Those with HAD (41%, n=19) had lower activity time (0.8 hrs/day vs. 1.4 hrs/day, p=0.04) and fewer step counts (1186 vs. 1808 steps/day, p=0.04), but no difference in sedentary time compared to those without HAD. The 900 steps/day threshold had poor sensitivity (40%) and high specificity (85%) for detecting HAD.

Conclusions: Low hospital physical activity, as measured by wearable accelerometers, is associated with hospital-acquired disability. Clinicians can utilize wearable technology data to refer patients to physical/occupational therapy services or other mobility interventions like walking programs.

Keywords

hospital mobility; accelerometers; hospital disability; older adults; physical activity

INTRODUCTION

Hospital acquired disability (HAD), functional loss acquired during hospitalization, is common, and a key contributor to this process is immobility.^{1,2} One barrier to improved clinical care in this area has been the lack of a reliable and clinically meaningful way to measure mobility in the inpatient setting.^{3–6} One possible solution is Mobile health (mHealth) technology, such as wearable accelerometers, to facilitate the acquisition, measurement, and reporting of walking activity during hospitalization.

Accelerometers have been shown to be a valid, precise, and reliable tool for collecting research data from older adults in the inpatient setting.^{7,8} However, it is unclear how well these data predict clinical outcomes such as HAD. Importantly, clinically meaningful thresholds of physical activity that predict serious health outcomes have not been established in the inpatient setting. Recent studies suggest that walking fewer than 900 steps per day is linked to functional decline during hospitalization.⁹ In this study, we assess whether accelerometer-measured activity (e.g. number of steps, time spent in activity) is associated with HAD, and examine the sensitivity and specificity of a previously established 900 steps per day threshold for detecting HAD.

METHODS

Subjects and Setting

This prospective observational study was conducted as a pre-planned secondary aim of a project that examined activity among hospitalized older adults and venous thromboembolism prophylaxis use, and methods are described elsewhere.¹⁰ Inclusion criteria were community-dwelling older adults aged ≥ 60 years, admitted to an academic hospital's general medicine service between January 2016 and March 2017, able to ambulate with or without assistance of another person or walking aid, cognitively able to follow instructions (defined as a score of ≥ 4 on the Six Item Screening)¹¹, and able to wear ankle-

mounted accelerometers. Exclusion criteria were patients with activity orders of “strict bed rest” and those on contact and respiratory precautions because their activity would not represent usual hospital activity. The Duke University institutional review board approved the study.

Measures

Accelerometer-measured physical activity.—We used the GT3x+ model ActiGraph (Pensacola, FL), a triaxial accelerometer. The ActiGraph has been validated in use among older adults with mobility limitations.¹² The ActiGraph was positioned on the ankle (above the lateral malleolus) for all patients in our study to avoid interference with wrist intravenous lines and blood draws and because hospital gowns preclude secure placement around the hip. A small disposable velcro strap tightly secured the monitor in place to minimize the potential movement between the monitor and skin. Accelerometers were applied within 24 hours of admission. Patients were instructed to wear the device continuously (even during sleep), removing only as needed for procedures, until the time of hospital discharge or for a maximum of seven days.

Accelerometer data were first processed for sufficient wear time using the non-wear threshold developed by Choi and colleagues, which consists of an interval of at least 90 minutes of zero activity counts that contain no more than 2-minute interval of nonzero activity counts with a 30-minute consecutive zero-count window.¹³ To maximize the sample size, patients with two or more days with ≥ 6 hours of valid wear time were included in this analysis. Actigraph acceleration data were also processed using band-pass filtering to attenuate unwanted acceleration signals outside the frequency range of normal human movements. We used the default 30-Hz sampling frequency. The epoch length for analysis was 60 seconds. Accelerometer data were scored using Sasaki and Troiano algorithms^{14,15} to calculate three daily metrics: 1) time spent in any activity using an accelerometer activity count cut-point of ≥ 100 counts/minute, 2) time spent in sedentary activity (defined as any waking behavior < 1.5 Metabolic equivalents (METs)),¹⁶ using activity counts of 0 to < 99 counts/minute, and 3) step counts. The lower frequency extension filter was applied to enable detection of lower frequency movements. Data were processed and analyzed using ActiLife v6.13.3.

