Walking in hospital is associated with a shorter length of stay in older medical inpatients

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Abstract

Introduction: Evidence suggests that inactivity during a hospital stay is associated with poor health outcomes in older medical inpatients. We aimed to estimate the associations of average daily step-count (walking) in hospital with physical performance and length of stay in this population.

Methods: Medical in-patients aged ≥65 years, premorbidly mobile, with an anticipated length of stay ≥3 days, were recruited. Measurements included average daily step-count, continuously recorded until discharge, or for a maximum of seven days (Stepwatch Activity Monitor); co-morbidity (CIRS-G); frailty (SHARE F-I); and baseline and end-of-study physical performance (Short Physical Performance Battery). Linear regression models were used to estimate associations between step-count and end-of-study physical performance or length of stay. Length of stay was log transformed in the first model, and step-count was log transformed in both models. Similar models were used to adjust for potential confounders.

Results: Data from 154 patients (mean 77 years, SD 7.4) were analysed. The unadjusted models estimated for each unit increase in the natural log of step-count, the natural log of length of stay decreased by 0.18 (95% CI -0.27 to -0.09). After adjustment of potential confounders, while the strength of the inverse association was attenuated, it remained significant ($\beta_{log(steps)}$ = -0.15, 95%CI -0.26 to -0.03). The back-transformed result suggested that a 50% increase in step-count was associated with a 6% shorter length of stay. There was no apparent association between step-count and end-of-study physical performance once baseline physical performance was adjusted for.

Conclusions: The results indicate that step-count is independently associated with hospital length of stay, and merits further investigation.

Introduction

Older medical patients occupy most hospital beds, and are most likely to experience prolonged hospital stays (ESRI, 2012) and functional decline (Covinsky et al., 2003, Brown et al., 2004). While non-modifiable factors, such as age or illness severity, contribute to these outcomes, other modifiable factors may also be involved, such as physical activity (PA), which is known to be low in hospitalised patients (Brown et al., 2009).

The reliable, valid measurement of PA in hospital is challenging. The most accessible form of PA for patients in the acute setting is walking, and for this reason, step-count or time spent upright are commonly used measurements of PA (Shadmi and Zisberg, 2011, Zisberg et al., 2011, Brown et al., 2009, Smith et al., 2008). Researchers have used direct observation (Brown et al., 2009), nurse or self-reports (Zisberg et al., 2011), and accelerometers (Smith et al., 2008) to capture PA. However, many issues exist with direct observation and self-reported questionnaires. Direct observation can be invasive, time consuming and laborious; and self-reported questionnaires, while easier to administer, have been found to both under and overestimate PA (Prince et al., 2008), be reliant on good cognition (Pitta et al., 2006), and have poor validity for proxy reports (Jorstad-Stein et al., 2005). Most importantly, they are not designed to detect light PA, which is most prevalent in older adults (Jorstad-Stein et al., 2005). Therefore, busy wards and high delirium levels in older inpatients may render these measurements invalid (Ryan et al., 2013, Timmons et al., 2015). An alternative option is accelerometry. Accelerometers have been used clinically to measure patients' recovery after a hip fracture (Benzinger et al., 2014), to measure PA in the rehabilitation setting (Smith et al., 2008) and to predict upper limb recovery after stroke (Gebruers et al., 2014). If accurate, wearable step-counters may provide an objective measurement of PA with minimal burden on staff or patients.

Bauman et al. (2016) recently reviewed the evidence suggesting that improved physical performance is associated with increased levels of PA in older community-dwellers. Interventional studies have also improved physical performance in this population (Pahor et al., 2014). Similar results have been found in hospital-based studies. Two large studies, using nursing-staff reports (Brown et al., 2004), and patients' self-reports (Zisberg et al., 2011), found that low PA was associated with poorer functional performance at discharge i.e., a poorer ability to perform activities of daily living such as washing, dressing and toileting. Many factors can contribute to functional performance, such as sequencing ability, problem solving and spatial awareness. Alternatively, walking activity in hospital may be more directly linked to patients' physical performance; balance, transfer and walking ability. Many studies have shown that additional exercise sessions (either independently or as part of a multifactorial programme), can improve older patients' physical performance and balance (de Morton et al., 2007, Jones et al., 2006, Trombetti et al., 2013) However, to date, the association between walking activity and physical performance has yet to be measured.

To date, only one study estimated the association between walking activity and length of stay using step-counters (Fisher et al. 2010). Focusing on the first two days of their hospital stay, they found that older medical patients (n=198) who increased their walking activity by 600 steps from the first to second day, tended to stay in hospital two days less. Of note, this study took place on a dedicated "Acute Care for Elders" unit, meaning the results may not be generalizable to older adults admitted to general hospital wards, and the study didn't include a measure of the person's functional ability or physical performance, which would be a possible confounding factor on the association between physical activity and length of stay.

Our aims were firstly, to identify which older medical patients are most at risk of deterioration in their mobility (physical performance) or prolonged length of stay and secondly, to determine if an association between the average daily walking activity (throughout the hospital stay) and length of stay exists and whether the patients' clinical presentation and physical performance on admission confounds this association.

Therefore, the aim of this study was to measure the association between average daily step-count in hospital and (1) length of stay and (2) end of study physical performance. We hypothesized that low levels of walking in hospital would be associated with poor physical performance and a longer length of stay.

Methods

This cross-sectional, observational study took place in a 350-bedded general teaching hospital. The study was conducted from July 2014 to January 2015. Ethical approval was granted by the Clinical Research Ethics Committee of the Cork Teaching Hospitals [ECM 3 (ss) 07/05/13].

Patient Selection

The inclusion criteria were: medical patients aged 65 and over; who have been admitted from home and initially planned for discharge home (rather than for institutional care); whose anticipated length of stay was ≥ 3 days; and who were mobile premorbidly. The exclusion criteria were: inpatient stay > 48 hours prior to screening; patients admitted for surgery;

inability to follow simple commands in the English language; bed or chair-bound premorbidly; admissions with an acute psychiatric condition; requirement of active end-of-life or critical care; presence of contraindications to walking (eg. hip fracture or fast atrial fibrillation); or poor ankle skin condition (precluding attachment of the accelerometer). Patients were recruited on weekdays only, and approached in chronological order of admission.

Outcome Measurements

Main Outcome Measurements

The main outcome measurements were length of stay (bed nights), walking activity (step-count) and physical performance (Short Physical Performance Battery).

Length of stay was available electronically through the hospital information system. Walking activity was measured in step-count with the Stepwatch Activity Monitor (SAM), a wearable tri-axial accelerometer with a frequency of 128 Hz. The SAM unit does not appear lose accuracy at slower walking speeds (Mudge et al., 2007, Cindy Ng et al., 2011), and has recently been found accurate in older and frail medical inpatients (McCullagh et al., 2014). The unit can be worn continuously, even while asleep and is fully waterproof, allowing the patients to shower. Using the software provided, the SAM's sensitivity was programmed specifically for each patient before it was attached. The level of sensitivity was based on the answers given to four questions relating to the patients' height, gait pattern and gait cycle, as follows: (Question 1) "Does the client regularly participate in activities that involve short quick steps?" (Question 2) "Is their walking speed fast or slow?" (…relative to people of similar height.)". (Question 3) "What is the client's range of walking speeds?" (Question 4) "Describe the appearance of the client's leg motion". These were answered specifically to the patients' presentation, e.g., if the patient walked with a walking frame, they were deemed to be "slow" walkers, who "rarely changed" their walking speed. The number of steps was saved in periods of 15 seconds (time interval/epoch), as it has demonstrated good accuracy at this setting (McCullagh et al., 2014).

