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Inpatient walking activity to predict readmission in older adults

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Abstract

Objective—To compare the 30-day readmission predictive power of in-hospital walking activity and in-hospital activities of daily living (ADL) in older acutely ill patients. In addition, we sought to identify preliminary walking thresholds that could support the targeting of interventions aimed at minimizing rehospitalizations.

Design—Prospective, observational clinical cohort study. Step counts during hospitalization were assessed via accelerometry. ADL function was assessed within 48 hours of admission.

Setting—Acute care hospital.

Participants—One hundred and sixty-four ambulatory persons aged 65 and older admitted to the hospital from the community with an acute medical illness.

Intervention—NA.

Main Outcome Measures—Readmission back to the index hospital (yes vs. no) within 30 days of discharge.

Results—Twenty-six patients (15.8%) were readmitted within 30 days of discharge. Walking activity during hospitalization was more strongly and significantly associated with 30-day readmission (OR: 0.90; CI: 0.82-0.98) than ADL function (OR: 0.45; CI: 0.14-1.45) after adjusting for relevant readmission risk factors. The predictive accuracy (area under the curve) was highest for models that included walking activity and changed little with the addition of ADLs. A walking threshold of 275 steps or more per day identified patients at reduced 30-day readmission risk.

Conclusion—Walking activity was a stronger predictor of readmission than ADLs. Monitoring patient activity during hospitalization may provide clinicians with valuable information on early

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readmission risk not captured by measures of ADLs. Further study is needed to replicate these findings and monitor walking activity post hospitalization to further advance our understanding of readmission risk.

Keywords

Readmission; geriatrics; mobility; activity

Almost half of hospitalized adults are 65 or older.¹ Of these, one in five is readmitted within 30 days of discharge.² Attention directed toward reducing unplanned hospital readmissions has increased substantially since the introduction of the Patient Protection and Affordable Care Act (Public Law 111-148).³ The Act created the Hospital Readmission Reduction Program (HRRP), which links hospital performance evaluations to 30-day readmission measures. Medicare payments to hospitals are reduced if their 30-day readmission rates are higher than expected for select diagnoses.^{2,4} Important to the implementation of programs designed to prevent or reduce avoidable readmissions is to accurately predict those that would benefit the most.^{5,6}

Currently available readmission prediction models have poor predictive ability at the patient level.⁷ A systematic review by Kansagara and colleagues suggested the addition of functional variables may improve a models overall performance.⁷ The scope of function related variables reported in the literature to help identify patients at higher risk for early readmission is actually quite narrow, however. "Function" in these predictive models is typically limited to multi-item Likert scales of ADL that are based on self or surrogate reported difficulty with behaviors such as grooming, bathing, eating, toileting, transferring, stooping, or walking.⁷ A changing health status over the course of hospitalization and an unfamiliar environment could influence their predictive power for some post discharge events.

Recent research suggests that more objective assessments of physical functioning during acute hospitalization may better integrate the effects of disparate factors and provide insight into the older patient's vulnerability and response to treatment.^{8,9,10} In this context, accelerometry derived measures of physical activity are unique in their ability to continuously monitor the cumulative effects of complex patient, clinical, and psychosocial factors. Walking during acute illness requires the coordinated effort of multiple biologic systems already under stress.¹¹⁻¹³

Metrics such as amount of walking may reflect the illness severity as well as the influence of factors that are inherently difficult to measure but may still impact recovery, such as pre-clinical depression and/or motivation. For example, quantitative gait dysfunction has been linked with depressive symptoms in the *absence* of major depression or dementia;¹⁴ conversely, highly motivated older persons demonstrate faster walking times and better recovery after hospitalization.¹⁵

For this research, we studied older adults during an acute hospitalization for a medical related illness. Our objectives were two-fold. We first compared the predictive power of accelerometry-derived walking activity and a measure of ADL function on risk of 30-day

readmission. Second, we examined potential walking activity thresholds that could be used to support clinical decision making and the delivery of resource-intensive interventions to reduce unplanned rehospitalizations.

