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Walking in hospital is associated with a shorter length of stay

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

2

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13 Keywords: accelerometry, physical activity, walking, gerontology, length of stay, physical
14 performance

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Abstract

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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 ($\beta_{\log(\text{steps})} = -0.15$, 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.

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

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Introduction

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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

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71 accurate, wearable step-counters may provide an objective measurement of PA with minimal
72 burden on staff or patients.

73

74 Bauman et al. (2016) recently reviewed the evidence suggesting that improved physical
75 performance is associated with increased levels of PA in older community-dwellers.

76 Interventional studies have also improved physical performance in this population (Pahor et
77 al., 2014). Similar results have been found in hospital-based studies. Two large studies, using
78 nursing-staff reports (Brown et al., 2004), and patients' self-reports (Zisberg et al., 2011),
79 found that low PA was associated with poorer functional performance at discharge i.e., a
80 poorer ability to perform activities of daily living such as washing, dressing and toileting.

81 Many factors can contribute to functional performance, such as sequencing ability, problem
82 solving and spatial awareness. Alternatively, walking activity in hospital may be more
83 directly linked to patients' physical performance; balance, transfer and walking ability. Many
84 studies have shown that additional exercise sessions (either independently or as part of a
85 multifactorial programme), can improve older patients' physical performance and balance (de
86 Morton et al., 2007, Jones et al., 2006, Trombetti et al., 2013) However, to date, the
87 association between walking activity and physical performance has yet to be measured.

88

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

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95 a measure of the person's functional ability or physical performance, which would be a
96 possible confounding factor on the association between physical activity and length of stay.

97

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

103

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

108

109

Methods

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

114

Patient Selection

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

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

126

127 Outcome Measurements

128 *Main Outcome Measurements*

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

131

132 Length of stay was available electronically through the hospital information system. Walking
133 activity was measured in step-count with the Stepwatch Activity Monitor (SAM), a wearable
134 tri-axial accelerometer with a frequency of 128 Hz. The SAM unit does not appear lose
135 accuracy at slower walking speeds (Mudge et al., 2007, Cindy Ng et al., 2011), and has
136 recently been found accurate in older and frail medical inpatients (McCullagh et al., 2014).
137 The unit can be worn continuously, even while asleep and is fully waterproof, allowing the
138 patients to shower. Using the software provided, the SAM's sensitivity was programmed
139 specifically for each patient before it was attached. The level of sensitivity was based on the
140 answers given to four questions relating to the patients' height, gait pattern and gait cycle, as
141 follows: (Question 1) "Does the client regularly participate in activities that involve short
142 quick steps?" (Question 2) "Is their walking speed fast or slow?" (...relative to people of
143 similar height.). (Question 3) "What is the client's range of walking speeds?" (Question 4)
144 "Describe the appearance of the client's leg motion". These were answered specifically to the

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145 patients' presentation, e.g., if the patient walked with a walking frame, they were deemed to
146 be "slow" walkers, who "rarely changed" their walking speed. The number of steps was
147 saved in periods of 15 seconds (time interval/epoch), as it has demonstrated good accuracy at
148 this setting (McCullagh et al., 2014).

149

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

162

163 *Descriptive Variables*

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

166

167 Co-morbidities were measured using the Cumulative Illness Rating Scale-Geriatrics, (CIRS-
168 G) (Salvi et al., 2008). This validated tool for geriatric patients, measures the severity of

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169 impairment over 14 organ systems, and produces a possible score ranging from 0 to 56; a
170 higher score reflecting a greater impairment in several systems.

171

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

176

177 Frailty was measured using the SHARE FI, a validated and simple frailty instrument based on
178 the Survey of Health, Ageing and Retirement Survey in Europe (Romero-Ortuno et al.,
179 2010). Five SHARE variables approximating Fried's frailty definition (Fried et al., 2001) are
180 used: fatigue, loss of appetite, grip strength, functional difficulties and physical activity. Four
181 of the five domains are self-reported and grip strength is objectively measured. Possible
182 scores range between -2.515 to 6.505, and SHARE-FI gender-specific calculators are freely
183 available on the web to determine the patient's frailty category (frail, pre-frail or not frail).
184 (Romero-Ortuno et al., 2010).