Objective measurement of physical performance was conducted on the ward using the Short Physical Performance Battery (SPPB) (Guralnik et al., 1994). The SPPB is a validated and widely used tool to measure physical performance and is a composite tool including balance, walking speed and chair-stand tests. Each section is scored between 0-4. Balance is measured by the patient's ability to maintain independent balance for ten seconds with their feet together, in semi-tandem and in tandem stance. Walking speed is measured over four metres, and patients are instructed to walk at usual pace, and use their regular walking aid. And finally, the chair-stand test (time taken to stand up five times as fast as possible, with their arms folded), is measured. The total lowest possible score is 0 (unable to stand up, balance independently with feet together, or walk) and the total highest score is 12 (able to stand up five times in less than 11.1 seconds, independent tandem balance and walk four metres in less than 4.82 seconds).

Descriptive Variables

The descriptive variables included co-morbidities, frailty, quality of life, cognitive ability and fear of falling.

Co-morbidities were measured using the Cumulative Illness Rating Scale-Geriatrics, (CIRS-G) (Salvi et al., 2008). This validated tool for geriatric patients, measures the severity of impairment over 14 organ systems, and produces a possible score ranging from 0 to 56; a higher score reflecting a greater impairment in several systems.

Cognitive status was tested using the Six Item Cognitive Impairment Test (6CIT) (Katzman et al., 1983), which is quick to administer has similar diagnostic accuracy to the Mini-Mental State Examination (Tuijl et al., 2012). For the purpose of this study, a highly sensitive cut-off of 6 out of a possible 28 points was used to determine whether a patient was confused.

Frailty was measured using the SHARE FI, a validated and simple frailty instrument based on the Survey of Health, Ageing and Retirement Survey in Europe (Romero-Ortuno et al., 2010). Five SHARE variables approximating Fried's frailty definition (Fried et al., 2001) are used: fatigue, loss of appetite, grip strength, functional difficulties and physical activity. Four of the five domains are self-reported and grip strength is objectively measured. Possible scores range between -2.515 to 6.505, and SHARE-FI gender-specific calculators are freely available on the web to determine the patient's frailty category (frail, pre-frail or not frail). (Romero-Ortuno et al., 2010).

Number of falls that occurred over the previous six months was recorded and fear of falling was measured using the Falls Efficacy Scale-International (Yardley et al., 2005). Its internal validity and test-retest reliability have been found high. This self-reported tool consists of 16 activity-related questions; typical community-dwelling tasks or activities, rather than activities in hospital. The questions aim to determine how concerned older adults are about falling while performing these activities on a scale of 1 (not concerned at all) to 4 (very concerned). The patients were asked to report how concerned they were when they felt well at home; in other words, before the onset of their current illness. A cut-off of above 19 points (out of a possible 64 points) indicates a moderate to high concern about falling (Delbaere et al., 2010). If the patient was unable to complete the report, their next-of-kin was interviewed. Validation studies have shown that while next-of-kin have been found to overestimate patients' fear of falling, the information that they provide is consistent and valuable (Higashi et al., 2005).

Quality of Life was measured using the EuroQol 5 Domain 5 Level Scale (van Hout et al., 2012). This is a commonly used and easy to administer scale. It covers the domains of mobility, self-care, activity, pain/discomfort and anxiety/depression, and a visual analogue scale, ranging from 0 to 100, to measure their self-reported health status. Once again, the next-of-kin was requested to complete this questionnaire on the patients' behalf if they were unable. To date, the next-of-kin's report has not been validated, but we felt that their input would be valuable.

Procedure

Following informed and written consent, the baseline data was collected. Demographics, home set-up (house structure and living arrangements) and social support, smoking and alcohol consumption history, comorbidities and number of medications on admission were extracted from the medical and nursing records.

The patients were then interviewed at the bedside. The grip strength (as part of the SHARE FI) was measured using the hydraulic Jamar® hand dynamometer (Sammons Preston, Roylan, Bolingbrook, IL, USA) and the SPPB was completed. The SAM was then attached to the patient using a disposable wide elastic strap, above the dominant malleolus if possible, as per the manufacturer's instructions. The main reasons for attachment to the non-dominant leg were skin fragility or patients' request. Walking activity was measured, and presented as step-count averaged for each day the SAM was worn (average daily step-count). Patients were visited every weekday until discharge or for the first seven days of their hospital stay when the condition of the patients' skin, where the SAM unit was attached, was checked. Patients were not visited on the weekends, but continued to wear the accelerometer.

On the day of discharge or after the first seven days, physical performance and Quality of Life were re-measured. The SAM unit was removed and the data was downloaded using the software provided. Length of stay was recorded from the electronic hospital information system.

Statistical Methods

Categorical variables were described by the count and proportion in each category. Continuous variables were described by their mean and standard deviation; their 25th, 50th, and 75th quartiles; and their observed range.

The relationship between average daily step-count and length of stay was estimated with linear regression. Due to the apparent non-linear relationship between these two variables, they were both transformed by taking their natural logarithms. We estimated both a crude linear regression model using

$$\log(y_i) = \alpha + \beta_1 \log(x_i) + \varepsilon_i,$$

and a multiple linear regression model adjusted for the potential confounders described above using

$$\log(y_i) = \alpha + \beta_1 \log(x_{1i}) + (\sum_{2}^{k} \beta_k x_{ki}) + \varepsilon_i$$

The relationship between average daily step-count and end of study physical performance score was similarly estimated with linear regression, though for these models only average daily step-count was log transformed. We estimated a crude linear regression model using

$$y_i = \alpha + \beta_1 \log(x_i) + \varepsilon_i$$

and a second model adjusted for baseline SBBP using

$$y_i = \alpha + \beta_1 \log(x_{1i}) + \beta_2 x_{2i} + \varepsilon_i$$

All linear regression models used a complete case sample, and model assumptions were explored using standard methods. We report estimated regression coefficients and 95% CIs, and respective p-values are for two sided tests of the null hypothesis of no association ($\beta = 0$). All analyses were conducted using the R Project for Statistical Computing (version 3.1.2).

Results

Over the course of the recruitment period, approximately 2,154 medical patients aged 65 and over, were admitted to the hospital. Within the resource restraints of the study, we were able to screen 227 of these for recruitment to this study; an average of two patients daily. Of these, 69 did not meet study criteria. Of the remaining 158 eligible patients, four refused to participate in the study, leaving 154 patients who consented and enrolled (95% response rate, 7% of all medical patients admitted during the study, 70% of all patients screened for recruitment). Patient ages ranged from 65 to 102 years of age (mean 77.5 ± 7.4 SD), and the sample was evenly split between males and females. Co-morbidity in this sample was common, with an average score of 6.9 (± 2.8 SD) on the CIRS-G and 6.5 (± 3.7 SD) medications prescribed on admission to hospital. Ninety-eight patients were categorised as frail on admission, and overall, their physical performance was poor (mean SPPB score 4.0 ± 3.3 SD) and fear of falling high (mean FES-I score 32.6 ± 14.4 SD). Further patient characteristics are provided in Table 1.

Table 1. Characteristics of 154 study participants (July 2014 to January 2015)

