Variations in Physical Activity and Sedentary Behavior During and After Hospitalization in Acutely Admitted Older Medical Patients: A Longitudinal Study

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Research Article

Keywords: Accelerometer, physical activity, sedentary, hospitalization, post-acute care, older adults

Posted Date: September 13th, 2021

DOI: https://doi.org/10.21203/rs.3.rs-864575/v1

Abstract

Background: Inactivity and bedrest are frequent among older patients during hospitalization and are associated with functional decline. No longitudinal objective evidence exists on how patients' diurnal profile for physical activity changes during acute hospitalization and what happens when the patient is discharged to own home. By the use of accelerometers, this study aims to describe and compare the distribution of physical activity and sedentary behavior in acutely hospitalized older patients during hospitalization and after discharge.

Methods: The study population consisted of 80 patients (+65 years) from the STAND-Cph trial, who were admitted with acute medical illness and were able to stand. Physical activity and sedentary behavior were measured as number of steps, uptime (walking/standing) and sedentary behavior (lying/sitting) per hour with an activity monitor worn on the thigh (activPAL3, PAL Technologies Ltd). The patients wore the monitor for three periods of one week: during hospitalization, after discharge, and four weeks after discharge.

Results: The patients' median age was 80 years [IQR: 75-88], 68% of the patients were female and The median DEMMI was 57 [IQR: 48-67]. The daily median uptime was 1.7 h [IQR: 1-2.8] during hospitalization, 4.0 h [IQR: 2.7-5.4] after discharge and 4.0 h [IQR: 2.8-5.8] four weeks after discharge. The median number of steps was 728 [IQR: 176-2089], 2207 [IQR: 1433-3148], and 2622 [IQR: 1714-3865], respectively. During hospitalization, a small peak was observed both for number of steps and uptime between 9-11 AM. However, the diurnal profile had no notable variation. At discharge and four weeks after discharge, the median of physical activity peaked 2-3 times and had mostly the same diurnal profile.

Conclusion: Older hospitalized patients spend most of their time engaged in sedentary behavior, where their main activity peak is in the morning between 9-11 AM. The uptime doubles and the number of steps triples after discharge, where peaks of activity are seen throughout the day. This indicates that daily routines are disrupted during hospitalization and that older patients have the potential to be more physically active during hospitalization. This emphasizes the need for interventions that encourage physical activity throughout the day during hospitalization.

Introduction:

Sedentary behavior among patients aged 65 years or older is linked to several adverse health outcomes [1], such as chronic conditions [2], cardiovascular disease, diabetes, poor mental health [3], dementia [4], poor quality of life [5], cancer [2], rehospitalization [6] and mortality [7-10]**.** Worldwide, the proportion of older adults over 65 years of age is growing rapidly [11]. Similarly, hospitalization rates are expected to continue to increase [12, 13]. For instance, in 2018, persons aged 65 years and older accounted for more than 40% of Denmark's acute hospitalizations [14]. The increasing demand for healthcare in this segment of the population is a global phenomenon [13]. Consequently, attention is

increasingly being given to factors contributing to more effective interventions and care for older (65+) patients during illness [15-18]. However, hospitalization is reported as an independent risk factor for loss of the ability to walk [19], loss of independence [20, 21], and functional decline after discharge, potentially leading to a higher level of sedentary behavior [19, 21, 22]. Multiple studies have assessed physical activity and sedentary behavior among older hospitalized patients [23] and have shown that older adults, including those who are able to walk independently [24-27], are inactive during the entire hospitalization period. The mean uptime (standing or walking) is reported to be 70 min. per day [23]. Also, a study by Zisberg et al. 2007 [28] found clear disruptions to the self-reported frequency, duration, and timing of patients' basic daily routines during hospitalization compared to pre-hospitalization. Preservation of basic daily routines is highly important, and promotes functional status, quality of sleep, and wellbeing [29-36]. Interestingly, Monk et al. found that irregularities in routines were linked to adverse outcomes such as depression, poor sleep quality and unhealthy aging [37, 38]. However, during hospitalization a hospital department's routines may conflict with older patients' routines. Therefore, an objective evaluation of the impact of hospitalization on patients' activity patterns is needed. To the best of our knowledge, there are no previous longitudinal studies investigating physical activity and sedentary behavior with repeated objective measurement, focusing on pattern variation during hospitalization and after discharge. Hence, the aim of this study was to assess and compare daily and hourly patterns in step count, time spent in uptime and sedentary behavior during hospitalization and after discharge in a group of older patients (+65) using accelerometers.