Hospital-Acquired Disability (HAD).—The primary outcome was HAD, defined as having one or more of the following: 1) a new ADL deficit from the Katz Activities of Daily Living scale,¹⁷ 2) a decline of 4 or more points from baseline to discharge in the functional component of the abbreviated Late-Life Function and Disability Instrument (LL-FDI),^{18,19} or 3) discharge to a skilled nursing facility (SNF) determined by chart review or telephone follow-up. Separate measures of mobility difficulty were also collected, including self-reported difficulty in walking up the stairs, walking 1/4 mile, and walking across a small room. Participants reported on all measures at three time points: two weeks prior to admission (collected with baseline), baseline (within 24 hours of admission), and on discharge (collected via telephone 1–3 days following hospital discharge).

Analysis

Descriptive statistics were calculated for all variables at baseline, admission, and discharge. Differences in daily activity time, sedentary time, and steps according to HAD were examined using non-parametric (Wilcoxon Rank-Sum tests) analyses since distribution of some variables demonstrated skew. We also examined the relationship between a 900 steps/day threshold and HAD with bivariate analyses. To describe the accuracy of the 900 steps/day threshold, we examined the sensitivity and specificity of this threshold for detecting HAD calculated as follows: 1) the proportion of patients with HAD who were also classified as walking < 900 steps/day (sensitivity), and 2) the proportion of patients without HAD who were classified as walking ≥ 900 steps/day (specificity). All analyses were performed using SAS Version 9.4 (SAS Institute, Cary, NC). Due to low sample size and our goal of identifying a generalizable activity threshold, no covariate adjustment was used.

RESULTS

One hundred and ninety-six patients met eligibility criteria and were approached for enrollment. Of these, 65 (33%) agreed to participate. Patients were excluded from this analysis due to insufficient accelerometer wear time (n=5) and missing discharge functional data (n=14). Among 46 patients with complete data, mean age was 73.2 years (SD 9.5), 48% were male, 77% were Caucasian. Median length of stay was 4 days (IQR 2.0, 6.0); Admission diagnoses included failure to thrive 39% (n=18), gastrointestinal 22% (n=10), cardiac 11% (n=5), neurological 11% (n=5), infectious 9% (n=4), other 9% (n=4); and 62% (n=40) reported being able to walk without assistance of another person or walking aid at baseline (Supplementary Table S1). Summary of function and mobility deficits across the hospital course are shown in Figures 1 and 2.

Accelerometer-measured physical activity and HAD.

For all participants, median activity time was 1.1 hrs/day (IQR 0.7, 1.7). Median time spent in sedentary activity was 14.6 hrs/day (IQR 12.8, 17.1). Median total daily step count was 1455.7 (IQR 908.5, 2643.0); Range: 83–6134 steps/day (Table 1 and Supplementary Figure S1a–c). Accelerometers were worn for a mean of 4.1 days (SD 2.0), mean wear time was 16 hrs (SD 2.8 hrs) of the day, and wear time was concentrated during the daytime hours. Of note, the first and last day of wear time were on average 12 hour days. Including only full day of wear, the average wear time was 22 hrs/day.

HAD rate was 41% (n=19). Among patients with HAD, 26% (n=12) of patients had a self-reported decline in ADL (n=3) or LL-FDI function (n=9), and 15% (n=7) were discharged to SNF. Patients with HAD had lower activity time (0.8 hrs/day vs. 1.4 hrs/day, p=0.04) and fewer step counts (1186 steps/day vs. 1808 steps/day, p=0.04) but no difference in sedentary time compared to those without HAD (Table 1).

Among all patients in the study, 24% (n=11) walked < 900 steps/day; of these, 64% (n=7) developed HAD, Odds Ratio 3.4 (95% CI 0.82, 13.8). The sensitivity and specificity of the 900-step threshold were 0.4 (95% CI 0.2–0.6) and 0.85 (95% CI 0.66–0.96), respectively.

DISCUSSION

We found that hospitalized older adults spend on average less than 1 hour/day in activity and that decreased activity hours and step counts were significantly associated with increased risk of HAD. These results suggest that wearable technologies such as activity monitors may provide clinically meaningful information and help physicians identify patients at risk for poor hospital outcomes.

Similar to previous reports, our study found that nearly 41% of cognitively-intact, community-dwelling older adults developed HAD during hospitalization.^{9,20} We extended these findings with a more detailed functional battery to define HAD including changes in basic ADLs and more discrete LL-FDI functional tasks. Overall, 23% of patients in our sample met the LL-FDI change threshold of 4 points. We also examined additional activity parameters (e.g. time spent in activity and sedentary time) with the view that other accelerometer parameters might have stronger associations with HAD. There may be individual differences in hospital activity patterns (i.e. duration of walking bouts, or timing of those bouts over a 24 hour period) that are particularly important, and warrants future study.