185

186 Number of falls that occurred over the previous six months was recorded and fear of falling
187 was measured using the Falls Efficacy Scale-International (Yardley et al., 2005). Its internal
188 validity and test-retest reliability have been found high. This self-reported tool consists of 16
189 activity-related questions; typical community-dwelling tasks or activities, rather than
190 activities in hospital. The questions aim to determine how concerned older adults are about
191 falling while performing these activities on a scale of 1 (not concerned at all) to 4 (very
192 concerned). The patients were asked to report how concerned they were when they felt well
193 at home; in other words, before the onset of their current illness. A cut-off of above 19 points

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194 (out of a possible 64 points) indicates a moderate to high concern about falling (Delbaere et
195 al., 2010). If the patient was unable to complete the report, their next-of-kin was interviewed.
196 Validation studies have shown that while next-of-kin have been found to overestimate
197 patients' fear of falling, the information that they provide is consistent and valuable (Higashi
198 et al., 2005).

199

200 Quality of Life was measured using the EuroQol 5 Domain 5 Level Scale (van Hout et al.,
201 2012). This is a commonly used and easy to administer scale. It covers the domains of
202 mobility, self-care, activity, pain/discomfort and anxiety/depression, and a visual analogue
203 scale, ranging from 0 to 100, to measure their self-reported health status. Once again, the
204 next-of-kin was requested to complete this questionnaire on the patients' behalf if they were
205 unable. To date, the next-of-kin's report has not been validated, but we felt that their input
206 would be valuable.

207

208 Procedure

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

213

214 The patients were then interviewed at the bedside. The grip strength (as part of the SHARE
215 FI) was measured using the hydraulic Jamar[®] hand dynamometer (Sammons Preston, Roylan,
216 Bolingbrook, IL, USA) and the SPPB was completed. The SAM was then attached to the
217 patient using a disposable wide elastic strap, above the dominant malleolus if possible, as per
218 the manufacturer's instructions. The main reasons for attachment to the non-dominant leg

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219 were skin fragility or patients' request. Walking activity was measured, and presented as
220 step-count averaged for each day the SAM was worn (average daily step-count).
221 Patients were visited every weekday until discharge or for the first seven days of their
222 hospital stay when the condition of the patients' skin, where the SAM unit was attached, was
223 checked. Patients were not visited on the weekends, but continued to wear the accelerometer.
224
225 On the day of discharge or after the first seven days, physical performance and Quality of
226 Life were re-measured. The SAM unit was removed and the data was downloaded using the
227 software provided. Length of stay was recorded from the electronic hospital information
228 system.

229

230

Statistical Methods

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

234

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

$$239 \log(y_i) = \alpha + \beta_1 \log(x_i) + \varepsilon_i,$$

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

$$242 \log(y_i) = \alpha + \beta_1 \log(x_{1i}) + \left(\sum_2^k \beta_k x_{ki} \right) + \varepsilon_i$$

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

$$246 \quad y_i = \alpha + \beta_1 \log(x_i) + \varepsilon_i$$

247 and a second model adjusted for baseline SBBP using

$$248 \quad y_i = \alpha + \beta_1 \log(x_{1i}) + \beta_2 x_{2i} + \varepsilon_i$$

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

253

254 Results

255 Over the course of the recruitment period, approximately 2,154 medical patients aged 65 and
256 over, were admitted to the hospital. Within the resource restraints of the study, we were able
257 to screen 227 of these for recruitment to this study; an average of two patients daily. Of these,
258 69 did not meet study criteria. Of the remaining 158 eligible patients, four refused to
259 participate in the study, leaving 154 patients who consented and enrolled (95% response rate,
260 7% of all medical patients admitted during the study, 70% of all patients screened for
261 recruitment). Patient ages ranged from 65 to 102 years of age (mean 77.5 ± 7.4 SD), and the
262 sample was evenly split between males and females. Co-morbidity in this sample was
263 common, with an average score of $6.9 (\pm 2.8$ SD) on the CIRS-G and $6.5 (\pm 3.7$ SD)
264 medications prescribed on admission to hospital. Ninety-eight patients were categorised as
265 frail on admission, and overall, their physical performance was poor (mean SPPB score $4.0 \pm$
266 3.3 SD) and fear of falling high (mean FES-I score 32.6 ± 14.4 SD). Further patient
267 characteristics are provided in Table 1.