Methods:

Design and patients

This study is based on data from the randomized, controlled STAND-Cph trial, which was conducted in two steps (N=158) from September 2013 to January 2018 at Copenhagen University Hospital Hvidovre in Denmark and in the patients' own homes. A full trial protocol is available with open access [39]. Briefly, the primary aim of the STAND-Cph trial was to investigate the effect of supervised, progressive strength training and post-training protein supplementation during and after hospitalization on mobility in older patients (≥ 65 years) admitted with acute medical illness. All included patients were home dwelling and were excluded on the following criteria: terminal illness; in treatment for diagnosed cancer; diagnosis of Chronic Obstructive Pulmonary Disease (COPD) and participation in a COPD rehabilitation program; inability to speak or understand Danish; inability to cooperate in tests/exercises; transfer to the intensive care unit; isolation-room stay; expected hospitalization lasting < 24 h; or inability to stand [39]. The patients were randomized to either the control group or the intervention group. This study involved patients allocated to the control group, who received routine care during hospitalization and following discharge [39]. The STAND-cph trail has been approved by the Ethics Committee of the Capital Region of Denmark (H-2-2012-115) and by the Danish Data Protection Agency (2007-58-0015). All participants gave written informed consent before participation, and the study was conducted in line with the Declaration of Helsinki.

Assessment of physical activity

Physical activity was assessed with an activity monitor worn on the thigh (activPAL3™, PAL Technologies Ltd., Glasgow, UK). The patients were asked to wear the monitor from the time of inclusion until discharge. After discharge, the patients wore the activity monitor for two periods of one week: immediately after discharge, and 4 weeks after discharge. The activPAL3™ recorded data continuously for 7 days, and the hourly number of steps taken, time spent standing, walking and sitting/lying (sedentary behavior) were measured. We regarded a day to extend from 12:00 A.M. until 12:00 A.M. to optimize the number of full days with 24 h of measurement and to avoid half-day measurements, as patients were usually enrolled in the study in the morning. This was in accordance with a previous observational study prior to this randomized clinical trial [25]. To avoid the inclusion of distorted days in the analysis, only patient-days with more than 20 h of measurements were included. Also, in the analysis we only included the first 6 days of hospitalization because very few patients were hospitalized for more than 6 days. ActivPal3™ has been shown to be valid and reliable for measuring walking at speeds of 0.67 m/s and above in healthy adults [40, 41], and transitions and posture in both healthy and functionally impaired older adults [42, 43]. However, the monitor has limited reliability for walking speeds below 0.67 m/s [41], why time spent in walking and standing were combined into one category, uptime [44].

Assessment of patient characteristics

The following descriptive variables were collected on admission: age, sex, weight, living status, history of smoking, use of ambulatory aids, and use of municipal assistance. Also, mobility was assessed on admission by the New Mobility Score (NMS) [45] and the De Morton Mobility Index (DEMMI), which is scored from 0 to 100 points where 100 points reflect a high level of mobility and a score below 62 is considered limited mobility [46, 47]. Furthermore, self-reported physical activity and NMS 14 days prior to admission were also assessed [48, 49].

Data management and analysis

The collected data were double entered into Epidata Entry 3.1 by the first and last author and two assistants. Data from the activPAL3™ monitors were downloaded using activPAL™ Professional software version 7.2.32 and transferred to SAS Enterprise Guide 7.1 (SAS Institute Inc., Cary, NC, USA). Depending on the distribution of the variables, data are presented as means with standard deviations, medians with interquartile ranges or frequencies with percentages. To determine changes in uptime (standing/walking), sedentary behavior (time spent lying/sitting) and steps, we log transformed the variables and used paired t-test to calculate difference between hospitalization, discharge and 4 weeks after discharge. The chi-squared ($\chi 2$) test and the Student´s t test were used to determine differences between patients included in the analysis and those who dropped out with regards to sex, age and DEMMI-score.

Results:

In the STAND-Cph trial, 158 patients were included and 80 patients were randomized to the control group and thereby included in this study. In the control group, 65 patients wore the accelerometer in one or more assessment timepoints. In total, 48 patients wore the accelerometer during hospitalization, 49 after discharge, and 43 patients four weeks after discharge. A total of 28 patients were lost to follow-up between hospitalization and 4 weeks after discharge. The reasons for missing data were: retreat from the study because of tiredness (n=10), withdrawal of consent (n=7), readmission with apoplexy (n=5), severe pain (n=3), cancer (n=1), abdominal surgery (n=1), and loss of contact with the subject (n=1).

