Changes in physical activity during hospital admission for chronic respiratory disease

Mark W Orme[1], Theresa C Harvey-Dunstan[1,2], Ismet Boral[3], Emma JL Chaplin[1], S Fayyaz Hussain[3], Mike DL Morgan[1], Michael C Steiner[1,2,4,5], Sally J Singh[1,4,5], Neil J Greening[1,2]

[1], Centre for Exercise and Rehabilitation Science, NIHR Leicester Biomedical Research Centre – Respiratory, Leicester, UK

[2], Department of Infection, Inflammation and Immunity, University of Leicester, Leicester, UK

[3], Respiratory Department, Kettering General Hospital NHS Foundation Trust, Kettering, UK

[4], Loughborough University, School of Sport, Exercise and Health Sciences, Loughborough, Leicestershire, UK

[5], National Centre for Sport and Exercise Medicine, UK

CORRESPONDING AUTHOR DETAILS

Mark Orme

Centre for Exercise and Rehabilitation Science

NIHR Leicester Biomedical Research Centre - Respiratory

Glenfield Hospital

Leicester

United Kingdom

LE3 9QP

Tel: 0116 250 2762

Email: mark.orme@uhl-tr.nhs.uk

ABBREVIATIONS LIST

ANCOVA	Analysis of covariance
COPD	Chronic Obstructive Pulmonary Disease
CI	Confidence interval
ICC	Intraclass correlation coefficient
METs	Metabolic equivalents
MRC	Medical Research Council
PA	Physical activity
SD	Standard deviation
SWA	SenseWear Armband

SUMMARY AT A GLANCE

Objectively measured inpatient physical activity (PA) was examined for 259 individuals hospitalised due to an acute exacerbation of chronic respiratory disease. PA did not recover as an inpatient, with patients averaging 616±649 steps/day. A single day of PA monitoring provided data representative of the entire inpatient stay.

Key words: Accelerometer, Acute exacerbations, Hospitalisation, Physical activity, Physical activity measurement

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ABSTRACT

Background: Establishing the amount of inpatient physical activity (PA) undertaken by individuals hospitalised for chronic respiratory disease is needed to inform interventions. This observational study investigated whether PA changes as an inpatient, how long is required to obtain representative PA measures, and whether PA varies within a day and between patients of differing lengths of stay.

Methods: 389 participants were recruited as early as possible into their hospitalisation. Patients wore a PA monitor from recruitment until discharge. Step count was extracted for a range of wear time criteria. Single-day intraclass correlation coefficients (ICCs) were calculated with an ICC ≥0.80 deemed acceptable.

Results: PA data were available in 259 participants. No changes in daily step count were observed during the inpatient stay (586 [95%CI 427-744] vs. 652 [95%CI 493-812] steps/day for day 2 and 7, respectively). ICCs across all wear time criteria were >0.80. The most stringent wear time criterion retaining 80% of the sample was ≥11 hours on ≥1 days. More steps were taken during the morning and afternoon than overnight and evening. After controlling for MRC grade or oxygen use, there was no difference in step count between patients admitted for 2-3 days (short-stay) and those admitted for 7-14 days (long-stay).

Conclusion: Inpatient PA did not increase during hospitalisation. A wear time criterion of 11 waking hours on any single day was representative of the entire hospital stay whilst retaining an acceptable proportion of the initial sample size. Patients should be encouraged to move more during their hospital stay.

INTRODUCTION

Physical activity (PA) is a complex behaviour typically defined as "any bodily movement produced by skeletal muscle which results in caloric expenditure".[1] Patients with respiratory disease are less physically active than healthy counterparts[2] and other populations with long-term conditions.[3] A lack of sufficient PA has been independently associated with all-cause mortality[4] and hospitalisation[5] in stable patients and readmission for patients recently experiencing an acute exacerbation of chronic obstructive pulmonary disease (COPD).[6]

Hospitalisation for an exacerbation is an important event in the history of COPD, with high rates of readmission and death.[7] Exacerbations also have considerable impact on the whole body, increasing risk of future events.[8,9] Hospital bed rest has also been associated with muscle atrophy and thromboembolic disease.[10] Establishing the volume and pattern of PA during the hospital stay is needed to inform inpatient and reablement interventions.