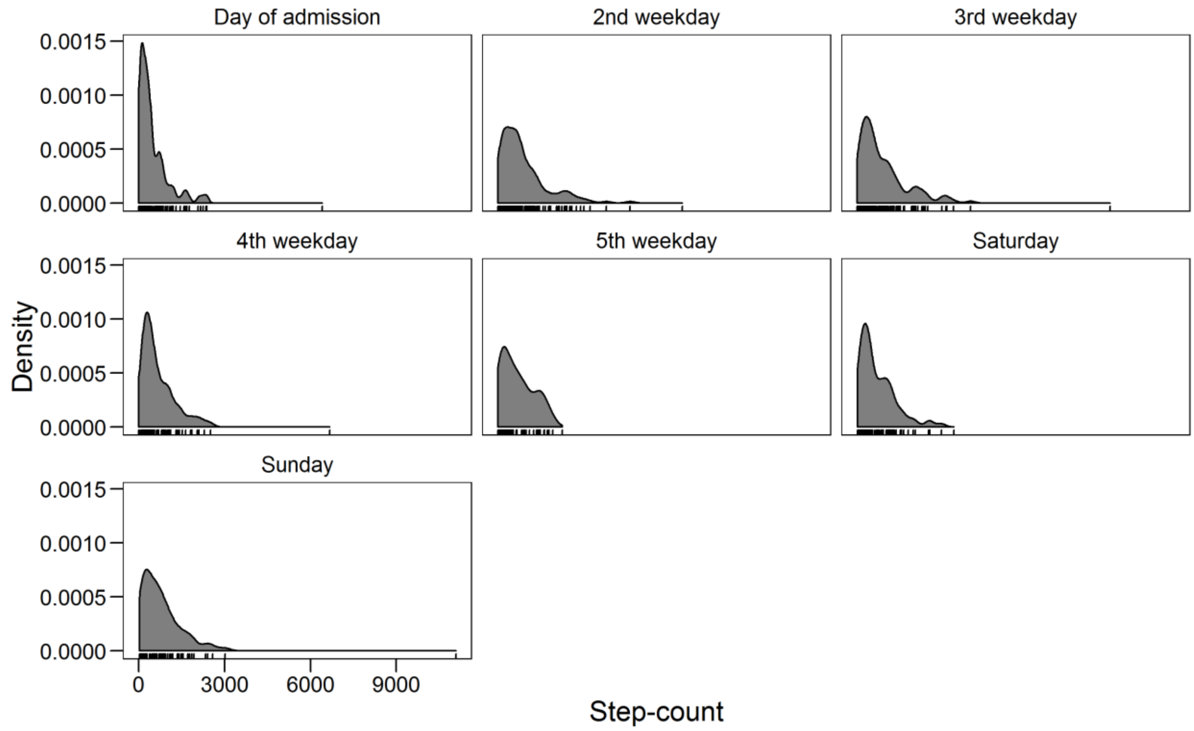
Variable	N	Mean ± SD or N (%)	(Min, Max)	25th, 50th, 75th quantiles
Female	154	77 (50%)		
Age (years)	154	77.5 ± 7.4	(65, 102)	71, 78, 83
Body mass index (kg/m2)	154	25.4 ± 6.3	(12.4, 46.1)	20.9, 24.5, 29.3
Height (cm)	154	169.2 ± 8	(150, 184)	163, 170, 175
Smoke	154			
Never		88 (60%)		
Former		53 (30%)		
Current		13 (10%)		
Alcohol	154			
Non drinker		73 (50%)		
Former		21 (10%)		
Current		55 (40%)		
Heavy		5 (0%)		
CIRS-G	154	6.9 ± 2.8	(0, 15)	5, 7, 8.8
Medications (number)	152	6.5 ± 3.7	(0, 19)	4, 7, 8
Marital status	154			
Single		29 (20%)		
Partner		73 (50%)		
Widowed		52 (30%)		
SPPB at baseline	154	4 ± 3.3	(0, 12)	1, 3.5, 7
SHARE FI score	154	3.1 ± 1.7	(-0.6, 6.5)	1.9, 3, 4.5
SHARE FI category	154			
Frail		98 (64%)		
Pre-frail		44 (29%)		
Not Frail		12 (7%)		
FES-I score	154	32.6 ± 14.4	(13, 64)	18, 30.5, 48
VAS Self-rated health (EQ5D5L)	154	53.9 ± 19.3	(0, 100)	45, 50, 70
6CIT Score	154	8 ± 7.6	(0, 28)	2, 6, 11.8
Average daily step-count	150	806.5 ± 740.5	(16.3, 5896.6)	308, 625.5, 1050.7
Log (average daily step-count)	150	6.3 ± 1	(2.8, 8.7)	5.7, 6.4, 7
Length of stay (days)	154	8.1 ± 5.4	(1, 28)	4, 7, 10
Log (length of stay)	154	1.9 ± 0.6	(0, 3.3)	1.4, 1.9, 2.3

Abbreviations and possible score ranges:
CIRS-G: Cumulative Illness Rating Scale-Geriatrics; [higher score reflects greater impairment in several systems, range 0-56]
SPPB: Short Physical Performance Battery [a higher score reflects a better physical performance, range 0-12]
SHARE FI: Survey of Health, Ageing and Retirement in Europe Frailty Index [a higher score reflects a higher level of frailty, range -2.55 to 6.505]
FES-I: Falls Efficacy Scale-International [a higher score reflects a greater concern about falling, range 0-64]

VAS Self-rated health (EQ5D5L): Visual Analogue Scale EuroQol 5-Domain 5-Level, [range 1-100],
6CIT: Six Item Cognitive Impairment Test [a higher score reflects a higher cognitive impairment, range 0-28]

Step-count data was saved incorrectly, and therefore, irretrievable for four patients. The remaining 150 patients were observed for an average of 4.8 days (median 5 days); 39 patients for seven days, and two patients for day only. The median step-counts for the day of admission was 299, and rose for the subsequent 4 weekdays of observation to 661, 593, 458, 586. Saturdays and Sundays were similar at 504 and 585. The distributions of daily step-counts for each day of observation are displayed in Figure 1.

Figure 1. Distributions of step-counts by day of observation in a sample of 150 patients.



The relationship between the natural logarithms of average daily step-count and length of stay was linear (Figure 2). Based on the unadjusted linear regression estimates (Table 2), for each unit increase in the average daily step-count, the length of stay decreased by 0.18 (95% CI -0.27 to -0.09). After adjustment for potential confounders, the strength of the inverse association was attenuated, but the 95% CI still excluded the null hypothesis of no association ($\beta_{\log(\text{steps})}$ = -0.14, 95% CI -0.26 to -0.03). After back-transforming this result from the natural log scale, the model indicated that a 50% increase in average daily step-count was associated with a 6% shorter length of stay ($100 * e^{\log\left(\frac{1+0.5}{1}\right)\beta} = 94\% = 100\% - 6\%$). The nonlinear nature of this association is illustrated in Supplemental Figure 1. The estimated regression coefficients for the covariates included in the full adjusted model are also given in Table 2. These can be multiplied by 100 to give the (approximate) percent change in the geometric mean of length of stay associated with a one unit increase in the covariate. For example, each additional chronic condition (CIRS-G) was associated with a 4% longer length of stay (β_{CIRSG} = 0.04, 95% CI 0.004 to 0.08).

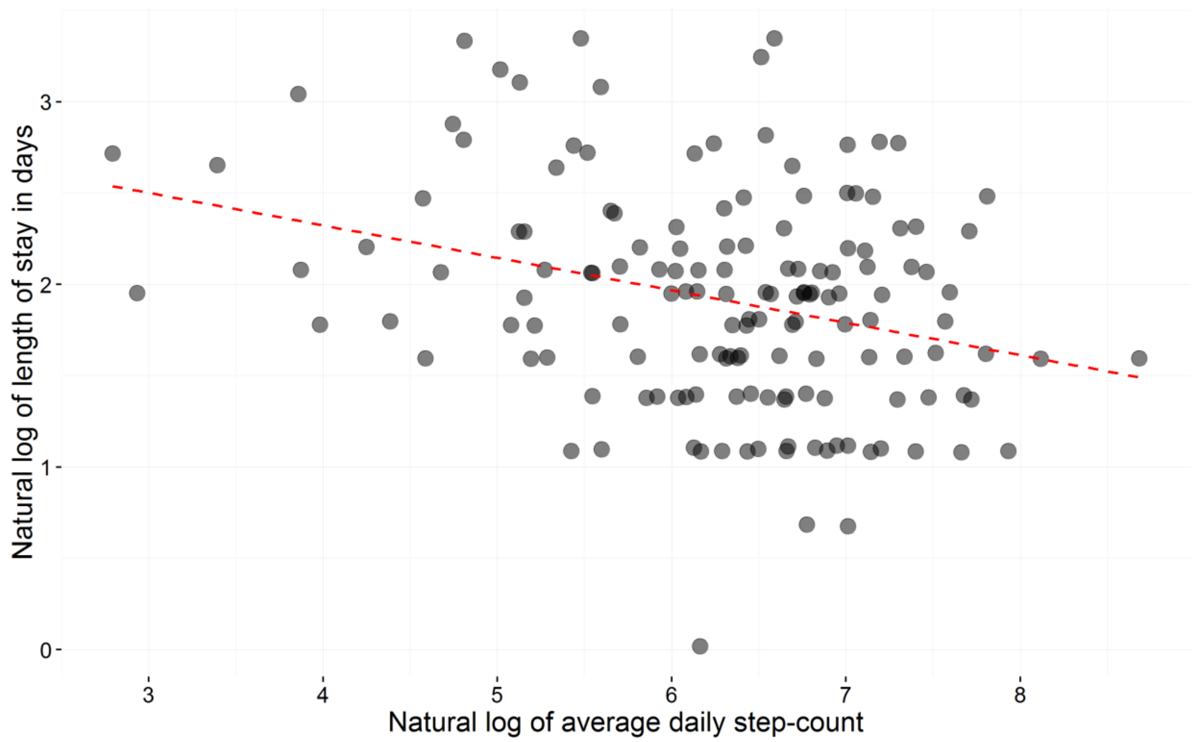
Table 2. Unadjusted and adjusted linear regression results where the natural log of length of stay is the dependent variable.