Baseline characteristics

The characteristics of the participants are shown in (Table 1). The patients´ median age was 80.9 years (IQR: 75-88), 69% were women, 98% were living at home, and 68% were living alone. At baseline, the median DEMMI score was 57 (IQR: 48-67) and 46% reported two hours or more of activity per day before admission. The median length of stay was 4 days (IQR: 2-6.5), and 41% were admitted to the hospital with respiratory symptoms.

Table 1

Baseline characteristics of patients.

Baseline variables	N	Overall
Demographic characteristics		
Age (median, IQR)	80	80.9 (75-88)
Sex (female, %)	80	55 (68%)
Length of stay	80	4 (2-6.5)
BMI[1]	80	26 (22.6-30.1)
Co-morbidities (median, IQR))	80	4 (3-5)
Living alone: (number, %)	80	54 (68%)
Self-reported activity level prior to admission:	80	
<2 hours (N, %)		43 (54%)
2-4 hours (N, %)		26 (33%)
>4 hour (N, %)		11 (13%)
New mobility score (median, IQR)		
Fourteen days prior to admission	80	7 (6-9)
Admission	80	6 (4-9)
DEMMI[2] (median, IQR)	79	57 (48-67)
BARTEL-20 (median, IQR)	79	19 (18-20)
OMC [3]	68	23 (18-26)
Walking speed m/s (median, IQR)	80	0.67(0.48-0.87)
Smoking:	80	64 (80%)
Smoking (no. yes, %)		13 (16.25)
Previous (no. yes, %)		51 (70.8%)
Assistive device (no., %)	80	26 (31%)
Walking stick		21 (26%)
Crutches		5 (6%)
Use of municipal help	80	46 (57.5%)
Personal assistance (no. yes, %)		7 (8.8%)
Food service (no. yes, %)		13 (16.3%)
Cleaning (no. yes, %)		10 (12.5%)

Admission diagnosis	80	
Pulmonary		33 (41%)
Cardiovascular		19 (24%)
Neurological		12 (15%)
Other		16 (20%)

Results are expressed as median (interquartile range) for continuous variables and as number of participants (percentage) for categorical variables. [1]: Body mass index (kg/m2). [2]: De Morton Mobility Index. [3]: Orientation-Memory-Concentration test.

Variation in steps, uptime and sedentary behavior measured during hospitalization and after discharge.

During hospitalization, the patients took approximately 67-70% fewer steps per day and spent 57% less time in an upright position (uptime) than at discharge and four weeks after discharge ($p < 0.001$). They took 728 (IQR: 176-2089), 2207 (IQR: 1433-3148) and 2622 (IQR:1714-3864) steps respectively. However, there was no significant difference between discharge and four weeks after (Table 2).

Table 2

Number of steps, time spent in uptime and sedentary behavior during the three periods.

Test time:	Patients	Steps (number per day)	Uptime (hours per day)	Sedentary behavior (hours per day)
Hospitalization	48	728 (176-2089)	1.7 (1.0-2.8)	21.4 (20.7-22.4)
Discharge	49	2207 (1433-3148) *$p<0.001$	4.0 (2.7-5.4) *$p<0.0001$	19.5 (18.1-21.0) *$p<0.001$
Four weeks after discharge	43	2622(1714-3865) **$p<0.2$	4.0 (2.8-5.8) **$p < 0.53$	19.6 (18.0-20.8) **$p <0.67$

Table 2: Daily number of steps, time spent in uptime and sedentary behavior during hospitalization, after discharge and four weeks after discharge. Results are expressed as medians with first and third quartile. Between-group comparison using paired t-test. *: The p-value was <0.001 between hospitalization and discharge and between hospitalization and four weeks after discharge. **: between discharge and four weeks after.