The need to get patients moving more in hospital has long been advocated[11] but PA remains low, with inpatients spending approximately 87% of time lying down, minimal improvement seen during the stay and patients remaining inactive after discharge.[12-14] However, conclusions are limited due to small sample sizes in reported studies and heterogeneity in PA data processing; including how many days and for how long each day individuals are required to wear an activity monitor in order to obtain representative data. Validated activity monitors such as the SenseWear Armband[15], measuring not only movement, but also physiological parameters, offer an opportunity to understand the impact of wear adherence on the representativeness of PA data by automatically detecting whether or not the device is being worn.

Objective assessments of PA using accelerometry for patients in the stable state are well accepted. A minimum of 4 days of at least 8 waking hours are recommended criteria to examine free-living PA for individuals with stable COPD.[16] However, it is unclear whether these criteria would be appropriate for measuring inpatient PA. The hospital environment does not mimic free-living conditions; potentially restricting walking to a greater extent than at home[12] and may reduce day-to-day variability in PA. Additionally, in free-living studies, participants commonly wear a monitor for a fixed number of days but the number of days people are hospitalised varies[17] rendering this approach unsuitable.

This study aimed to; (i) determine the variability of PA during inpatient stay for an exacerbation of chronic respiratory disease and minimum wear requirement to be representative of the hospital stay; and (ii) measure how PA changes during inpatient recovery. It was hypothesised that inpatient PA would be less variable than free-living studies, resulting in fewer days required to obtain data representative of the hospital stay. In addition, it was hypothesised that there would be no change in PA as an inpatient. Exploratory analyses were conducted to examine how PA varies within a day and between patients of differing lengths of hospital stay.

MATERIAL AND METHODS

Study subjects

Inpatient PA was obtained as part of an early rehabilitation trial previously reported.[18] This was approved by the National Research Ethics Service Nottingham committee and all participants provided written informed consent. 389 participants were recruited to the study as early as possible into hospital admission and randomised to usual care or early rehabilitation. Early rehabilitation comprised supervised strength, aerobic training and neuromuscular electrical stimulation. Additionally, all patients received standard ward-based physiotherapy, including assessment and supervision of mobility. Inclusion criteria were age ≥40 years; diagnosis of chronic respiratory disease; and Medical Research Council (MRC) dyspnoea grade ≥3 when stable. Exclusion criteria included concomitant acute cardiac event; presence of comorbidities preventing the delivery of early rehabilitation; and >4 emergency hospital admissions in previous 12 months. Activity monitors were removed during the additional rehabilitation intervention, so not to influence habitual PA. For this study, groups were pooled as there was no significant difference in PA between control and rehabilitation groups (mean±SD 657±712 vs. 577±582 steps/day, p=0.323).

Methods

Physical activity

PA was measured using the SenseWear Armband (SWA) Pro 3, worn as per manufacturer recommendations. Patients were asked to wear the monitor continuously from recruitment until their date of discharge. Data from the SWA was processed in 60-second epochs. Periods of non-wear were determined by the SWA failing to detect physiological signals. Waking

wear time was then extracted by removing time in SWA-detected sleep. Step count was extracted for each day the device was worn for at least one hour.

The first full 24-hour period of PA onwards was used for the analyses. Daily summaries for step count were created for minimum wear time criteria of ≥1 hour to ≥12 hours in increments of one hour. Acceptable sample retention was deemed 80%. Change in PA was assessed across inpatient days (day 2 to day 7 after recruitment) and variability in step count within the day was examined using hourly summaries. PA was compared between patients of differing lengths of hospital stay: short-stay (2-3 days), medium-stay (4-6 days) and long-stay (7-14 days).

Additional measures

Lung function was measured by spirometry performed to national standards.[19] Self-reported dyspnoea was obtained upon admission and reported retrospectively (during stable disease) using the MRC dyspnoea scale.[20]

Analysis

Descriptive data are presented as mean (SD) for continuous data. Pearson correlations were used to examine associations between continuous data. Repeated measures ANCOVA (waking wear time) were used to compare between days and between hours of the day. Greenhouse-Geisser adjusted F was used to determine statistical significance. For a significant F, post-hoc Bonferroni pairwise comparisons were used to identify differences between individual days or hours. ANCOVA was conducted to compare average step count between length of stay groups. Single-day intraclass correlation coefficients (ICCs; two-way mixed; consistency) were calculated across the range of wear time criteria. The minimum number of days required to obtain representative inpatient activity data (i.e. an ICC of 0.80)[21] was estimated using the Spearman-Brown prophecy formula.[22,23] Analyses were conducted using SPSS 23 with alpha set to 0.05.

