European Journal of Internal Medicine 69 (2019) 50–56

Contents lists available at ScienceDirect

European Journal of Internal Medicine

journal homepage: www.elsevier.com/locate/ejim

Original Article

Evaluation of a technology assisted physical activity intervention among hospitalised patients: A randomised study

Christian Have Dall[a,b,c,*], Helle Andersen[a], Tina Myung Povlsen[d], Marius Henriksen[a,c]

[a] Department of Physical and Occupational Therapy, Bispebjerg Frederiksberg University Hospital, Copenhagen and University of Copenhagen, Denmark
[b] Department of Cardiology, Bispebjerg Frederiksberg University Hospital, Copenhagen and University of Copenhagen, Denmark
[c] The Parker Institute, Bispebjerg Frederiksberg University Hospital, Copenhagen and University of Copenhagen, Denmark
[d] VihTek, Rigshospitalet, Valdemar Hansens Vej 2, 2600 Glostrup, Denmark

ARTICLE INFO

Keywords:
Bedrest
Physical inactivity
Hospitalisation
Technology assisted physical activity
Visual feedback

ABSTRACT

Background: Physical inactivity is common during hospitalisation and poses a threat to functional capacity and independency in the elderly.
Aim: We aimed to assess the effect of physical activity measurements with visual feedback about time spent in various activities on the average daily time spent out of bed during hospitalisation.
Methods: We recorded physical activity during hospitalisation by accelerometers and compared the effect of the visual feedback (intervention) with no feedback (control) on time spent out of bed. Patients admitted to the pulmonary ward were invited and assigned to intervention with feedback or control with no feedback in 6 alternating waves of approximately 18 patients each. The order of feedback/no feedback was randomised at the outset of the study. The visual feedback intervention group was provided with visual feedback of the daily time spent in bed, sitting, standing, and walking. The control group did not receive feedback.
Results: 93 patients completed the study with a median length of stay of 5 days. Across all patients there were no statistically significant group differences in daily time out of bed; however, patients with independent mobility spent 51 minutes (95% CI 0 to 102; P = .049) more out of bed when provided with visual feedback compared to no feedback.
Conclusions: A simple technology assisted physical activity intervention with visual feedback to encourage mobility was not effective at increasing time spent out of bed among hospitalised patients. With feedback, a subgroup of patients with independent walking abilities increased time out of bed and may benefit from this type of intervention.
Trial registration: clinicaltrials.gov Identifier: NCT01945749.

1. Introduction

During hospitalisation, physical inactivity is largely accepted, and the focus is on treating the medical disease. It has been demonstrated that older hospitalised patients spend as much as 17–20 h in bed per day [1,2]. This is unfortunate, since prolonged bed rest can have negative consequences, in terms of reduced ability to perform activities of daily living (ADL), including the ability to be independent in transferring, walking, dressing and toileting - fundamental activities that greatly impact quality of life [3]. Also, a strong association between low physical activity during hospitalisation and increased risk of death in older patients hospitalised for medical disease after discharge has been observed [4]. Such decrease in functional capacity and physical activity can be attributed to loss of muscle tissue. Immobilisation for < 14 days has been seen to reduce muscle mass with 5–9% in otherwise healthy individuals [3,5,6]. Both in young and older adults the muscle atrophy can present a number of health complications and in older patients hospitalised for medical disease the loss of muscle mass leads to delayed regain of physical function [3].

Thus, prolonged bed rest or inactivity associated with hospitalisation poses a threat to functional capacity and independency in the elderly. Pulmonary function and particular pulmonary functional residual capacity increases with a more upright position to its largest in the standing position [7]. Also, a physically active body in an upright position is ideal for gas exchange, ventilation and circulation and is thus of great importance for patients with respiratory and pulmonary diseases [8,9]. There is no existing medication that prevents the detrimental effects of inactivity. Therefore, physical activities and exercises should

* Corresponding author at: The Department of Physical and Occupational Therapy, Bispebjerg Bakke 23, building 10, 2400 Copenhagen NV, Denmark.
E-mail address: christian.have.dall@regionh.dk (C.H. Dall).

https://doi.org/10.1016/j.ejim.2019.08.019
Received 8 May 2019; Received in revised form 19 August 2019; Accepted 20 August 2019
Available online 04 September 2019