During hospitalization, the first steps were taken at 8 AM and reached a small peak at 11 AM (Figure 1). With regard to uptime (Figure 2), a peak was reached at 9 AM and persisted to 11 AM. Figures 1 and 2 show nearly straight-line median curves with no notable variation in steps per hour and a small peak in uptime between 9 and 11 AM, with no subsequent variation. However, after discharge, the patients'

diurnal profiles changed. The participants took their first steps at 7 AM, and the number of steps reached a peak at 10 - 11 AM that lasted two hours. Additionally, another peak was reached at 5 PM that lasted one hour. Four weeks after discharge, the patients' diurnal profile for steps resembled the pattern after discharge, but there was an additional peak reached at 3 PM that lasted one hour. The patients' uptime was 4.0 h (IQR: 2.7-5.4) per day after discharge and 4.0 h (IQR: 2.8-5.8) per day four weeks after discharge. The median time spent in sedentary behavior was 21.4 (IQR: 20.7-22.4), 19.5 (IQR: 18.1-21.0), and 19.6 (IQR: 18.0-20.8) hours per day during hospitalization, after discharge, and four weeks after discharge, respectively. During hospitalization, the patients spent most of their time in sedentary behavior (Figure 3), with 93% of the daytime spent lying or sitting. From 7–8 AM, the patients' median time spent in sedentary behavior was 55-59 minutes (IQR: 47-60) per hour (Figure 3). Between 9–11 AM, when the patients' exhibited the least sedentary behavior, the time spent lying or sitting decreased to 53.5 minutes (IQR: 44.3-60). After 12 PM, the patients' time spent in sedentary behavior was 56 minutes or more per hour for the rest of the day. At discharge and four weeks later, the patients spent 80% of the daytime in sedentary behavior. From 7 AM, the patients' median time spent in sedentary behavior was 51-53 minutes, decreasing between 10 – 12 PM to 43-44 minutes.

Discussion:

To our knowledge, this is one of the first studies measuring physical activity during and after hospitalization with an accelerometer in a heterogeneous group of older patients hospitalized for acute illness. Our results show that during hospitalization, the patients spent most of their time engaged in sedentary behavior and took fewer steps and were less physically active than after discharge. The included patients moved less than 900 steps per day and were therefore at risk of hospitalization-associated functional decline [17]. During hospitalization, the diurnal profiles for steps and uptime showed no notable variation in activity after 9 AM whereas we found a characteristic diurnal profile for steps and uptime after discharge and four weeks after discharge with most physical activity occurring between 9-11 AM, 14-16 PM and 17-18 PM. Hence, differences were seen in the number of steps taken, the time spent in uptime, and peaks in activity during the day. However, no remarkable difference was seen between discharge and four weeks after discharge. During hospitalization, the patients spent 93% of the daytime engaged in sedentary behavior and spent 1.7 hours upright This is consistent with a review of studies in acute-care settings in which the daily time spent lying or sitting accounted for 89–99%, and the duration of uptime was 1–2 hours per day [23]. A second important finding was that during hospitalization only one minor peak in uptime occurred at 9 AM. This suggests that the patients only get out of the bed in the morning, maybe for the morning toileting or breakfast, and spent most time engaged in sedentary behavior for the rest of the day. However, right after discharge and four weeks later, several peaks in activity occur at similar timepoints throughout the day. The doubling in the duration of uptime, and the consequent decrease in sedentary time after discharge, in conjunction with the lack of a second peak in activity during hospitalization suggests that sedentary behavior is a result of a culture of bed rest at the departments and that the patients could potentially be more physical active.

A study by Mai et al. [50] analyzed the diurnal physical activity profile in non-hospitalized, community-dwelling individuals older than 70 years. Consistent with our study, they identified two peaks, one at 10-11 AM and a second at 3-4 PM; sex, age, morbidity, and season had no moderating effects. Limited mobility was the only factor that significantly moderated the profile, reducing the number of peaks to one, which could supports the lack of a second peak in our group during hospitalization, since the median DEMMI score in the included patients was 57 on admission, which reflect limited mobility. In contrast to our study, a recent study by Tasheva et al. [51], which assessed the distribution of physical activity levels in older patients hospitalized for acute medical illness, found three peaks of physical activity during the day: between 8-10 AM, at 12 PM, and at 6 PM. Tasheva et al. proposed that older inpatients are primarily active during meals, as reflected in the three peak times. Although the patients in our study did receive three meals per day, this was not reflected in their peak times and may indicate that meals were consumed close to or in bed. This is well in line with recent studies by our research group, Pedersen et al. 2020 [52] and Stefánsdóttir et al. [53], that investigated facilitators and barriers for mobility during hospitalization. They found that the barriers for mobility in this patient group were the provision of excessive service and care by the department, a culture of bed rest, and lack of encouragement by health care professionals to motivate the patients to increase activity. Also, Stefansdottir et al. reported that the staff brought food, beverages, and clothes to patients, including those who were able to get out of bed and walk.