RESULTS

Study recruitment

Inpatient PA data were available in 259 participants (67% of the total sample) (Figure 1), with a total of 1,393 days in hospital (mean±SD 5.4±3.1 days per person) of which 1,202

days (86.3%) had inpatient PA data (4.6±2.8 days per person). On average, patients wore the activity monitor each day during waking hours for 14.3±4.9 hours.

Patients included in the present study were significantly younger than patients excluded (70.0±9.7 vs. 73.5±9.2 years, p=0.001). No other differences in participant characteristics were observed between patients included or excluded from the original cohort.

Reasons for data not being available were; patients being discharged on the day of consent, not wearing the monitor and device malfunctions. 15 participants were excluded from analyses due to being admitted for more than 14 days.

Participant characteristics

Participant characteristics are provided in Table 1. Patients took a mean of 616±649 steps/day. Average daily step counts across the range of minimum wear time criteria are provided in Table S1. Patients receiving oxygen took fewer steps than those not (617 [95%CI 491-744] vs. 1058 [95%CI 848-1270] steps/day, p=0.001).

Changes in step count during the hospital stay

No significant changes in step count were observed between days during the inpatient stay (586 [95%CI 427-744] vs. 652 [95%CI 493-812] steps/day for days 2 and 7, respectively) (Table 2, Figure 2); and findings were unchanged after controlling for wear time. Across all wear time criteria, a single day of activity monitor data was sufficient to provide representative inpatient PA data. ICCs for step count across all wear time criteria were higher than 0.80; demonstrating that >80% of variance for PA was accounted for using any single day during hospital stay. Pairwise ICCs between days also revealed low variability in daily step count (ICC 0.669-0.907).

Impact of wear time and valid day criteria on sample size

The more hours a patient wears an activity monitor, the more representative the data. However, increasing the number of hours or days required to be considered a valid file will sample size retention. Using an 80% acceptable retention threshold, the most stringent criteria were ≥11 hours on ≥1 day and ≥7 hours on ≥2 days (Table S2). Given that a single day is representative of a patient's inpatient stay, a minimum wear time of ≥11 hours on ≥1 day was used as the processing criteria for data presented from this point onwards.

Accumulation of steps during a day in hospital

The pattern for step count during an average hospital day was examined by dividing the day into six hour slots (overnight, morning, afternoon and evening. Significant differences in the proportion of total daily step count were observed between quarters of the day (p<0.001) except between morning and afternoon (Figure 3). 50% of total daily steps were taken by 13:00 and 75% by 18:00.

Physical activity between patients of differing lengths of hospital stay

Patients admitted for 7-14 days (long stay; N=89) reported a higher MRC grade (p=0.006) and greater use of oxygen (p=0.047) during admission than patients admitted for 2-3 days (short stay; N=93). Short stay patient took more steps per day than long stay patients (956 [95%CI 734-1179] vs. 565 (95%CI 386-744]) but this difference was no longer present after controlling for MRC grade and oxygen use (p=0.368).

DISCUSSION

This study reports the largest cohort to date for the objective assessment of inpatient PA in patients admitted with an exacerbation of chronic respiratory disease, capturing more than 85% of inpatient days. PA did not increase during their hospital stay and the number of steps taken by patients was much lower than would be expected during free-living periods of stable disease. A minimum of 11 waking hours on any single inpatient day was representative of the entire hospital stay whilst retaining an acceptable proportion of patients recruited. PA varied considerably within a typical day, with peaks of activity seen in the late morning and early afternoon. PA did not differ between patients of varying lengths of hospital stay.