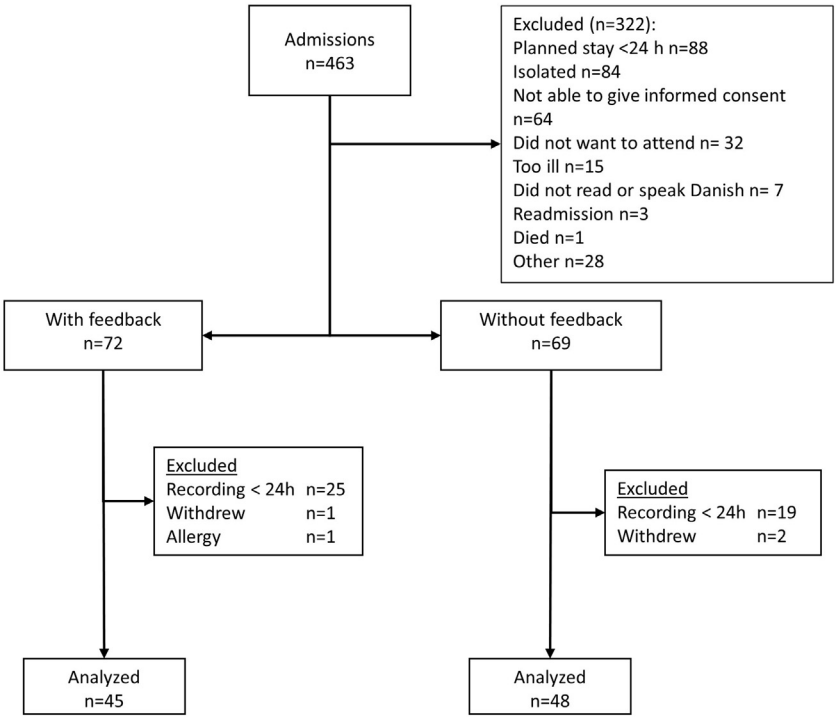

Fig. 1. Study participant flow.

be a more integrated part of the hospital intervention and should receive more attention from the multidisciplinary staff.

Being more physically active requires a conscious choice by the patient. During hospitalisation, where bedrest is the prevailing culture, this can require external motivation. Recent developments in technology provides a feasible means of measuring physical activity and providing feedback to the patient via miniaturised activity sensors (accelerometers) and visual display of the amount of physical activity during a day. Indeed, physical activity during hospitalisation has been measured using accelerometers [4,10,11]. While these studies document a high degree of physical inactivity, the information was not utilised to promote increased physical activity during hospitalisation.

Consequently, the aim of this study was to assess the effect of a physical activity measuring system with visual feedback about the patient's activity level on the amount of physical activity during hospitalisation.

2. Methods

We performed a randomised study of patients hospitalised to the pulmonary ward at Bispebjerg-Frederiksberg hospital in Copenhagen, Denmark. The protocol (available from corresponding author) was submitted to the Regional Health Research Ethics Committee (Journal no.: 17017548) and was registered at www.clinicaltrials.gov (identifier: NCT01945749) before commencement of the study. The study was conducted in accordance with the Helsinki Declaration.

2.1. Participants

We invited patients admitted to the pulmonary ward from November 6th 2017 to June 2nd 2018 to participate. The inclusion criteria were: Signed informed consent and ability to read and speak Danish. Exclusion criteria were: isolated patients (e.g. due to highly contagious infections), known allergy to band-aids, expected stay for < 24 h, participation in other studies, and previous enrolment in this study (re-admission).

2.2. Design

The study was designed as a single cluster-randomised cross-over study to compare a group that had physical activity recorded with visual feedback (intervention) with a group that had physical activity recorded but did not receive visual feedback (control). Participants were recruited in 6 cohorts. Three cohorts (1, 3 & 5) were allocated to the control group with no feedback and three cohorts (2, 4 & 6) to the feedback intervention group. Assignment of the cohorts was determined at the outset of the study before any recruitment took place by a coin toss. The cohort sizes were set to 18 in each cohort corresponding to the number of beds on the ward. Participants were assigned to the cohorts in order of admission to the ward; i.e. the first 18 included patients were assigned to cohort one, the next 18 to cohort two and so on. Once 18 patients had been allocated to a cohort, inclusion to that cohort was stopped. When all patients in a cohort had left the ward (either by discharge or department transfer), inclusion to the next cohort was started. This means that there were smaller periods in which no patients were included. Physical activity recordings were terminated at discharge or after a maximum of 7 days for all patients in all cohorts. As this was an “open-label” study neither the participants nor the clinical staff were blinded to treatment allocation.