We consider all of these barriers explanations for the lack of a second peak during hospitalization in our study. After discharge and four weeks after discharge, the patients started physical activity one hour earlier and had higher levels of physical activity in the morning and afternoon hours. Moreover, the peaks persisted longer and declined more gradually. These findings are consistent with those of Zisberg et al. [28], who showed that the timing of getting dressed in the morning moved an hour and a half during hospitalization, and most basic activities were reduced in frequency and duration. Our findings indicate that older patients could potentially be more physically active during hospitalization and emphasize the need for interventions that encourage more physical activity during hospitalization. It could be in the form of simple routine activities, such as patients eating their breakfast out of bed in a common room and changing clothes by themselves. Another starting point for the effort to increase patients' physical activity during hospitalization could be to encourage physical activity around 10-11 AM, 3 PM, and 5-6 PM, which would be more consistent with their habitual. Our findings are also consistent with a recent study by Kolk et al. [54], which showed a doubling in steps only one day after discharge compared with one day prior to discharge. Presumably, the relatively high level of activity after discharge in our study, with a median of 2207 steps per day after discharge and 2622 four weeks after discharge, indicates that patients' return to their basic routines occurs earlier than expected, our results indicate a recovery of activity the first week after discharge.

It is known that older patients are vulnerable to disturbances in their routines and that this can lead to delirium during hospitalization [55]. Thus, suggested efforts should be made to re-establish routines among those at risk of loss of functional decline and delirium. Since our results showed a wide range in steps, uptime and sedentary behavior, a personalized intervention strategy would be a reasonable means

of optimizing physical activity during hospitalization. Recently, guidelines on physical activity for admitted older patients have also highlighted the importance of integrating physical activity throughout daily care, with a focus on functionality and activities of daily living; and bearing in mind that it is important for patients and staff to share the responsibility of promoting physical activity and minimizing sedentary behavior [16]. An alternative method of providing clinical care to a segment of this group of older patients has recently been suggested in a systematic review [56], which found that hospital-at-home (HaH) treatment may be a clinically effective approach and suggested that this treatment method may result in less functional decline in patients than the traditional ward-based treatment method. However, further research is needed, and the implementation of this alternative method of treatment (HaH) would necessitate significant changes to the current practice as well as time, it can takes several years making structural changes in the healthcare systems. In the short term, a relevant indicator is needed to identify patients at a high risk of inactivity during their time in the hospital. In the long term, systematic changes in the hospital environment and care setting are needed where the responsibility to encourage physical activity should be a shared responsibility and delegated to all health professionals.

Strengths and limitations:

This study's major strength was the longitudinal measurement of physical activity during hospitalization, at discharge, and at four weeks after discharge in a heterogeneous cohort of older adults hospitalized for acute illness. This study has some limitations. First, we assessed number of steps using the activPAL3™ activity monitor, which has an uncertainty in detecting walking at speeds less than 0.67 m/s [40,41]. At baseline, the patients in the current study had a median walking speed of 0.67 (IQR: 0.48-0.87), and therefore likely that walking was underestimated in some patients. An underestimation would affect the absolute level of steps, but not affect the distribution of activity throughout the day as a result of we are looking at uptime (walking and standing), therefore the diurnal physical activity profiles may be regarded as a true reflection of older adults' patterns of daily physical activity.

Conclusion:

This study showed that in older acutely admitted adults the diurnal activity profile during hospitalization was distinct from the diurnal profile when the patients returned home. During hospitalization, the patients took fewer steps, spent less time standing and walking, and spent most of their time engaged in sedentary behavior. The first week after discharge, the patients doubled their time spent standing and walking and lowered their time spent in sedentary behavior, suggesting that sedentary behavior is a result of a culture of bed rest in the hospital. Therefore, general mobility regimes and motivation should be provided to all patients during acute hospitalization.

Abbreviations

IQR: interquartile range; BMI body mass index; DEMMI: De Morton Mobility Index; MSE: Mini-Mental State Examination; NMS: New mobility score

Declarations

Ethics approval and consent to participate:

All participants gave written informed consent before participation and the study procedures were approved by the Ethics Committee of the Capital

Region of Denmark (H-2-2012-115) and by the Danish Data Protection Agency (2007-58-0015).

Consent for publication:

Not applicable.