Clinically meaningful thresholds are needed for application in clinical practice.²¹ Screening for patients with activity below clinical thresholds can target these individuals for mobility promotion programs or PT/OT consults. These clinical thresholds could also be used as goal-setting targets for mobility intervention programs and clinical recovery. There is preliminary evidence supporting the recommendation for 900 steps/day to prevent functional decline in the hospital;^{9,20} however, this threshold may not be suitable for all patients. Whereas a threshold of 900 steps was reliable in the Agmon study,⁹ in our study there were many false negatives; a third of patients that developed new HAD were missed (sensitivity 40%, specificity 85%). Differences in the performance of the 900 step/day threshold can be explained by variability in the study populations or in the measures used for HAD. Further studies are needed to determine if higher step count thresholds can improve the sensitivity for the identification of hospitalized populations at increased risk for functional decline during hospitalization.

Future Implications.—One important unanswered question is whether objective daily reports of accelerometer-derived activity data can help providers detect immobility early in the hospital course and take clinical action to mitigate the risk of functional decline.^{5,22–27} Whereas capacity-based measures, (i.e. Short Physical Performance Battery, Tinetti balance scores, or gait speed) can predict functional decline and hospital discharge destination,^{28,29} they are rarely incorporated into the inpatient clinical workflow. Further, functional status and walking activity are important to acknowledge but often missing from clinical documentation. Wearable-derived activity measures, such as step counts, would not replace important capacity-based measures or self-reported ADL assessments. However, having a way to measure activity with minimal time investment in the inpatient setting is very valuable. Ultimately, wearable-derived data could interface with electronic health records (EHRs) to give providers feedback about patient activity and link to algorithms that guide clinical decisions to increase the frequency and/or duration of activity. Although the current

available technology restricts the use of research-grade accelerometers in clinical practice (i.e. downloading logistics, data processing time, cost of devices and processing software), we provide evidence that accelerometer-derived data gives useful and clinically meaningful information about hospital physical activity that supports the clinical utility of wearable technology.

Limitations:

Limitations include the relatively small sample size and involvement of only general medicine patients from a single health system that requires results be replicated in larger and more heterogeneous populations. Further, although the reliability and validity of accelerometer step counts has been validated in the inpatient setting, the use of a single ankle-worn device misses some physical activity that involves upper body movement (ADLs), or may inflate active time with fidgeting of the foot/ankle. We processed the accelerometer data to attenuate unwanted spurious movements. Additionally, objective physical activity assessments are heavily dependent on patient compliance with wearing the device, and the loss of precision due to missing data and wear-time variability across participants remains a consideration.^{7,8,30} Lastly, inclusion of discharge to SNF in the definition of HAD should be viewed with caution as preadmission functional impairment and social factors can also influence SNF placement. Despite these limitations, our findings may facilitate the development of interventions to improve activity in hospitalized older adults.

Conclusions:

In conclusion, among medically-ill, hospitalized older adults, physical activity is low and incidence of hospital-acquired disability (HAD) is high. Our results demonstrate that mean daily activity time and step counts were inversely associated with developing HAD at discharge, and supports a path towards clinical utility of wearable technology.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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Figure 1. Percentage of Participants with Deficits in Activities of Daily Living Around Episode of Hospitalization (n=39)^a

^aThis figure excludes n=7 patients who went to skilled nursing facilities at discharge but did not have a discharge follow-up phone call.

Figure 2. Mean Late-Life Functional Disability Index (LLFDI) Scores Around Episode of Hospitalization (n=39)^a

^aThis figure excludes n=7 patients who went to skilled nursing facilities at discharge but did not have a discharge follow-up phone call.

Table 1.

Description of Accelerometer-based hospital physical activity and association with hospital acquired disability

	Overall Sample, N= 46 Median (IQR)	New Hospital Acquired Disability, N=19^a Median (IQR)	No Hospital Acquired Disability, N=27 Median (IQR)	Wilcoxon P-Value
Activity Variables				
Total Time In Activity (Hours/ Day)	1.1 (0.7, 1.7)	0.80 (0.5, 1.3)	1.4 (0.8, 2.8)	.04
Total Time Sedentary (Hours/ Day)	14.6 (12.8, 17.1)	14.9 (13.6, 18.7)	14.3 (12.4, 16.4)	.16
Total Steps (Steps/Day)	1455.7 (908.5, 2643.0)	1186.0 (714.3, 1692.1)	1808.8 (1002.0, 3849.5)	.04

^aThe 7 patients discharged to skilled nursing facility (SNF) had no functional impairments that met institutional requirements prior to hospitalization, none experienced loss of function in the 2 weeks prior to hospitalization, and they had no alternative needs for SNF placement, such as IV medication administration or wound care.