2.3. Assessment of physical activity

To assess physical activity two small tri-axial accelerometers embedded in medical Band-Aids were used. The accelerometers were discretely worn on the chest and on the lateral aspect of the thigh. The devices are water proof and does not interfere with other activities related to the treatment or care of the patients. The band-aid used is a standard medical band-aid, tested for allergens and can be changed and moved under supervision.

The accelerometers sampled accelerations at 12.5 Hz continuously during hospitalisation and were connected via Bluetooth technology to a dedicated app installed on a tablet that uploads data to a secure server. The device has on board memory capacity for several weeks to prevent data loss due to occasional lack of connectivity. In the

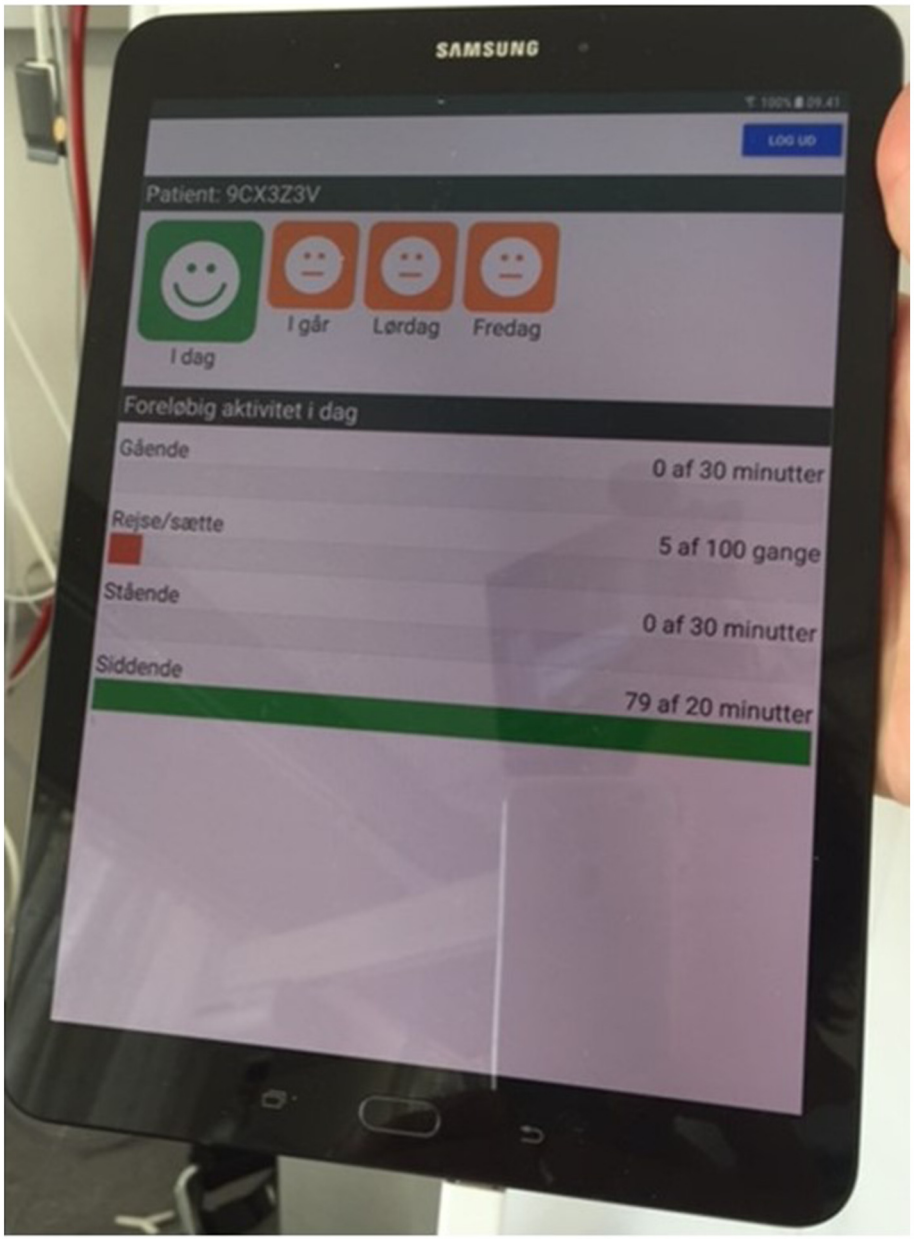

Fig. 2. Example of a visual feedback screen.