269 **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/m ²)	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			
		<i>Never</i>	88 (60%)	
		<i>Former</i>	53 (30%)	
		<i>Current</i>	13 (10%)	
Alcohol	154			
Non drinker		73 (50%)		
		<i>Former</i>	21 (10%)	
		<i>Current</i>	55 (40%)	
		<i>Heavy</i>	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			
		<i>Single</i>	29 (20%)	
		<i>Partner</i>	73 (50%)	
		<i>Widowed</i>	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			
		<i>Frail</i>	98 (64%)	
		<i>Pre-frail</i>	44 (29%)	
		<i>Not Frail</i>	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

270 **Abbreviations and possible score ranges:**271 **CIRS-G:** Cumulative Illness Rating Scale-Geriatrics; [higher score reflects greater impairment in several
272 systems, range 0-56]273 **SPPB:** Short Physical Performance Battery [a higher score reflects a better physical performance, range 0-12]274 **SHARE FI:** Survey of Health, Ageing and Retirement in Europe Frailty Index [a higher score reflects a higher
275 level of frailty, range -2.55 to 6.505]276 **FES-I:** Falls Efficacy Scale-International [a higher score reflects a greater concern about falling, range 0-64]

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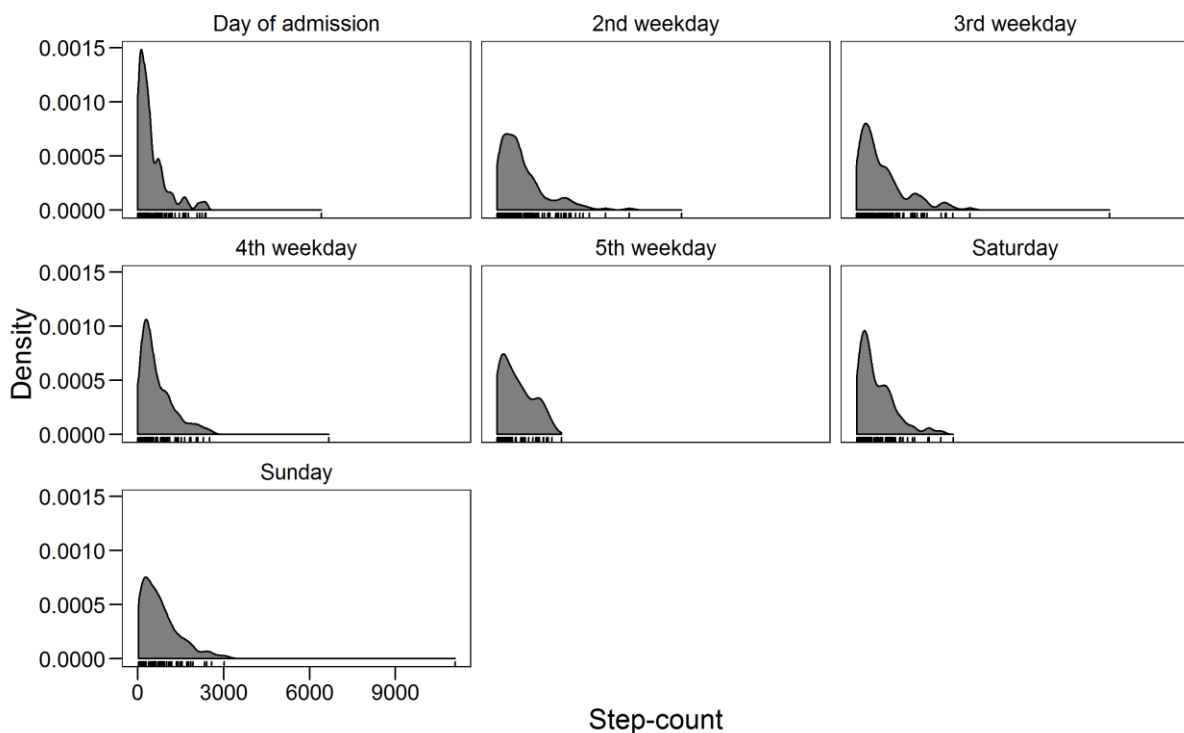
277 **VAS Self-rated health (EQ5D5L):** Visual Analogue Scale EuroQol 5-Domain 5-Level, [range 1-100],
278 **6CIT:** Six Item Cognitive Impairment Test [a higher score reflects a higher cognitive impairment, range 0-28]
279

280

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

287

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



289

290

291 The relationship between the natural logarithms of average daily step-count and length of
 292 stay was linear (Figure 2). Based on the unadjusted linear regression estimates (Table 2), for
 293 each unit increase in the average daily step-count, the length of stay decreased by 0.18 (95%
 294 CI -0.27 to -0.09). After adjustment for potential confounders, the strength of the inverse
 295 association was attenuated, but the 95% CI still excluded the null hypothesis of no
 296 association ($\beta_{\log(\text{steps})} = -0.14$, 95% CI -0.26 to -0.03). After back-transforming this result
 297 from the natural log scale, the model indicated that a 50% increase in average daily step-
 298 count was associated with a 6% shorter length of stay ($100 * e^{\log(\frac{1+0.5}{1})\beta} = 94\% =$
 299 $100\% - 6\%$). The nonlinear nature of this association is illustrated in Supplemental Figure
 300 1. The estimated regression coefficients for the covariates included in the full adjusted model
 301 are also given in Table 2. These can be multiplied by 100 to give the (approximate) percent
 302 change in the geometric mean of length of stay associated with a one unit increase in the

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303 covariate. For example, each additional chronic condition (CIRS-G) was associated with a
 304 4% longer length of stay ($\beta_{\text{CIRSG}} = 0.04$, 95% CI 0.004 to 0.08).