Methods

Study population

We studied patients admitted to a university teaching hospital. Eligible subjects were at least 65 years old, reported they were able to walk across a small room with or without an assistive device 2 weeks prior to hospitalization, were admitted from the community, resided in the county of the index hospital, were cognitively able to provide their own informed consent, had no medical contraindication to wearing a loose fitting Velcro strap on one ankle (for the accelerometer – see below), and were admitted for the following medical diagnoses: cardiovascular, pulmonary, infection, gastrointestinal, or endocrine. Patients with musculoskeletal or neurologic related conditions were excluded. Patients also had to have an anticipated length of stay of at least 48 hours and be able to enroll in the study on the day of admission. One-hundred ninety-nine patients met these inclusion criteria during active study months from 2010 and 2011 and agreed to participate. Of these, 35 either discharged within 48 hours of admission, withdrew, or the accelerometer was removed and not put back on. The final cohort included 164 patients with complete admission to discharge and 30-day follow-up data. The study was approved by the University's Institutional Review Board.

Independent measures

Walking activity was defined as number of steps taken during consecutive, complete 24-hour hospital days (i.e. midnight to midnight). To capture average daily activity over the hospital course, a mean daily steps variable was calculated for each patient. Total steps for each 24-hour day were summed and divided by the number of days. The half days representing the hours between placement of the monitor on the day of admission and midnight of that same day, and for the hours between midnight of the day preceding the day of discharge and the time of discharge were not included in the calculations.

A dual-axis ankle-worn accelerometer (Orthocare Innovations StepWatch Activity Monitor) was used for the study. This accelerometer has been validated for use in clinical populations.^{16,17} Number of steps are recorded in 1-minute intervals per 24-hour day; it does not record leg movements when the patient is lying down (i.e. off-axis accelerations are not registered)¹⁸ and provides no feedback to the wearer. We have previously quantified common hospital walking activities using the device.¹⁸

The monitor was put on the day of admission after informed consent and only removed during bathing or medical tests / procedures in which it may have interfered. Research staff rounded on all study patients during the day and evening hours to ensure the accelerometer was being worn, worn correctly, and to answer any questions the patient or family may have had. Discharge status was monitored continually via EHR and brief daily contact with the patient and nursing. Multiple levels of communication with hospital staff (e.g., chart

notifications, in-room flyers, and attendance at day and night shift nursing department meetings) were also part of the compliance protocol.

We used Katz ADL scale as the measure of ADL function.¹⁹ Level of difficulty or dependency with bathing, toileting, transferring from bed to chair, walking across a small room, personal grooming, dressing, and eating was assessed within 48 hours of admission. Patients were also asked to report on their status across these same items 2 weeks prior to hospitalization. For analytic purposes the scale was dichotomized 0 = no reported difficulty; and 1 = any reported difficulty or dependency.

Demographic and clinical variables with known associations with early readmission were extracted from the electronic health record (EHR). These included age, gender, race / ethnicity, body mass index (weight in kilograms/height in meters squared), marital status (yes vs. no), and the Charlson Comorbidity Index.^{20,21} The Charlson is a measure of the burden of chronic illness and encompasses 19 medical conditions weighted 1–6 with total scores ranging from 0–37. Reason for admission was determined at admission via the EHR. Length of hospital stay (in days), discharge destination (home, skilled nursing facility, rehab center, or other), and the number of prescribed medications were obtained at discharge. Number of medications was dichotomized according to the following criteria for polypharmacy: 4 medications and 5 medications.²²

Outcome measure

Our outcome was readmission back to the index hospital within 30 days of discharge. Hospital records where the study was conducted were reviewed at >30 days after discharge. A hospitalization that occurred within that time window was recorded. Elective admissions such as scheduled procedures were excluded.

Statistical Analysis

Means (with standard deviations) and percentages were calculated for subject demographic and clinical variables. Median (with interquartile range) was used as the measure of central tendency for the step data. We stratified subjects by readmission status: yes vs. no. Chi-square and Fisher's exact tests were used to determine if distributions of categorical variables differed significantly between those who were and were not readmitted. T-tests and the Man-Whitney U test were used to test for group differences on continuous variables.