Availability of data and materials:

The data supporting the conclusions of this article are included within the article. The datasets analysed in this study are not publicly available due to regulations set out by the European and Danish Data Protection Agency regarding data anonymization but are available from the corresponding author on reasonable request.

Competing interests:

The authors declare that they have no competing interests.

Funding:

This study was funded by the Danish Ministry of Health (grant number 9170); Danish Regions/The Danish Health Confederation; the Lundbeck Foundation (UCSF) (grant numbers FP 07/2012, FP 48/2012 and FP 61/2013); the Research Foundation of Hvidovre Hospital; the Capital Region of Copenhagen; and The Danish Foundation for Research in Physiotherapy. The funding bodies have had no authority over study design, collection and interpretation of data, or the writing of the manuscript.

Authors' contributions:

MMP and JP, designed the original study. MMP was the primary investigator and project leader and responsible for patient recruitment and data management for the STAND-Cph trial. BNJ, MMP, OA and JP designed these secondary analyses. BNJ and MMP performed the data management. BNJ was responsible for analyzing the data in this study under supervision of MMP and JP. BNJ wrote the first

manuscript draft. Hereafter, all authors BNJ, MMP, OA and JP revised the manuscript critically. All authors approved the final version to be submitted for publication.

Acknowledgment:

We thank Thomas Bandholm for his contribution to the study design, the Emergency Department at Copenhagen University Hospital Amager and Hvidovre, Denmark, and the staff at Department of Clinical Research, Copenhagen University Hospital Amager and Hvidovre, Copenhagen, Denmark for the work during data collection.