	Dependent variable: log(Length of stay in days)	
	Unadjusted	Adjusted
log (Average daily step-count)	-0.18 (-0.27, -0.09)	-0.14 (-0.26, -0.03)
Female (vs. male)		0.20 (-0.07, 0.48)
Age (years)		0.001 (-0.02, 0.02)
Body mass index (kg/m)		-0.01 (-0.02, 0.01)
Height (cm)		0.02 (0.01, 0.04)
Former smoker (vs. never)		0.12 (-0.11, 0.35)
Current smoker (vs. never)		-0.06 (-0.43, 0.31)
Doesn't drink alcohol anymore (vs. never)		-0.15 (-0.46, 0.17)
Still drinks alcohol (vs. never)		0.07 (-0.15, 0.29)
Heavy drinker (vs. never)		-0.36 (-1.00, 0.28)
CIRS-G		0.04 (0.005, 0.08)
Number of medications		-0.02 (-0.05, 0.01)
Married (vs. single)		-0.01 (-0.29, 0.26)
Widowed (vs. single)		0.07 (-0.24, 0.37)
SPPB at baseline		-0.02 (-0.06, 0.02)
SHARE FI score		0.03 (-0.03, 0.09)
FES-I score		0.004 (-0.004, 0.01)
VAS Self-rated health (EQ5D5L)		0.0003 (-0.005, 0.01)
6CIT Score		-0.002 (-0.02, 0.01)
Constant	3.03 (2.45, 3.62)	-1.43 (-4.79, 1.92)
Observations	150	148
R^2	0.09	0.24
Adjusted R^2	0.08	0.13
Residual Std. Error	0.57 (df = 148)	0.56 (df = 128)

F Statistic	14.52 (df = 1; 148; p < 0.01)	2.13 (df = 19; 128; p <0.01)

Abbreviations:
CIRS-G: Cumulative Illness Rating Scale-Geriatrics
SPPB: Short Physical Performance Battery
SHARE FI: Survey of Health, Ageing and Retirement in Europe Frailty Index
FES-I: Falls Efficacy Scale-International
VAS Self-rated health (EQ5D5L): Visual Analogue Scale EuroQol 5-Domain 5-Level
6CIT: Six Item Cognitive Impairment Test

Figure 2. The linear relationship between the natural logarithms of length of stay (days) and average daily step-count in a sample of 150 patients (July 2014 to January 2015).



Caption: The red dashed line is the unadjusted linear regression line reported in Table 2.

While there was a strong positive relationship between end of study physical performance and average daily step-count (Supplemental Table 1 and Supplemental Figure 2), this relationship disappeared once the baseline physical performance was accounted for

(Supplemental Table 1). This is further illustrated by the lack of association between average daily step-count and change in physical performance scores over the course of the study (Supplemental Figure 3).

Discussion

There were two main findings from this study. First, average daily step-count in hospital was associated with length of stay, even after adjustment for a number of potential confounders such as age, gender, baseline physical performance and co-morbidities. Second, the positive association between average daily step-count and end of study physical performance (discharge or seven days of admission) was fully explained away by baseline physical performance.

Walking activity in hospital has been suggested as a modifiable determinant of length of stay, but few studies have measured their association using objective measures, e.g. step-count (Fisher et al., 2010). Twenty-five per cent of patients walked less than 300 steps (which equates to 6 minutes of slow walking (Perry and Burnfield, 2010)), while half of the patients stayed in hospital for seven days or more. Based on our results and a seven-day length of stay, trebling their walking from 300 to 900 steps (to 18 minutes of walking) could be associated with one less day of hospitalisation. This may be a particularly important finding for the frailer, inactive patients. Increasing walking activity in patients who remain in the room or transfer from bed to chair could be a clinically feasible intervention in real terms. Alternatively, independently mobile patients might require nothing more than education, encouragement and monitoring. Therefore, relatively simple interventions may result in considerable health gains.

The association between more walking and a shorter length of stay is significant and similar to that found by Shadmi and Zisberg (2011). They found that patients who were mobile outside of their room remained in hospital 1.5 days less. The difference in effect appears large in their study, but this may reflect their inclusion of patients from institutional care and those who had low mobility levels. They reported that 65% of the patients walked at least once a day outside their room, 16% walked only in their room and 19% only transferred from bed to chair. This suggests that 35% of patients were confined to the room, of which 19% took very few steps. Including patients with very low mobility possibly allowed detection of differences between mobile and minimally mobile patients, whereas all patients included in our study were mobile premorbidly.

Fisher et al. (2010) also included patients who were required significant help from another to walk premorbidly. However, the aim of our study was to examine patients whose physical performance and independence was critical to their discharge home – i.e., to independent community dwelling. Therefore, we specifically recruited premorbidly independently mobile community-dwellers. Nonetheless, the results of this study are similar to those found by (Fisher et al., 2010), with similar average step-counts recorded, considerably low levels of walking in hospital, and that more walking, either early in the hospital stay (Fisher et al., 2010) or as this study has shown, throughout the hospital stay, was associated with a shorter length of stay. Results from all studies support the importance of mobilisation and activity during patients' hospital stays.

It is important to note that this was an observational study, thus causal associations cannot be determined. This association may exist simply because those with a prolonged stay in hospital are frailer, their situations are more complex and they require more healthcare intervention. Therefore, a definitive randomised controlled trial is now underway to measure whether increased walking activity and exercise affects length of stay.

There are a number of limitations to this study. The aim of this study was to determine whether walking activity in hospital is associated with end of study physical performance or length of stay. For this reason, physical performance was measured immediately after the period of observed walking activity, not at discharge for those patients who remained in hospital after the observation period. Therefore, we are unable to draw conclusions relating to physical performance at discharge for those with a length of stay longer than one week.

This study was limited to one centre. While all patients recruited were typical general medical or geriatric medicine patients, the results may not apply to other hospitals or patient cohorts. Resource restraints resulted in only 7% of the potentially eligible patients recruited to the study, challenging the generalizability of the results. The average daily step-count was used to represent PA in hospital; however bouts or changes in PA may have provided more sensitive information, as currently suggested by many researchers (Cassidy et al., 2016, Hollekim-Strand et al., 2014).

Conclusion

To conclude, the results of this study show that there is a small negative association between walking activity in hospital and length of stay, independent of age, baseline physical performance, co-morbidities and frailty. Walking activity is a simple and modifiable factor. For this reason, and based on this observational study, a definitive randomised controlled trial is currently underway to determine whether increased walking activity and exercise in this population shortens length of stay and improves physical performance.

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References

Bauman, A., Merom, D., Bull, F. C., Buchner, D. M. & Fiatarone Singh, M. A. 2016. Updating the Evidence for Physical Activity: Summative Reviews of the Epidemiological Evidence, Prevalence, and Interventions to Promote "Active Aging". *The Gerontologist,* 56**,** S268-S280.