We computed three multivariable logistic regression models to compare the relative effects of ambulatory activity (steps) and ADL disability on 30-day readmission while controlling for basic demographic (age and gender) characteristics. Steps and ADL disability were included in separate models and then together in the third model. Because the step data was continuous individual step counts, odds ratios (OR) and 95% confidence intervals were calculated on 100 step intervals. Next we repeated the process while controlling for additional demographic and clinical characteristics previously reported to be associated with 30-day readmission. The area under the curve (AUC or *C-statistic*) from each logistic regression model was used as a measure of predictive accuracy for 30-day readmission. The AUC can range from 0.5 (no discrimination) to 1.0 (perfect discrimination).²³

A receiver operating characteristic (ROC) curve was produced for mean daily steps. Two different approaches were used to identify initial cut-points that could be considered for mobility based interventions to increase the amount of walking in-hospital: the “Closest-to-0, 1” approach and the “Youden Index”. The “Closest-to-0, 1” approach identifies the point on the ROC curve that is closest to perfect discrimination (i.e., 0 or 1 on the figure axes). The “Youden Index” approach identifies the point on the ROC curve that is furthest from chance discrimination (i.e., largest vertical distance from the diagonal line).^{23,24} The Youden approach is particularly useful when sensitivity and specificity are equally important, such as in the case in interventions. Because we were also interested in step activity as a screening tool for readmission risk, test diagnostics (sensitivity, specificity, positive predictive value, and negative predictive value) were also calculated at 100 step intervals, two above the identified threshold and two below. Higher specificity was of interest to us to help rule out those patients likely not at risk for readmission. For this study, sensitivity was defined as the percentage of patients who were readmitted with mean daily steps at or below the threshold (*a positive test result*); specificity was defined as the percentage of patients who were not readmitted with mean daily steps above the threshold (*a negative test result*). Testing was 2-sided for all models using $p < 0.05$. All analyses were performed using SAS version 9.2 (SAS Institute, Inc., Cary, NC) and SPSS version 22 statistical software.

Results

Table 1 shows demographic and clinical characteristics for the entire sample and stratified by 30-day readmission status. The overall mean age was 76.2 ± 7.0 years. The majority (70.7%) were women. Most were white (69.5%), non-married (58.5%), and most reported no limitations in ADLs two weeks prior to admission (80.4%). Cardiovascular conditions were the most frequent (37.2%) reason for admission; infection was the least frequent (11.5%). Approximately 20% of patients were discharge with at least 5 medications. The mean length of stay was 5.2 ± 4.2 days. A large majority (87.7%) were discharged home.

Twenty-six patients (15.8%) had an unscheduled readmission back to the index hospital within 30 days of discharge. Readmitted patients were significantly older on average than patients who were not readmitted (79.2 ± 7.9 vs. 75.6 ± 6.6 ; $p = 0.01$). Patients who were readmitted also reported significantly more difficulty with ADLs both prior to hospitalization and early during their hospital stay. Readmitted patients walked significantly less in hospital than patients who were not readmitted: 323 steps (IQR: 71-652) vs. 674 steps (IQR: 324-1604); $p < 0.01$. Comparatively fewer readmitted patients were discharged directly to home (73 % vs. 90 %; $p = 0.02$). Patients who were not readmitted did not significantly differ from readmitted patients by gender, race, marital status, BMI, comorbid burden, reason for admission, presence of poly pharmacy, or length of stay.

Table 2 shows the results of the logistic regression models. The first series of models shows steps, in-hospital ADL, and the relative effects of the combination of in-hospital walking and ADL on readmission status, while adjusting for age and gender. There was a significant association between mean daily steps and readmission (0.89; CI: 0.82 – 0.98); the odds of readmission decreased by approximately 10% with each 100 step increase in mean daily

steps. The ORs for age and gender were: 1.06; CI: 0.99 - 1.12 and 0.47; CI: 0.15 - 1.40, respectively. The association between ADL and readmission was also significant (0.37; CI: 0.15 - 0.90). The ORs for age and gender in the ADL model were: 1.06; CI: 1.00 - 1.13 and 0.54; CI: 0.17 - 1.47, respectively. In the combined steps and ADL model, only mean daily steps was significantly associated with 30-day readmission. The second series of models show the results for steps and ADL after adjustment for known readmission risk factors. Walking was the only variable significantly associated with 30-day readmission in the fully adjusted models. In both series, the AUC was highest for models that included the steps variable and changed little with the addition of ADL.