305

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

<i>Dependent variable: log(Length of stay in days)</i>		
	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)

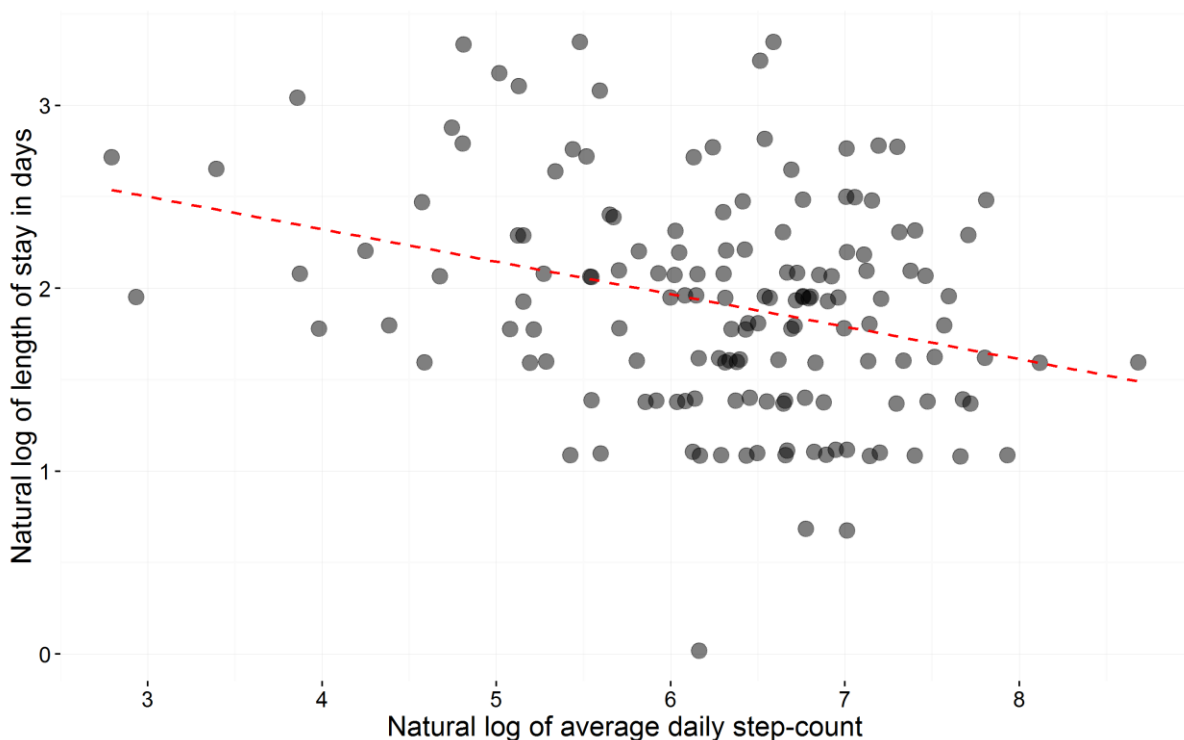
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F Statistic 14.52 (df = 1; 148; p < 0.01) 2.13 (df = 19; 128; p < 0.01)

- 308 Abbreviations:
309 **CIRS-G**: Cumulative Illness Rating Scale-Geriatrics
310 **SPPB**: Short Physical Performance Battery
311 **SHARE FI**: Survey of Health, Ageing and Retirement in Europe Frailty Index
312 **FES-I**: Falls Efficacy Scale-International
313 **VAS Self-rated health (EQ5D5L)**: Visual Analogue Scale EuroQol 5-Domain 5-Level
314 **6CIT**: Six Item Cognitive Impairment Test
315

316

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



319

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

321

322

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

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

329

330

Discussion

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

337

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

Walking in hospital is associated with a shorter length of stay

350

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

361

362 Fisher et al. (2010) also included patients who were required significant help from another to
363 walk premorbidly. However, the aim of our study was to examine patients whose physical
364 performance and independence was critical to their discharge home – i.e., to independent
365 community dwelling. Therefore, we specifically recruited premorbidly independently mobile
366 community-dwellers. Nonetheless, the results of this study are similar to those found by
367 (Fisher et al., 2010), with similar average step-counts recorded, considerably low levels of
368 walking in hospital, and that more walking, either early in the hospital stay (Fisher et al.,
369 2010) or as this study has shown, throughout the hospital stay, was associated with a shorter
370 length of stay. Results from all studies support the importance of mobilisation and activity
371 during patients' hospital stays.