Benzinger, P., Lindemann, U., Becker, C., Aminian, K., Jamour, M. & Flick, S. E. 2014. Geriatric rehabilitation after hip fracture. Role of body-fixed sensor measurements of physical activity. *Z Gerontol Geriatr,* 47**,** 236-42.

Brown, C. J., Friedkin, R. J. & Inouye, S. K. 2004. Prevalence and outcomes of low mobility in hospitalized older patients. *J Am Geriatr Soc,* 52**,** 1263-70.

Brown, C. J., Redden, D. T., Flood, K. L. & Allman, R. M. 2009. The underrecognized epidemic of low mobility during hospitalization of older adults. *J Am Geriatr Soc,* 57**,** 1660-5.

Cassidy, S., Thoma, C., Hallsworth, K., Parikh, J., Hollingsworth, K., Taylor, R., Jakovljevic, D. & Trenell, M. 2016. High intensity intermittent exercise improves cardiac structure and function and reduces liver fat in patients with type 2 diabetes: a randomised controlled trial. *Diabetologia,* 59**,** 56-66.

Cindy Ng, L. W., Jenkins, S. & Hill, K. 2011. Accuracy and responsiveness of the stepwatch activity monitor and ActivPAL in patients with COPD when walking with and without a rollator. *Disabil Rehabil,* 34**,** 1317-22.

Covinsky, K. E., Palmer, R. M., Fortinsky, R. H., Counsell, S. R., Stewart, A. L., Kresevic, D., Burant, C. J. & Landefeld, C. S. 2003. Loss of independence in activities of daily living in older adults hospitalized with medical illnesses: increased vulnerability with age. *J Am Geriatr Soc,* 51**,** 451-8.

De Morton, N. A., Keating, J. L. & Jeffs, K. 2007. Exercise for acutely hospitalised older medical patients. *Cochrane Database Syst Rev***,** Cd005955.

Delbaere, K., Close, J. C. T., Mikolaizak, A. S., Sachdev, P. S., Brodaty, H. & Lord, S. R. 2010. The Falls Efficacy Scale International (FES-I). A comprehensive longitudinal validation study. *Age Ageing,* 39**,** 210-216.

Esri 2012. Activity in Acute Public Hospitals in Ireland, Annual Report, 2012. *http://www.esri.ie/__uuid/dbadf914-7da3-4bd0-bede-2e878b56f78b/AR_2012_FINAL.pdf.*

Fisher, S. R., Kuo, Y. F., Graham, J. E., Ottenbacher, K. J. & Ostir, G. V. 2010. Early ambulation and length of stay in older adults hospitalized for acute illness. *Arch Intern Med,* 170**,** 1942-3.

Fried, L., Tangen, C., Walston, J., Newman, A., Hirsch, C., Gottdiener, J., Seeman, T., Tracey, R., Kop, W. & Burke, G. 2001. Frailty in older adults: evidence for a phenotype. *J Gerontol A-Biol,* 56A**,** M146 - M156.

Gebruers, N., Truijen, S., Engelborghs, S. & De Deyn, P. P. 2014. Prediction of Upper Limb Recovery, General Disability, and Rehabilitation Status by Activity Measurements Assessed by Accelerometers or the Fugl-Meyer Score in Acute Stroke. *Am J of Phys Med Rehabil,* 93**,** 245-252.

Guralnik, J. M., Simonsick, E. M., Ferrucci, L., Glynn, R. J., Berkman, L. F., Blazer, D. G., Scherr, P. A. & Wallace, R. B. 1994. A short physical performance battery assessing lower extremity function: association with self-reported disability and prediction of mortality and nursing home admission. *J Gerontol,* 49**,** M85-94.

Higashi, T., Hays, R. D., Brown, J. A., Kamberg, C. J., Pham, C., Reuben, D. B., Shekelle, P. G., Solomon, D. H., Young, R. T., Roth, C. P., Chang, J. T., Maclean, C. H. & Wenger, N. S. 2005. Do proxies reflect patients' health concerns about urinary incontinence and gait problems? *Health Qual Life Outcomes,* 3**,** 75.

Hollekim-Strand, S. M., Bjorgaas, M. R., Albrektsen, G., Tjonna, A. E., Wisloff, U. & Ingul, C. B. 2014. High-intensity interval exercise effectively improves cardiac function in patients with type 2 diabetes mellitus and diastolic dysfunction: a randomized controlled trial. *J Am Coll Cardiol,* 64**,** 1758-60.

Jones, C. T., Lowe, A. J., Macgregor, L. & Brand, C. A. 2006. A randomised controlled trial of an exercise intervention to reduce functional decline and health service utilisation in the hospitalised elderly. *Australas J Ageing,* 25**,** 126-133.

Jorstad-Stein, E. C., Hauer, K., Becker, C., Bonnefoy, M., Nakash, R. A., Skelton, D. A. & Lamb, S. E. 2005. Suitability of physical activity questionnaires for older adults in fall-prevention trials: a systematic review. *J Aging Phys Act*, 13**,** 461-81.

Katzman, R., Brown, T., Fuld, P., Peck, A., Schechter, R. & Schimmel, H. 1983. Validation of a short Orientation-Memory-Concentration Test of cognitive impairment. *Am J Psychiatry*, 140**,** 734-9.

McCullagh, R., O'Connell, A.M., Dillon, C., Horgan, F. & Timmons, S. Comparative Accuracy of Motion Sensors for Frail-Older Hospitalised Patients. Ir JMed Sci, 2014 Galway. Irish Gerontological Society Conference, S354-S354.

Mudge, S., Stott, N. S. & Walt, S. E. 2007. Criterion validity of the StepWatch Activity Monitor as a measure of walking activity in patients after stroke. *Arch Phys Med Rehabil*, 88**,** 1710-5.

Pahor, M., Guralnik, J. M., Ambrosius, W. T., Blair S., Bonds, D.E., Church T.S., et al. 2014. Effect of structured physical activity on prevention of major mobility disability in older adults: The life study randomized clinical trial. *JAMA*, 311**,** 2387-2396.

Perry, J. & Burnfield, J. M. 2010. *Gait Analysis: Normal and Pathological Function. Second Edition*, Slack Books.

Pitta, F., Troosters, T., Probst, V. S., Spruit, M. A., Decramer, M. & Gosselink, R. 2006. Quantifying physical activity in daily life with questionnaires and motion sensors in COPD. *Eur Respir J*, 27**,** 1040-1055.

Prince, S. A., Adamo, K. B., Hamel, M. E., Hardt, J., Gorber, S. C. & Tremblay, M. 2008. A comparison of direct versus self-report measures for assessing physical activity in adults: a systematic review. *Int J Behav Nutr Phys Act*, 5**,** 1-24.

Romero-Ortuno, R., Walsh, C. D., Lawlor, B. A. & Kenny, R. A. 2010. A frailty instrument for primary care: findings from the Survey of Health, Ageing and Retirement in Europe (SHARE). *BMC Geriatr*, 10**,** 57.

Ryan, D. J., O'regan, N. A., Caoimh, R. O., Clare, J., O'connor, M., Leonard, M., Mcfarland, J., Tighe, S., O'sullivan, K., Trzepacz, P. T., Meagher, D. & Timmons, S. 2013. Delirium in an adult acute hospital population: predictors, prevalence and detection. *BMJ Open*, 3.

Salvi, F., Miller, M. D., Grilli, A., Giorgi, R., Towers, A. L., Morichi, V., Spazzafumo, L., Mancinelli, L., Espinosa, E., Rappelli, A. & Dessi-Fulgheri, P. 2008. A manual of guidelines to score the modified cumulative illness rating scale and its validation in acute hospitalized elderly patients. *J Am Geriatr Soc,* 56**,** 1926-31.