PA did not increase during hospital stay, demonstrating that recovery does not immediately translate into more walking. This observation aligns with Pitta and colleagues[12] who found no difference between day 2 and day 7 of hospitalisation in 17 individuals with COPD. Daily step count observed in the present study (616±649 steps/day) was lower than previously reported (1557±1319 steps/day)[24]. Regardless, physical inactivity of patients during an inpatient stay is unlikely to confine itself to individuals with respiratory disease; as highlighted by negative impact of prolonged bed rest in general adult populations.[25,26] Therefore, the constraints of the hospital setting appear to be the key ceiling on PA rather than disease or behavioural constraints which would increase variability in activity levels and a gradual increase towards discharge. In the UK, pressures on bed capacity may have

contributed to present study observations because once a patient starts being more physically active, they may be discharged and their improvement not captured.

The low day-to-day variation in step count meant that one day of at least 11 hours of PA data was sufficient to obtain a representative measure of the whole hospital stay whilst retaining sufficient sample size. In a study of individuals with stable COPD attending pulmonary rehabilitation, it was recommended that at least two days of step count data was required with variability plateauing at a minimum threshold of four days (n=57, SenseWear Pro Armband) based on an ICC >0.8.[16] Similarly, in healthy adults, a minimum of two to six days has been suggested across wrist-worn GENEActiv-derived physical activity.[27] The reduced variability in PA during hospitalisation in this study, compared with other studies of free-living data, confirms the need for specific inpatient PA criteria. Differences in how activity monitors determine wear time may also contribute, with the SWA using physiological sensing compared to sustained inactivity for physics-based devices. It does not matter how far into their hospital stay patients are when their PA is monitored but varying lengths of hospital stay between patients leads us to recommend measuring inpatient PA as soon as possible. Findings from the present study may help to reduce the patient burden of wearing an activity monitor when acutely unwell, allow measurements in patients with short admission durations and potentially enhance affordability and feasibility for researchers investigating PA in this setting.

The pattern of inpatient PA observed over the course of the day in the present study was similar to individuals with stable respiratory disease.[16,28] PA (stepping in the present study and metabolic equivalents in previous studies) peaked between 09:00 and 12:00. A secondary peak in hourly activity around 14:00 in this study was consistent with the stable disease literature[28,29] despite the differences in the setting where the current measurements were made. Patients in the present study were generally, confined to indoors with access to smaller spaces for movement, had a reduced number of activities of daily living to perform and were acutely unwell. The higher levels of activity earlier in the day may be the consequence of increasing fatigue as the day goes on, potentially coupled with investigatory measures conducted during typical working hours and visiting times (3-5pm and 6-8pm). It may also be that the habitual nature of free-living PA transfers to the hospital environment; albeit at a lower level.

Limitations of the present work should be considered. The SWA may not have been sensitive enough to detect all steps taken by patients, such as those taken at a walking speed <1.8km/hour, leading to an underestimation of step count.[30,31] In addition, the SWA only permits data to be exported in 60-s epochs. Therefore, it was not appropriate to investigate time spent walking due to the forced assumption that participants were walking for each full minute; which is likely to lead to a significant overestimation. Future work should explore the impact of shorter epochs in order to provide more accurate outputs for time spent walking as well as provide additional insights into patterns of PA.[32] Whilst most PA monitors follow the basic premise of measuring acceleration along one, two or three axes, differences in outputs exist between devices.[15] However, the examination of step count in the present study offers the most transferrable findings and may be most appropriate for assessing the PA of hospitalised individuals.

CONCLUSION

In the largest reported cohort with objectively measured inpatient PA in patients admitted with an exacerbation of chronic respiratory disease, the volume of PA did not change as patients recover in hospital and the variability in step count was low. A minimum wear time criterion of 11 waking hours on any single inpatient day was representative of the entire hospital stay whilst retaining an acceptable proportion of the initial sample size. Whilst it does not matter how far into their hospital stay patients are when PA is measured, we suggest capturing this information as early as possible due to varying lengths of hospital stay. Length of hospital stay was not associated with inpatient PA. PA varied considerably within a typical day, with peaks of activity seen in the late morning and early afternoon. The processing and analysing methods presented here may have positive implications for study designs; potentially minimising participant burden and reducing costs for researchers.

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CONFLICTS OF INTEREST STATEMENT

The authors declare no conflicts of interest.

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TABLES

Table 1 Participant characteristics, reported as mean (SD) unless otherwise stated.