The ROC curve assessing daily steps to 30-day readmission is shown in Figure 1. The AUC was 0.71, which suggests mean daily steps is a moderate to good predictor for classifying patients by readmission status.²⁴ The “Closest-to-0, 1” approach and the Youden Index method both produced a cut-point of 475 mean daily steps. This value yielded a roughly equal balance between sensitivity and specificity. Test diagnostics for the two 100 step intervals above and below that threshold are shown in Table 3. Specificity ranged from 78% to 49%, with lower step activity yielding higher specificity. At 275 mean daily steps, a positive test (i.e., averaging less than 275 steps) indicates that 16% of cases who were readmitted walked more than this value (i.e., false positives); the high negative predictive value indicates that 88% of patients who had a negative test (averaged more than 275 steps) were not readmitted.

Discussion

This study compared the readmission predictive power of accelerometry-derived walking activity and a commonly used measure of ADL function. For this sample, how much patients got up and moved around during their hospital stay was more strongly associated with 30-day readmission than a measure of ADL function. Findings also show potential for the use of walking thresholds to support clinical decision making for targeting the delivery of interventions designed to prevent rehospitalizations.

ADL deficits are associated with a number of negative outcomes in older adults.^{25,26} It is a well understood construct, and the items are relatively easy to administer. Time constraints dictate that hospital based assessments of ADL function usually rely on self-report or staff estimates of performance, however. In sub analyses we found that patients identified with mobility related ADL disability walked less than patients without mobility disability. It could be that accelerometry derived walking measures simply provide a higher resolution for discriminating among patients known to be more vulnerable to effects of acute illness and hospitalization. There is also some evidence that objective measures of physical performance may provide more meaningful information than self-report.^{8,9}

Identifying clinically useful measures to help predict hospital readmission has proven to be a difficult task. Previous research established several risk factors associated with readmission. These include type and severity of illness, age, comorbidities, social support, discharge location, adverse events related to specific drugs and polypharmacy, among others.⁷ There are also unknown risk factors, or risk factors that are suspected, but difficult to measure. One

example might be motivation of the patient to recover. Another might be individual tolerance for discomfort in the recovery process. A walking activity measure may mediate the relationship of some currently known risk factors and also some unknown or difficult to measure risk factors. This could improve the power of predictive readmission models. The final product would be a model with greater discrimination and perhaps fewer data elements.

In addition to step activity as a global marker of health status, this research suggests there are therapeutic levels of mobility in hospital that appear to be correlated with readmission risk. The 475 steps value identified via the Closest-to-0, 1 and Youden Index methods (balanced sensitivity and specificity) could be considered a preliminary clinical threshold of minimal walking activity in hospital for this outcome. Early mobilization, physical therapy, walking programs, and other approaches may improve mobility in older patients and potentially reduce rehospitalizations. Previously it has been shown that older ambulatory patients who have the capacity to walk do not necessarily do so when hospitalized.²⁷

As a screening tool, the lower threshold higher specificity value holds promise to rule out patients at decreased risk for readmission. An even lower threshold value would result in higher specificity but at the expense of increasing the proportion of false negative classifications (i.e., those patients who walked more than the threshold but were readmitted). In hospital, 275 steps is equivalent to just a few trips to and from the bathroom¹⁰ or approximately 5 minutes of slow walking - an amount that could potentially be estimated in the absence of accelerometry derived step counts. Healthy older adults in the community average between 4000 and 8000 steps per day.²⁸ While the development of actionable thresholds for measures such as walking activity are important for their use in clinical decision making, further study with larger samples is needed to validate and refine walking thresholds for this outcome.

Study Limitations

The primary limitations to the study were the relatively small sample size for this outcome, subject selection procedures, and the methods for identifying readmissions. To account for the relatively low number of responses (i.e., readmissions) and potential for over parameterization in multivariate logistic regression models, we first took a parsimonious approach with the primary independent variables adjusting only for age and gender. The predictive accuracy of the fully adjusted models followed the same pattern for steps and ADL as the parsimonious models. Our selection procedures for this sample were also potentially biased toward higher functioning patients. Patients who were too ill to be approached on the day of admission would not have been enrolled. Cognitively impaired patients were also excluded from the study. As sensor technology expands into the clinical environment, their incorporation into the hospital admission process will be able to capture this kind of information for all patients. Obtaining accelerometry derived activity information immediately preceding the admission would of course aid in determining the independent effect of hospitalization on activity level, but the nature of acute care admissions makes that impractical. The pathophysiologic effects of low mobility during acute illness occur regardless of the reason for not ambulating, however. Lastly, we only registered admissions back to the index hospital. Readmission to a different hospital was not

counted. It is possible our study underestimated the number of readmissions associated with the total sample. The association of step versus ADL function to readmission, however, should not have been affected by the potential under estimation.