Shadmi, E. & Zisberg, A. 2011. In-hospital mobility and length of stay. *Arch Int Med,* 171**,** 1298-1299.

Smith, P., Galea, M., Woodward, M., Said, C. & Dorevitch, M. 2008. Physical activity by elderly patients undergoing inpatient rehabilitation is low: an observational study. *Aust J Physiother,* 54**,** 209-213.

Timmons, S., Manning, E., Barrett, A., Brady, N. M., Browne, V., O'shea, E., Molloy, D. W., O'regan, N. A., Trawley, S., Cahill, S., O'sullivan, K., Woods, N., Meagher, D., Ni Chorcorain, A. M. & Linehan, J. G. 2015. Dementia in older people admitted to hospital: a regional multi-hospital observational study of prevalence, associations and case recognition. *Age Ageing,* 44**,** 993-9.

Trombetti, A., Hars, M., Herrmann, F., Rizzoli, R. & Ferrari, S. 2013. Effect of a multifactorial fall-and-fracture risk assessment and management program on gait and balance performances and disability in hospitalized older adults: a controlled study. *Osteoporosis International,* 24**,** 867-876.

Tuijl, J. P., Scholte, E. M., De Craen, A. J. & Van Der Mast, R. C. 2012. Screening for cognitive impairment in older general hospital patients: comparison of the Six-Item Cognitive Impairment Test with the Mini-Mental State Examination. *Int J Geriatr Psychiatry,* 27**,** 755-62.

Van Hout, B., Janssen, M. F., Feng, Y. S., Kohlmann, T., Busschbach, J., Golicki, D., Lloyd, A., Scalone, L., Kind, P. & Pickard, A. S. 2012. Interim scoring for the EQ-5D-5L: mapping the EQ-5D-5L to EQ-5D-3L value sets. *Value Health,* 15**,** 708-15.

Yardley, L., Beyer, N., Hauer, K., Kempen, G., Piot-Ziegler, C. & Todd, C. 2005. Development and initial validation of the Falls Efficacy Scale-International (FES-I). *Age Ageing,* 34**,** 614-9.

Zisberg, A., Shadmi, E., Sinoff, G., Gur-Yaish, N., Srulovici, E. & Admi, H. 2011. Low mobility during hospitalization and functional decline in older adults. *J Am Geriatr Soc,* 59**,** 266-73.

Table 1. Characteristics of 154 study participants (July 2014 to January 2015)

Variable		**N**	**Mean ± SD or N (%)**	**(Min, Max)**	**25th, 50th, 75th quantiles**
Female		154	77 (50%)		
Age (years)		154	77.5 ± 7.4	(65, 102)	71, 78, 83
Body mass index (kg/m2)		154	25.4 ± 6.3	(12.4, 46.1)	20.9, 24.5, 29.3
Height (cm)		154	169.2 ± 8	(150, 184)	163, 170, 175
Smoke		154			
	Never		88 (60%)		
	Former		53 (30%)		
	Current		13 (10%)		
Alcohol		154			
Non drinker			73 (50%)		
	Former		21 (10%)		
	Current		55 (40%)		
	Heavy		5 (0%)		
CIRS-G		154	6.9 ± 2.8	(0, 15)	5, 7, 8.8
Medications (number)		152	6.5 ± 3.7	(0, 19)	4, 7, 8
Marital status		154			
	Single		29 (20%)		
	Partner		73 (50%)		
	Widowed		52 (30%)		
SPPB at baseline		154	4 ± 3.3	(0, 12)	1, 3.5, 7
SHARE FI score		154	3.1 ± 1.7	(-0.6, 6.5)	1.9, 3, 4.5
SHARE FI category		154			
	Frail		98 (64%)		
	Pre-frail		44 (29%)		
	Not Frail		12 (7%)		
FES-I score		154	32.6 ± 14.4	(13, 64)	18, 30.5, 48
VAS Self-rated health (EQ5D5L)		154	53.9 ± 19.3	(0, 100)	45, 50, 70
6CIT Score		154	8 ± 7.6	(0, 28)	2, 6, 11.8
Average daily step-count		150	806.5 ± 740.5	(16.3, 5896.6)	308, 625.5, 1050.7
Log (average daily step-count)		150	6.3 ± 1	(2.8, 8.7)	5.7, 6.4, 7
Length of stay (days)		154	8.1 ± 5.4	(1, 28)	4, 7, 10
Log (length of stay)		154	1.9 ± 0.6	(0, 3.3)	1.4, 1.9, 2.3

Abbreviations and possible score ranges:
CIRS-G: Cumulative Illness Rating Scale-Geriatrics; [higher score reflects greater impairment in several systems, range 0-56]
SPPB: Short Physical Performance Battery [a higher score reflects a better physical performance, range 0-12]
SHARE FI: Survey of Health, Ageing and Retirement in Europe Frailty Index [a higher score reflects a higher level of frailty, range -2.55 to 6.505]
FES-I: Falls Efficacy Scale-International [a higher score reflects a greater concern about falling, range 0-64]
VAS Self-rated health (EQ5D5L): Visual Analogue Scale EuroQol 5-Domain 5-Level, [range 1-100],
6CIT: Six Item Cognitive Impairment Test [a higher score reflects a higher cognitive impairment, range 0-28]

Table 2. Unadjusted and adjusted linear regression results where the natural log of length of stay is the dependent variable.

	Dependent variable: log(Length of stay in days)	
	Unadjusted	Adjusted
log (Average daily step-count)	-0.18 (-0.27, -0.09)	-0.14 (-0.26, -0.03)
Female (vs. male)		0.20 (-0.07, 0.48)
Age (years)		0.001 (-0.02, 0.02)
Body mass index (kg/m)		-0.01 (-0.02, 0.01)
Height (cm)		0.02 (0.01, 0.04)
Former smoker (vs. never)		0.12 (-0.11, 0.35)
Current smoker (vs. never)		-0.06 (-0.43, 0.31)
Doesn't drink alcohol anymore (vs. never)		-0.15 (-0.46, 0.17)
Still drinks alcohol (vs. never)		0.07 (-0.15, 0.29)
Heavy drinker (vs. never)		-0.36 (-1.00, 0.28)
CIRS-G		0.04 (0.005, 0.08)
Number of medications		-0.02 (-0.05, 0.01)
Married (vs. single)		-0.01 (-0.29, 0.26)
Widowed (vs. single)		0.07 (-0.24, 0.37)
SPPB at baseline		-0.02 (-0.06, 0.02)
SHARE FI score		0.03 (-0.03, 0.09)
FES-I score		0.004 (-0.004, 0.01)
VAS Self-rated health (EQ5D5L)		0.0003 (-0.005, 0.01)
6CIT Score		-0.002 (-0.02, 0.01)
Constant	3.03 (2.45, 3.62)	-1.43 (-4.79, 1.92)
Observations	150	148
R^2	0.09	0.24
Adjusted R^2	0.08	0.13
Residual Std. Error	0.57 (df = 148)	0.56 (df = 128)
F Statistic	14.52 (df = 1; 148; p < 0.01)	2.13 (df = 19; 128; p <0.01)

Abbreviations:
CIRS-G: Cumulative Illness Rating Scale-Geriatrics
SPPB: Short Physical Performance Battery
SHARE FI: Survey of Health, Ageing and Retirement in Europe Frailty Index

Walking in hospital is associated with a shorter length of stay

FES-I: Falls Efficacy Scale-International
VAS Self-rated health (EQ5D5L): Visual Analogue Scale EuroQol 5-Domain 5-Level
6CIT: Six Item Cognitive Impairment Test

Figure 1. Distributions of step-counts by day of observation in a sample of 150 patients.