Descriptive variable	**All participants (N=259)**
Age (years)	70.0 (9.7)
Gender (%): *Male/ Female*	108 (42)/ 151 (58)
BMI (kg/m^2)	26.5 (7.2)
Length of hospital stay (days)	5.4 (3.1)
Primary diagnosis (%): *COPD/ Chronic asthma/ ILD/ Bronchiectasis*	217 (84)/17 (7)/14 (5)/11 (4)
FEV_1 (L)	1.2 (0.6)
FVC (L)	2.3 (0.8)
FEV_1/FVC	52.2 (17.6)
FEV_1 % predicted	54.7 (23.4)
MRC grade at admission (%): *3/4/5*	5 (2)/67 (26)/187 (72)
MRC grade during stable disease (%): *3/4/5*	74 (29)/124 (48)/58 (22)
Smoking status (%): *Never/ Former/ Current*	19 (7)/177 (68)/63 (24)
NIV during hospital stay (%): *Yes/ No*	12 (5)/247 (95)
Oxygen during hospital stay (%): *Yes/ No*	184 (71)/75 (29)

Abbreviations: BMI, body mass index; COPD, chronic obstructive pulmonary disease; FEV_1, forced expiratory volume in one second; FVC, forced vital capacity; ILD, interstitial lung disease; MRC, Medical Research Council; NIV, non-invasive ventilation

Table 2 Changes in step count per day during the inpatient stay, intraclass correlation coefficients and required number of days of activity monitoring in order to acquire representative data, across a range of minimum wear time criteria

Wear time criteria	N	Step count (mean(95%CI))						ICCs	Number of days needed [A]	Number of days needed [B]
		Day 2	Day 3	Day 4	Day 5	Day 6	Day 7			
≥5 hours	58	605 (443-766)	622 (446-798)	663 (481-846)	642 (487-798)	707 (519-895)	659 (494-823)	0.834	0.80	1.0
≥6 hours	56	596 (429-763)	628 (447-810)	661 (473-790)	632 (475-790)	700 (507-892)	643 (475-812)	0.841	0.76	1.0
≥7 hours	53	625 (451-798)	658 (469-846)	688 (492-884)	661 (497-824)	734 (535-934)	678 (505-852)	0.835	0.79	1.0
≥8 hours	53	625 (451-798)	658 (469-846)	688 (492-884)	661 (497-824)	734 (535-934)	678 (505-852)	0.835	0.79	1.0
≥9 hours	50	599 (425-773)	655 (456-855)	674 (466-881)	612 (449-775)	707 (499-915)	654 (472-836)	0.854	0.68	1.0
≥10 hours	49	566 (402-730)	615 (429-800)	640 (440-839)	589 (430-749)	675 (473-877)	630 (451-808)	0.841	0.76	1.0
≥11 hours	44	585 (404-767)	646 (441-851)	676 (457-895)	613 (437-788)	704 (483-925)	668 (472-864)	0.839	0.77	1.0
≥12 hours	41	602 (410-794)	669 (451-886)	684 (452-915)	633 (447-819)	707 (476-939)	696 (488-904)	0.843	0.75	1.0

Abbreviation: CI, confidence interval; ICCs, Intraclass correlation coefficient for single day of measurement

N, number of participants with valid data for all days (days 2 through 7)

[A], minimum number of days needed to achieve an ICC of 0.80 calculated using the Spearman-Brown prophecy formula; [B], estimates from the Spearman-Brown prophecy formula should be rounded up (e.g., an estimate of at least 2.3 days should be interpreted as at least 3.0 days because 2.0 days will not be sufficient to obtain an ICC ≥0.80

FIGURE CAPTIONS

Figure 1 CONSORT flow diagram

Figure 2 Step count between inpatient days using a minimum wear time of ≥11 hours. Data are reported as mean (95%CI) from all available valid days (White bars; Day 2: N=194; Day 3: N=144; Day 4: N=107; Day 5: N=77; Day 6: N=63; Day 7: N=49) and from patients with valid data on all days (Grey bars; N=44).

Figure 3 Step count per hour as a proportion of total daily step count across an average 24-hour period using a minimum wear time of ≥11 hours; stratified by quarter of the day (overnight=00:00-05:59; morning=06:00-11:59; afternoon=12:00-17:59; evening=18:00-23:59). Data are reported as mean (95%CI).