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Figures

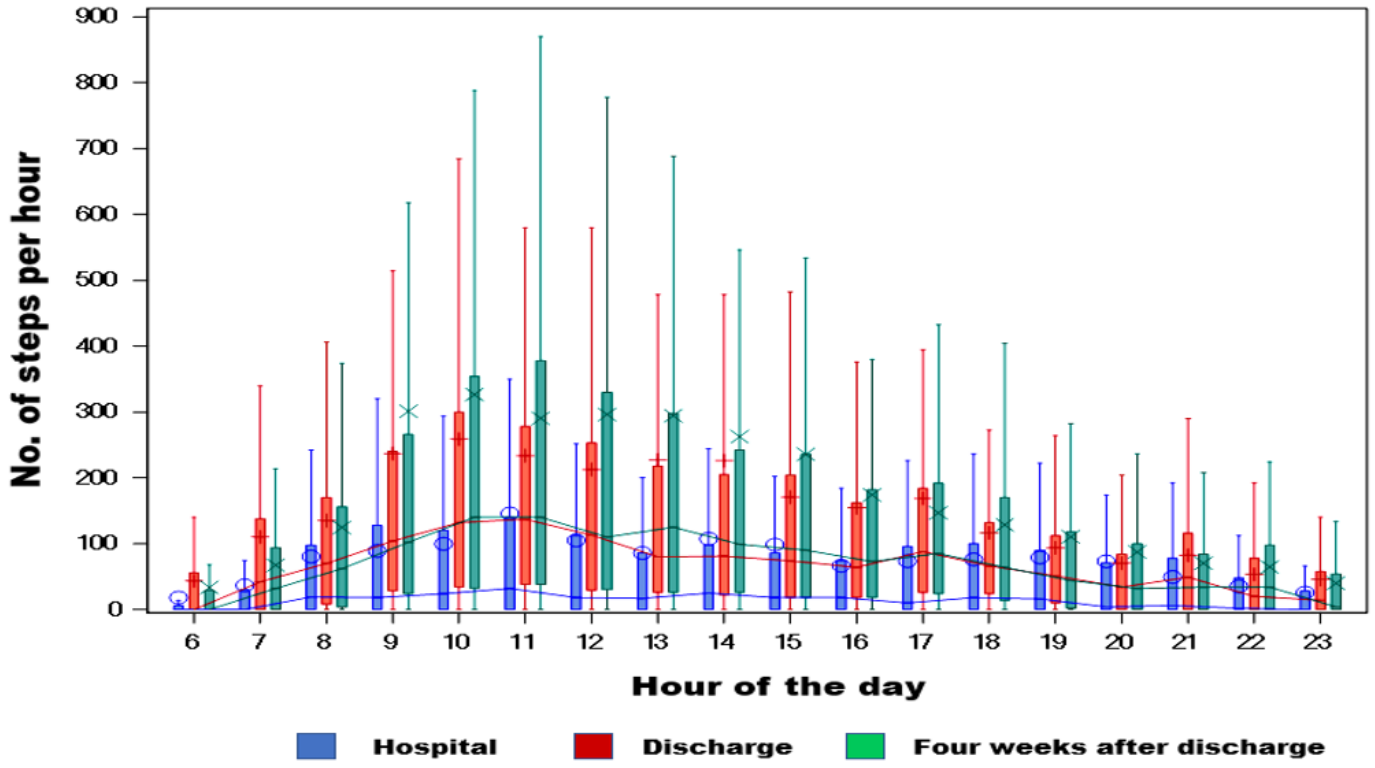

Figure 1

Number of steps taken per hour from 6 am to 11 pm. Boxplots illustrating lower quartile, median, upper quartile and extremes per hour during hospitalization (blue), after discharge (red) and four weeks after discharge (green). The lines (blue, red, green) connect the medians during the day. X-mark (green), line-mark (red) and circle-mark (blue) illustrating the mean.

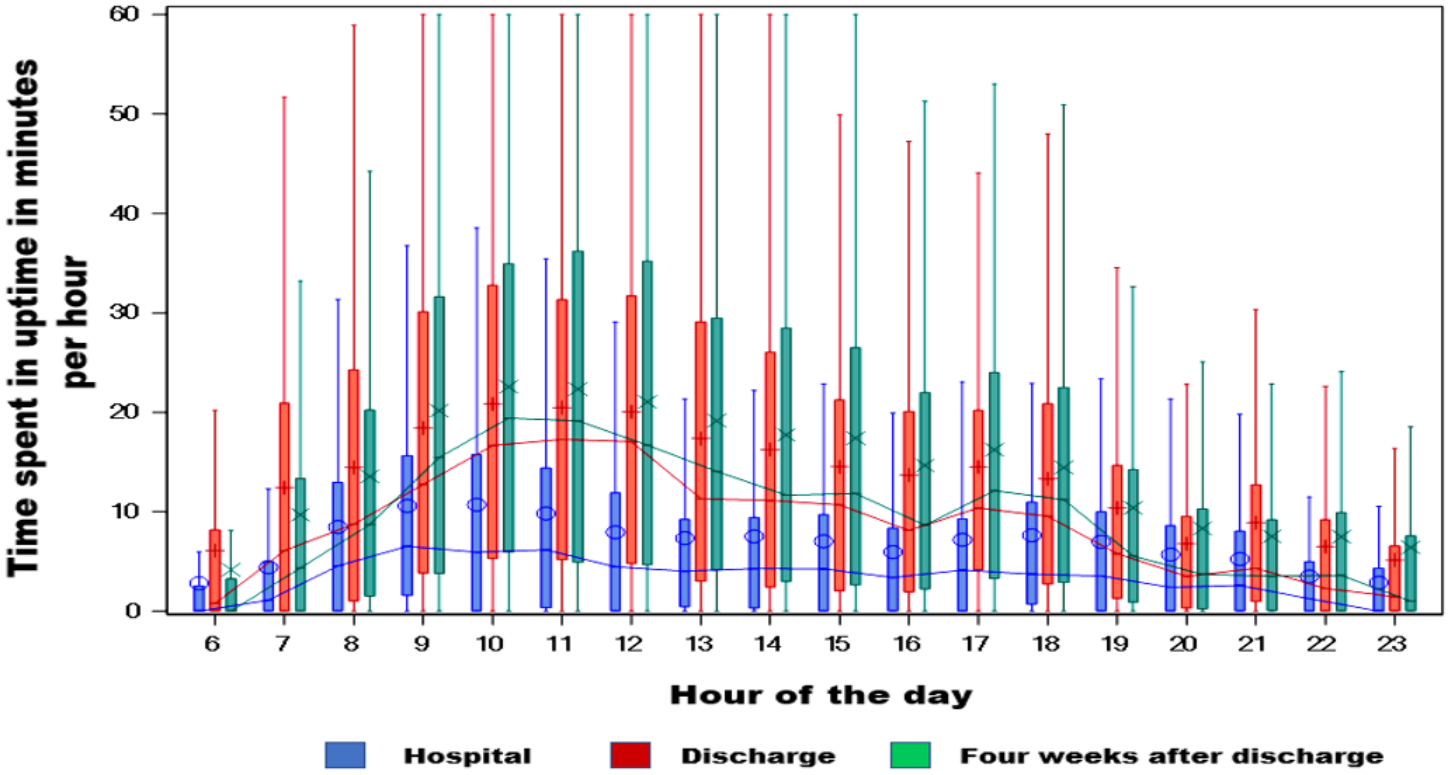

Figure 2

Time spent standing or walking (uptime) in minutes per hour from 6 am to 11 pm. Boxplots illustrating lower quartile, median, upper quartile and extremes in minutes per hour during hospitalization (blue), after discharge (red) and four weeks after discharge (green). The lines connect the medians during the day. X-mark (green), line-mark (red) and circle-mark (blue) illustrating the mean.