dedicated app, an inbuilt algorithm detects the orientation and movements of the accelerometers and classify the recordings as bedridden (lying down), sitting, standing (including small bouts of shuffling), and walking summarized every 10 s.

2.4. Procedures

As close to admission as possible the patients were seen by a physiotherapist who invited the patient to participate. Oral and written information material was handed out, and it was stressed to all potential participants that physical activity is important – also during a hospital stay.

Upon signed informed consent, the physiotherapist assessed the patients' basic mobility using the cumulated ambulatory score (CAS) [12]. The CAS describes a patient's independence regarding getting in and out of bed, sit-to-stand-to-sit from a chair, and walking (use of a walking aid allowed). Each activity is assessed on a three-point ordinal scale from 0 to 2 (0 = Not able to, despite assistance and verbal cueing, 1 = Able to, with assistance and/or verbal cueing, 2 = Able to safely, without assistance or verbal cueing) resulting in a total CAS score ranging from 0 to 6 [12].

Based on the CAS-walking score the patients were categorized as being unable to walk (CAS-walking score 0), needing some assistance to walk (CAS-walking score 1) or having independent walking ability (CAS-walking score 2).

Subsequently, the physiotherapists mounted the accelerometers, and if appropriate according to allocation, installed feedback screens (7 in. tablets) on the bedside table. Upon discharge, department transfer or after 7 days of recording the accelerometers were inactivated and removed.

2.5. Visual feedback intervention

The visual feedback intervention cohorts (cohorts no. 2, 4 & 6) were provided with visual feedback of the daily time spent lying in bed, sitting, standing, and walking. The visual feedback was provided via a

Table 1
Characteristics of study population.

	Feedback (n = 45)	No feedback (n = 48)	Mean difference (SE)	P*
Age, mean (SD), y	73.8 (12.8)	71.9 (13.6)	1.9 (0.1)	0.48
Female, *n* (%)	22 (48.9)	25 (52.1)	–	0.76**
Main diagnoses				
Asthma, *n* (%)	3 (7)	1 (2)	–	0.43**
Cancer, *n* (%)	1 (2)	1 (2)	–	
COPD, *n* (%)	7 (16)	11 (23)	–	
Dyspnoea, *n* (%)	4 (9)	–	–	
Pleural effusion, *n* (%)	3 (7)	2 (4)	–	
Pneumonia, *n* (%)	20 (44)	23 (48)	–	
Pneumothorax, n (%)	2 (4)	4 (8)	–	
Other, n (%)	5 (11)	6 (13)	–	
LOS, mean (SD) [median], days	7.3 (12.2) [5]	8.3 (10.4) [5]	−1.0 (2.3)	0.68
Accelerometer wear time, mean (SD), days	3.3 (2)	3.6 (1.9)	−0.3 (0.4)	0.47
Accelerometer wear time, mean (SD), %LOS	64 (24)	62 (24)	2 (5)	0.73
Charlson comorbidity index, mean (SD)	3.8 (1.9)	3.7 (2)	0.1 (0.4)	0.74
Readmissions within 90 days, *n* (%)	21 (46.7)	17 (35.4)	–	0.73**
Mobility category				
Independently mobility, *n* (%)	27 (60)	30 (63)	–	0.20**
Need of assistance, *n* (%)	13 (29)	17 (35)	–	
No mobility, *n* (%)	5 (11)	1 (2)	–	

LOS, length of stay.
* *T*-test.
** Chi-squared.

Table 2
Average daily time spent out of bed, walking, standing inactive, sitting and bedridden. Time out of bed is the sum of time spent standing and walking. Time spent inactive is the sum of sitting and in bed.