372

Walking in hospital is associated with a shorter length of stay

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

378

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

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

392

393

Conclusion

394 To conclude, the results of this study show that there is a small negative association between
395 walking activity in hospital and length of stay, independent of age, baseline physical

Walking in hospital is associated with a shorter length of stay

396 performance, co-morbidities and frailty. Walking activity is a simple and modifiable factor.
397 For this reason, and based on this observational study, a definitive randomised controlled trial
398 is currently underway to determine whether increased walking activity and exercise in this
399 population shortens length of stay and improves physical performance.

400

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408 and interpretation of the data, manuscript preparation. **CD**: concept and design, analysis and
409 interpretation of the data. **ST**: concept and design, analysis and interpretation of the data,
410 manuscript preparation. **NFH**: concept and design, manuscript preparation. **DD**: analysis and
411 interpretation of the data, manuscript preparation.

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414

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525

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

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

527 **Abbreviations and possible score ranges:**528 **CIRS-G:** Cumulative Illness Rating Scale-Geriatrics; [higher score reflects greater impairment in several
529 systems, range 0-56]530 **SPPB:** Short Physical Performance Battery [a higher score reflects a better physical performance, range 0-12]531 **SHARE FI:** Survey of Health, Ageing and Retirement in Europe Frailty Index [a higher score reflects a higher
532 level of frailty, range -2.55 to 6.505]533 **FES-I:** Falls Efficacy Scale-International [a higher score reflects a greater concern about falling, range 0-64]534 **VAS Self-rated health (EQ5D5L):** Visual Analogue Scale EuroQol 5-Domain 5-Level, [range 1-100],535 **6CIT:** Six Item Cognitive Impairment Test [a higher score reflects a higher cognitive impairment, range 0-28]

Walking in hospital is associated with a shorter length of stay

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

<i>Dependent variable: log(Length of stay in days)</i>		
	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)

538 Abbreviations:

539 **CIRS-G:** Cumulative Illness Rating Scale-Geriatrics

540 **SPPB:** Short Physical Performance Battery

541 **SHARE FI:** Survey of Health, Ageing and Retirement in Europe Frailty Index

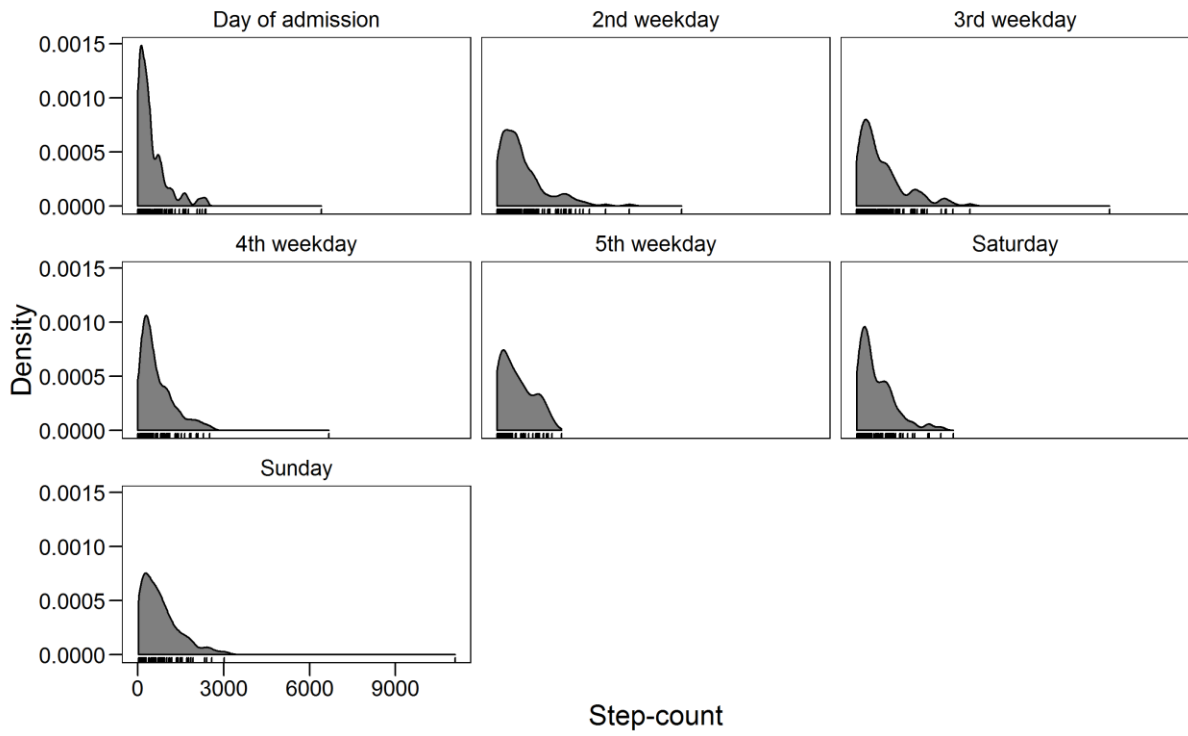
Walking in hospital is associated with a shorter length of stay