Conclusions

Advances in the field of body worn motion sensors represent a new frontier for patient assessment and prospective interventions in the acute setting. The application of continuous activity monitoring also represents a movement away from the reliance on discrete clinical measures to inform clinical decision making and toward the use of integrated technologies that better reflect the functioning of the whole person. The potential to extend patient monitoring into the post-discharge environment²⁹ has implications for new models of hospital reimbursement based on expected costs for entire clinically-defined episodes of care.³⁰ These technologies would likely be used in combination with self-reported or observation based measures of physical functioning. Further study is needed to replicate these findings and to explore ways to effectively integrate the use of activity monitoring devices into 21st century patient care.

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Figure 1.

Receiver operating characteristic (ROC) curve of mean daily steps on readmission status. AUC = area under the curve. The value of 475 mean daily steps represent the walking threshold identified via the Youden Index criteria.

Table 1

Characteristics of patients who were and were not rehospitalized within 30 days of discharge.

Characteristic	All N=164	Not Rehospitalized N=138	Rehospitalized N=26	<i>p</i>
Age, mean $\pm$ SD	76.25 $\pm$ 7.02	75.67 $\pm$ 6.67	79.2 $\pm$ 7.99	0.01
Women, %	70.73	68.84	80.77	0.22
Non-white, %	30.49	31.61	26.92	0.83
Married, %	41.46	40.48	46.15	0.59
BMI, mean $\pm$ SD	27.84 $\pm$ 7.25	27.67 $\pm$ 7.37	28.70 $\pm$ 6.63	0.50
Any ADL limitations prior to hospital, %	19.51	16.67	34.62	0.03
Any ADL limitations in hospital, %	39.02	34.78	61.54	0.01
Charlson Comorbidity Index, mean $\pm$ SD	3.16 $\pm$ 2.14	3.10 $\pm$ 2.17	3.5 $\pm$ 1.98	0.38
Reason for Admission, %				0.19
Cardiovascular	37.20	34.78	50.00	
Pulmonary	18.90	17.39	26.92	
Gastrointestinal	13.41	15.22	3.85	
Infection	11.59	13.04	3.85	
Endocrine	18.90	19.57	15.38	
Poly pharmacy, %	21.34	19.57	30.77	0.20
Length of Stay (days), mean $\pm$ SD	5.22 $\pm$ 4.29	4.99 $\pm$ 4.13	6.46 $\pm$ 4.96	0.10
Average steps, median (interquartile range)	626 (266-1403)	674 (324-1604)	323 (71-652)	<0.01
Discharge home, %	87.70	90.58	73.08	0.02

Table 2

Multivariable linear regression models predicting 30-day readmission by mean daily steps and ADL disability.

Adjustment for age and gender					
Steps Model			ADL Disability Model		
OR	95% CI		OR	95% CI	
Steps ^a	0.90	0.82-0.98			
Any difficulty with ADL ^b			0.37	0.15-0.90	0.19-1.24
AUC ^c	0.74		0.70		0.75
Adjustment for age, gender, and pre-hospital function, Charlson, length of stay, diagnosis, discharge destination					
Steps Model			ADL Disability Model		
OR	95% CI		OR	95% CI	
Steps ^a	0.89	0.82-0.98			
Any difficulty with ADL ^b			0.38	0.13-1.16	0.14-1.45
AUC ^c	0.79		0.76		0.79

^a Confidence intervals are for 100 step intervals

^b Compared to no ADL difficulty. Collected during hospitalization within 48 hours of admission.

^c AUC = Area under the curve

Table 3

Classification results for mean daily steps thresholds to identify readmission risk.

Mean Daily Steps	Sensitivity	Specificity	PPV ^a	NPV ^b
275	0.42	0.78	0.26	0.88
375	0.62	0.72	0.30	0.91
475	0.73	0.67	0.29	0.93
575	0.73	0.59	0.25	0.92
675	0.77	0.49	0.22	0.92

^aPPV positive predictive value;

^bNPV negative predictive value.