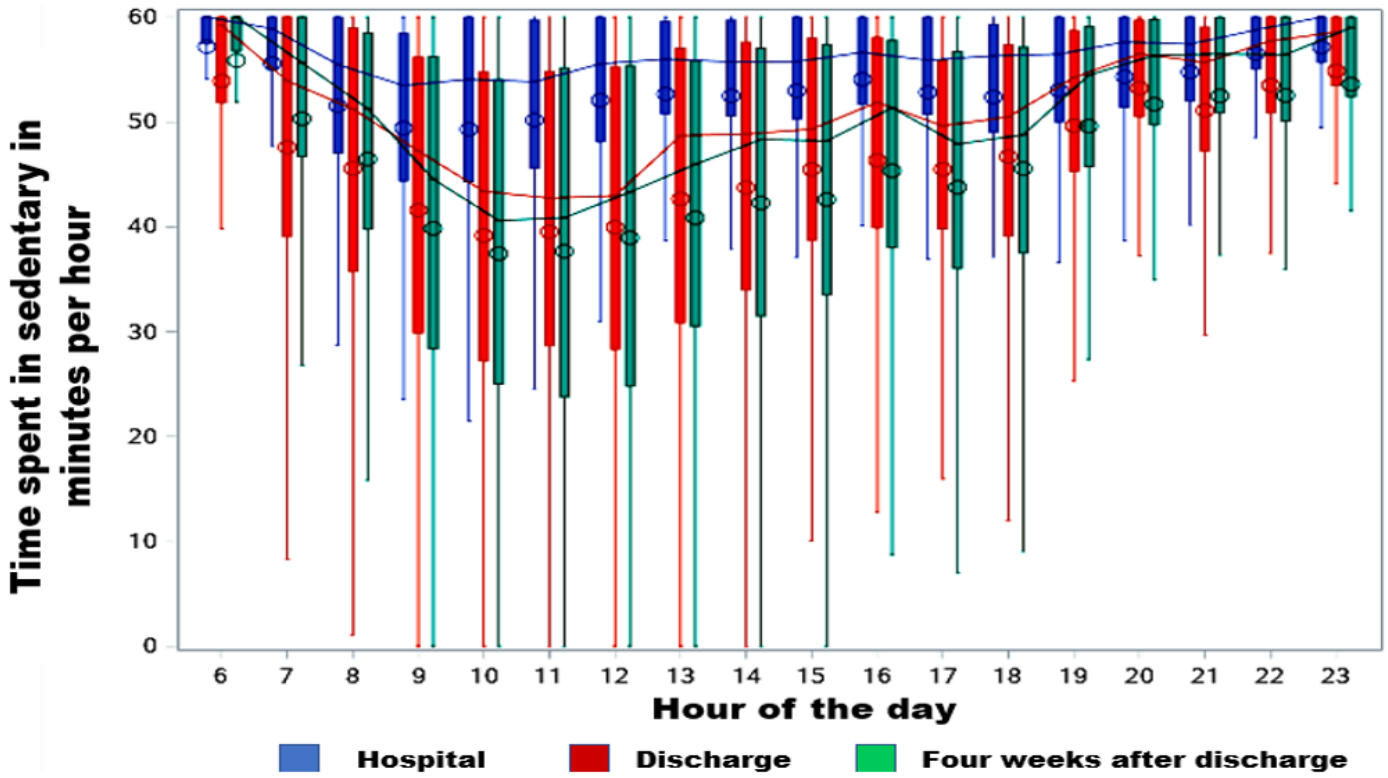

Figure 3

Time spent sitting or lying (sedentary behavior) in minutes per hour from 6 am to 11 pm. Boxplots with lower quartile, median, upper quartile and extremes in minutes per hour during hospitalization (blue), after discharge (red) and four weeks after discharge (green). The lines connect the medians during the day. X-mark (green), line-mark (red) and circle (blue) illustrating the mean.