542 **FES-I:** Falls Efficacy Scale-International
543 **VAS Self-rated health (EQ5D5L):** Visual Analogue Scale EuroQol 5-Domain 5-Level
544 **6CIT:** Six Item Cognitive Impairment Test
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Walking in hospital is associated with a shorter length of stay

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



549

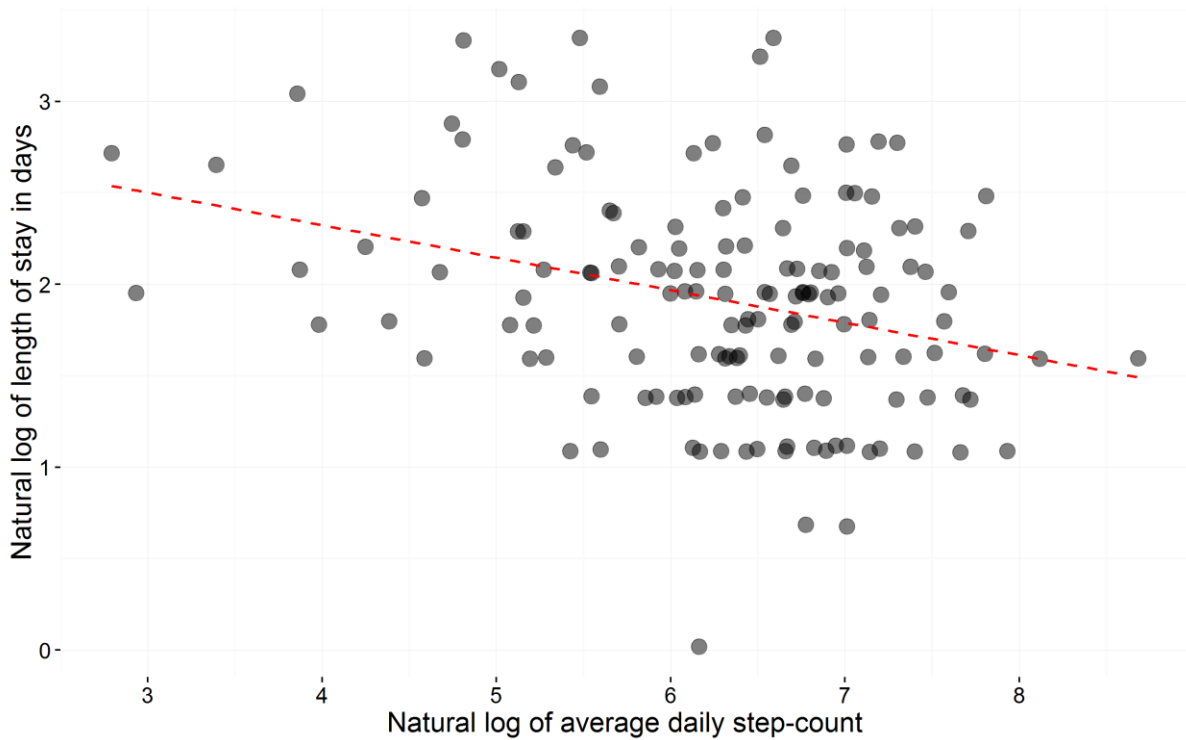
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Walking in hospital is associated with a shorter length of stay