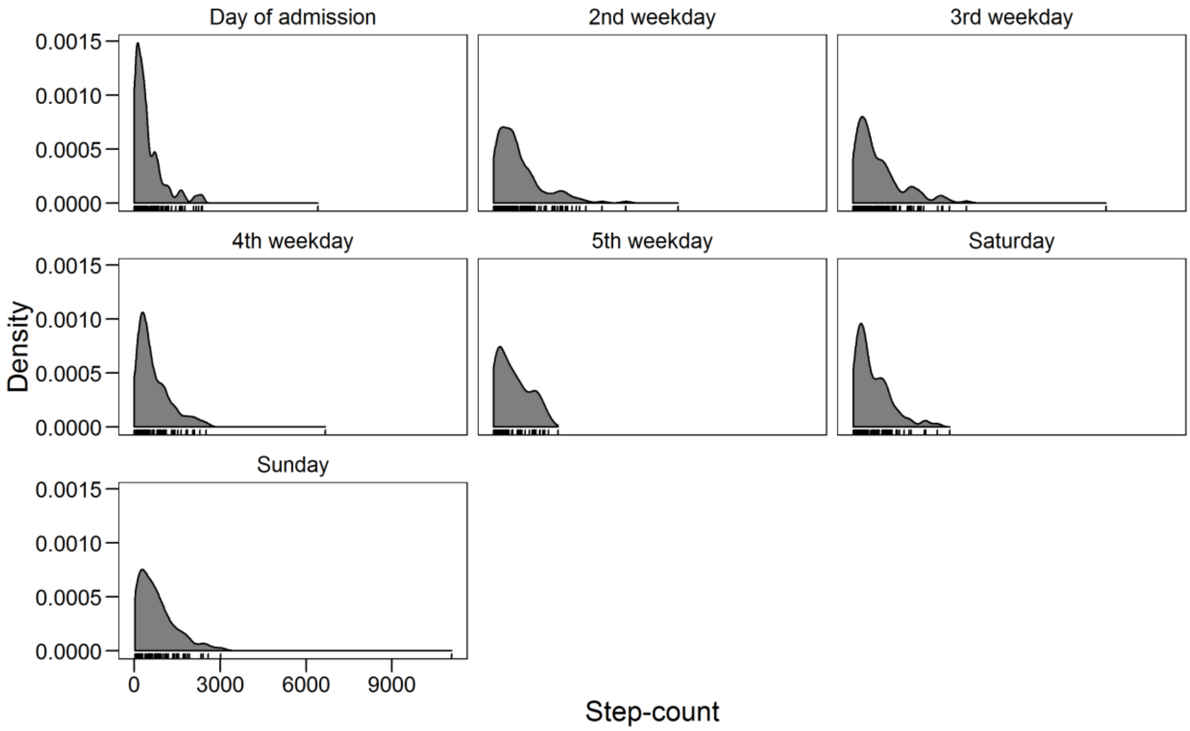
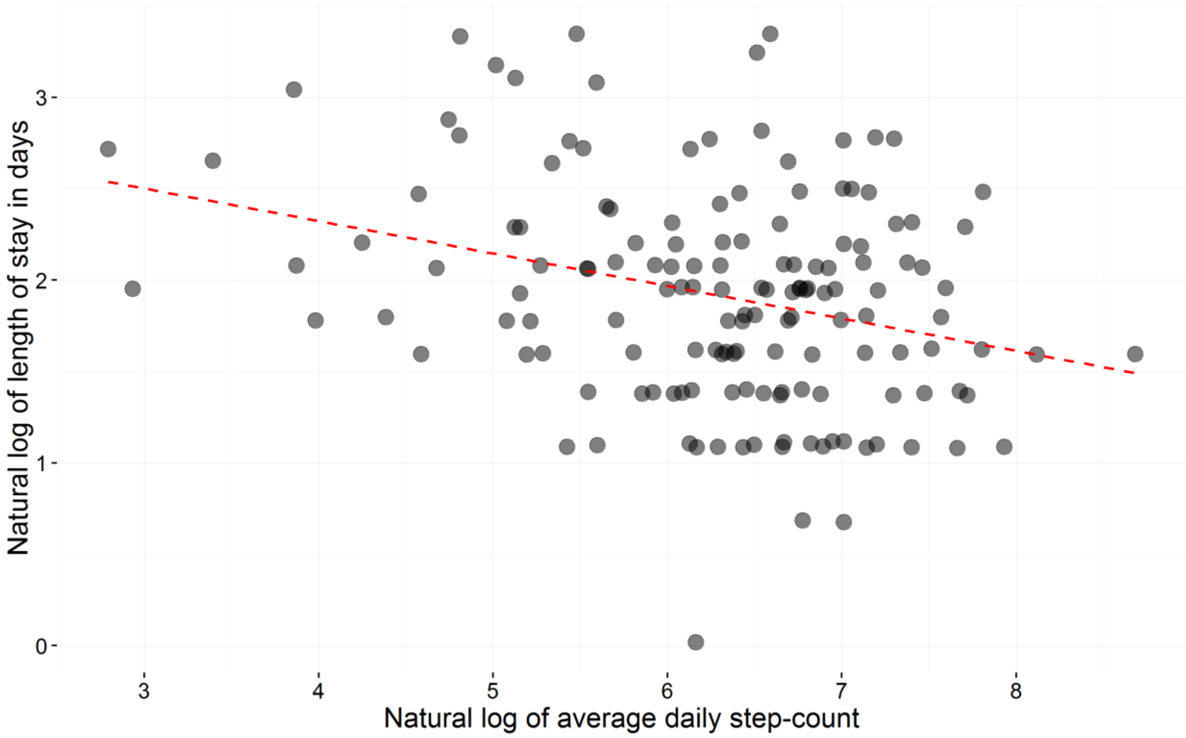
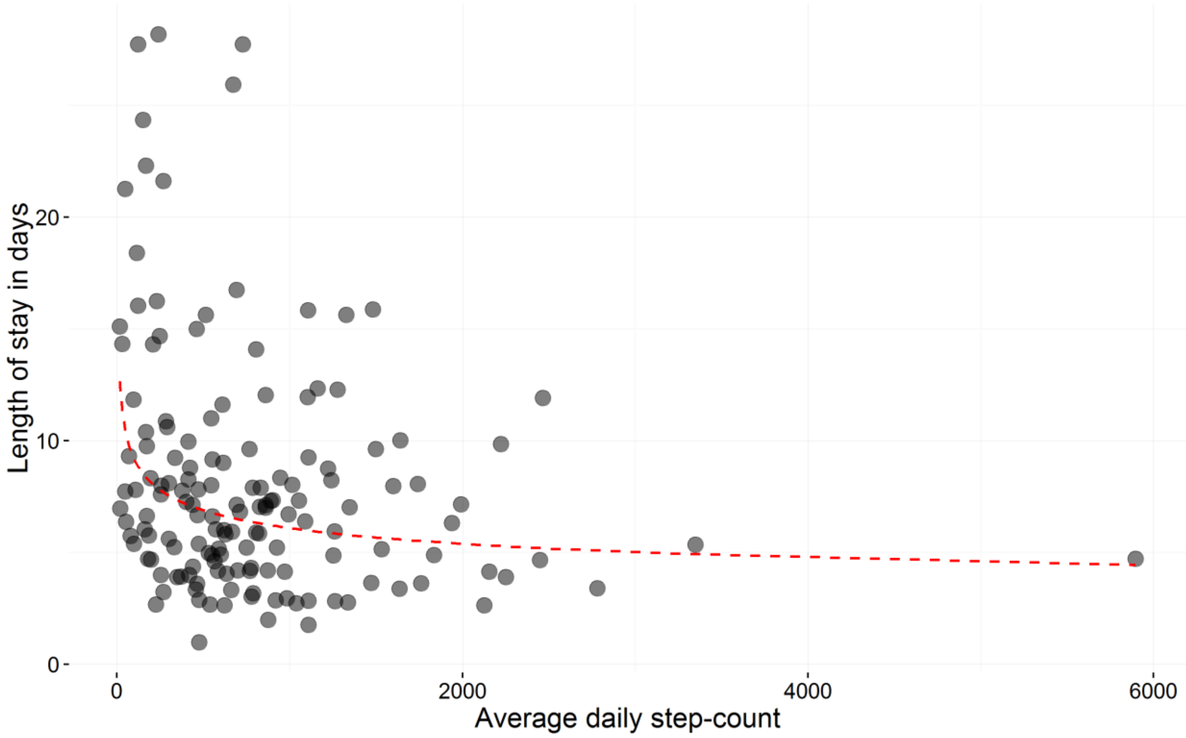


Figure 2. The linear relationship between the natural logarithms of length of stay (days) and average daily step-count in a sample of 150 patients (July 2014 to January 2015).