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



555

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

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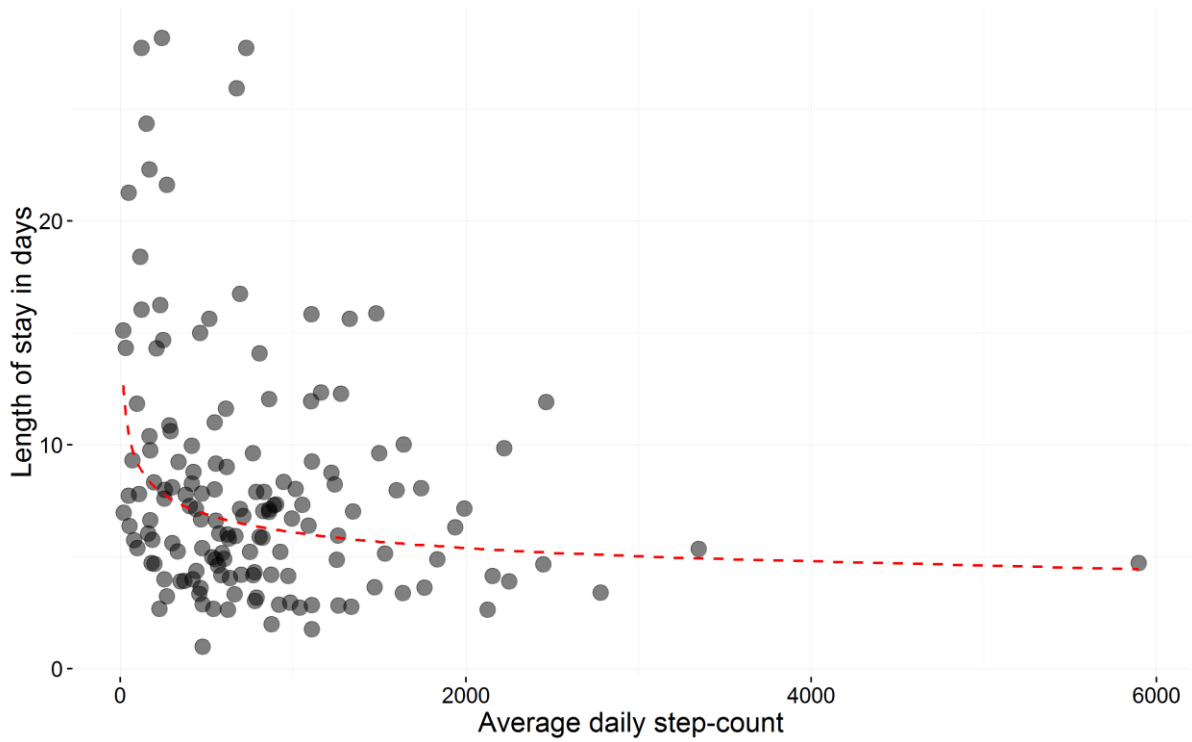
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Walking in hospital is associated with a shorter length of stay

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

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563

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

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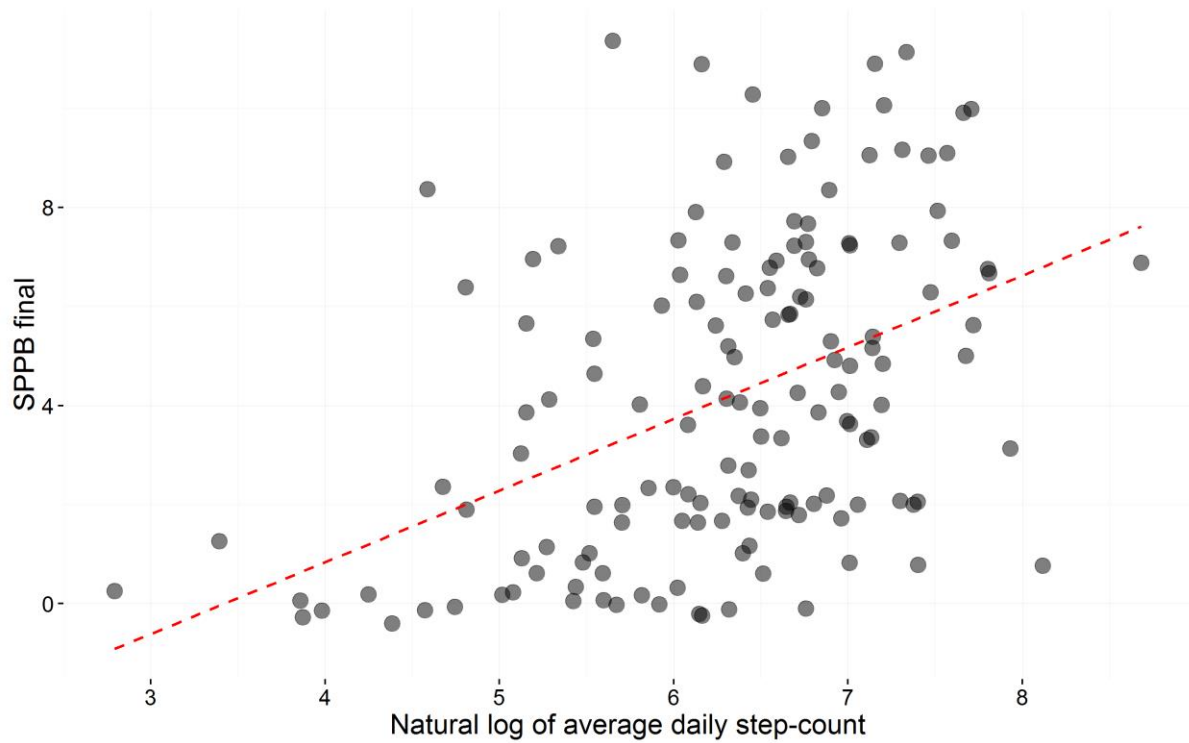
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571 **Supplemental Figure 2.** The linear relationship between end of study physical performance
572 (SPPB) and the natural logarithm of average daily step-count in a sample of 150 patients
573 (July 2014 to January 2015).

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575

576 *Caption: The red, dashed line is the unadjusted linear regression line reported in*

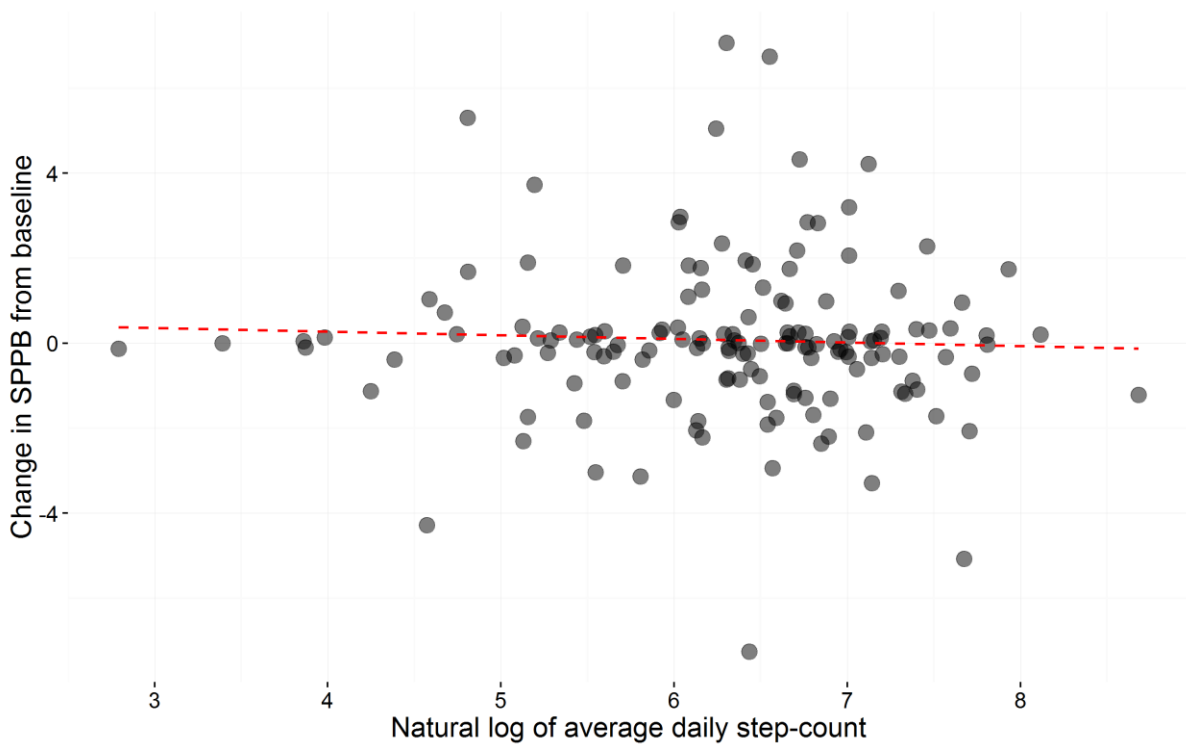
577 *Supplemental Table 1.*

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Walking in hospital is associated with a shorter length of stay

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

582



583

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

585

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Walking in hospital is associated with a shorter length of stay

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

	<i>Dependent variable: End of study SPPB</i>	
	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)

590 Abbreviations:

591 **SPPB:** Short Physical Performance Battery