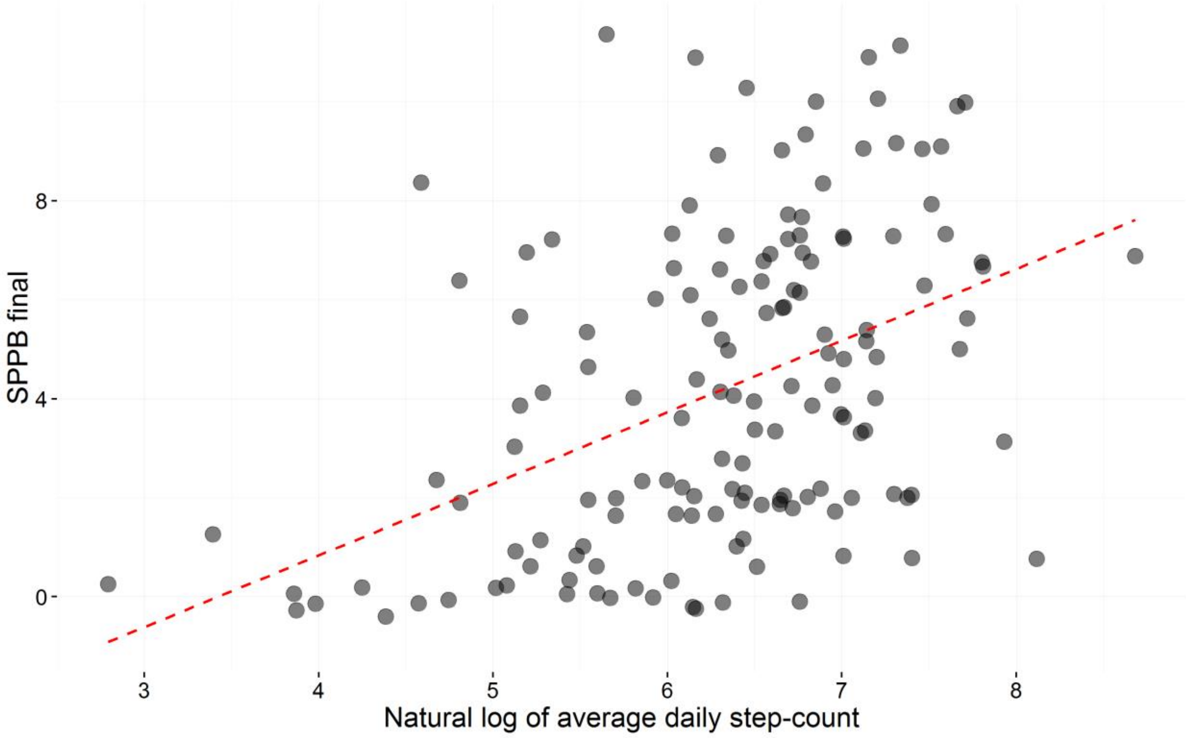
Caption: The red dashed line is the unadjusted linear regression line reported in Table 2.

Supplemental Figure 1. The non-linear relationship between length of stay in days and average daily step-count in a sample of 150 patients (July 2014 to January 2015).



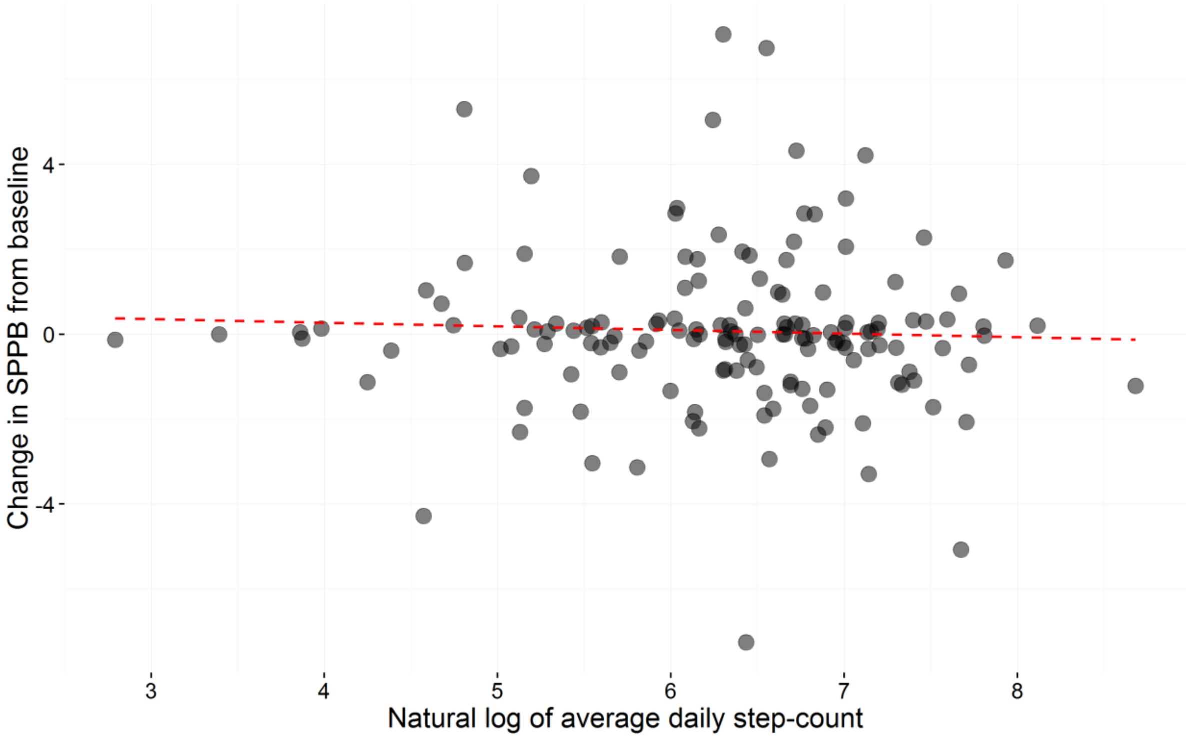
Caption: The red dashed line is the unadjusted linear regression line reported in Table 1, back-transformed from the log to the raw scales of the x and y axes.

Supplemental Figure 2. The linear relationship between end of study physical performance (SPPB) and the natural logarithm of average daily step-count in a sample of 150 patients (July 2014 to January 2015).



Caption: The red, dashed line is the unadjusted linear regression line reported in Supplemental Table 1.

Supplemental Figure 3. There was no apparent relationship between change in physical performance (SPPB) and the natural logarithm of average daily step-count in a sample of 150 patients (July 2014 to January 2015).



Caption: The red dashed line is the unadjusted linear regression line.

Supplemental Table 1. Unadjusted and adjusted linear regression results where the end of study physical performance (SPPB) is the dependent variable.

	Dependent variable: End of study SPPB	
	Unadjusted	Adjusted
log(Average daily step-count)	1.45 (0.98, 1.91)	0.31 (-0.01, 0.62)
SPPB at baseline		0.75 (0.66, 0.84)
Constant	-4.95 (-7.92, -1.99)	-0.80 (-2.66, 1.06)
Observations	149	149
R^2	0.20	0.71
Adjusted R^2	0.20	0.71
Residual Std. Error	2.80 (df = 147)	1.69 (df = 146)
F Statistic	37.33 (df = 1; 147; p < 0.01)	179.78 (df = 2; 146; p < 0.01)

Abbreviations:

SPPB: Short Physical Performance Battery