	Feedback mean (95% CI)	No feedback mean (95% CI)	Group difference mean (95% CI)	P
Time out of bed, min/day	81 (46 to 117)	64 (−3 to 131)	18 (−58 to 94)	0.65
Walking, min/day	51 (28 to 74)	47 (4 to 89)	4 (−44 to 52)	0.86
Standing, min/day	30 (11 to 50)	17 (−19 to 53)	13 (−28 to 55)	0.52
Inactive, min/day	1359 (1323 to 1394)	1376 (1309 to 1443)	−18 (−94 to 58)	0.65
Sitting, min/day	331 (250 to 412)	279 (128 to 429)	52 (−118 to 223)	0.54
In bed, min/day	1027 (935 to 1120)	1097 (926 to 1269)	−70 (−265 to 125)	0.48

Table 3
Average daily time spent out of bed, walking, standing inactive, sitting and bedridden in patients categorized according to basic mobility at admission.

	Feedback mean (95% CI)	No feedback mean (95% CI)	Group difference mean (95% CI)	P
Time out of bed, min/day				
Independent mobility	167 (130 to 204)	116 (81 to 151)	51 (0 to 102)	0.049
Need of assistance	69 (16 to 122)	75 (28 to 122)	−6 (−77 to 65)	0.87
No mobility	9 (−78 to 95)	1 (−191 to 193)	7 (−203 to 218)	0.94
Walking, min/day				
Independent mobility	103 (80 to 126)	83 (61 to 105)	20 (−12 to 52)	0.22
Need of assistance	47 (13 to 81)	57 (28 to 87)	−10 (−55 to 35)	0.65
No mobility	3 (−51 to 58)	1 (−121 to 122)	3 (−131 to 136)	0.97
Standing, min/day				
Independent mobility	64 (44 to 84)	33 (14 to 52)	31 (4 to 59)	0.027
Need of assistance	22 (−7 to 51)	17 (−8 to 43)	4 (−34 to 43)	0.82
No mobility	5 (−41 to 52)	0 (−104 to 104)	5 (−109 to 119)	0.93
Inactive, min/day				
Independent mobility	1273 (1236 to 1310)	1324 (1289 to 1359)	−51 (−102 to 0)	0.049
Need of assistance	1371 (1318 to 1424)	1365 (1318 to 1412)	6 (−65 to 77)	0.87
No mobility	1431 (1345 to 1518)	1439 (1247 to 1631)	−7 (−218 to 203)	0.94
Sitting, min/day				
Independent mobility	454 (371 to 538)	461 (382 to 540)	−7 (−121 to 108)	0.91
Need of assistance	373 (253 to 493)	252 (147 to 356)	121 (−38 to 280)	0.13
No mobility	166 (−28 to 359)	123 (−309 to 555)	42 (−431 to 516)	0.86
In bed, min/day				
Independent mobility	819 (724 to 913)	863 (773 to 953)	−45 (−175 to 86)	0.50
Need of assistance	998 (861 to 1135)	1113 (994 to 1233)	−115 (−297 to 66)	0.21
No mobility	1266 (1045 to 1486)	1316 (822 to 1809)	−50 (−590 to 491)	0.86

tablet (connected to the accelerometers via Bluetooth) placed on the bedside table. The feedback consisted of horizontal bars (with numbers) representing the daily time (in minutes) spent bedridden (lying down), sitting, standing, and walking. The display showed the current day's activities together with the preceding days. Furthermore, 'smiley-faces' were displayed in different colours depending on time spent lying down, sitting, and walking (see Fig. 2). Based on the CAS-walking categorization, the thresholds for a colour change of the 'smileys' differed: CAS-walking 0: No feedback on walking – only feedback on time spent sitting and lying down; CAS-walking 1: Red 0–15 min, yellow 15–30 min, green 30+ min; CAS-walking 2: Red 0–30 min, yellow 30–60 min, green 60+ min.

The feedback was available constantly and the summarized data were updated regularly (approximately every 5 min). Hence, the feedback information was visible to the patients, their relatives and other visitors, and the health care personnel.

In the control group no visual feedback was provided.

2.6. Outcome measures

The protocol of this study defined the primary outcome as time spent out of bed (standing or walking) measured in minutes related to the total hospitalisation time (minutes). However, as the total hospitalisation time was quite different from the accelerometer wear time, the interpretation of the accelerometer outcomes is easier if related to the actual accelerometer wear time. Hence, we report the time spent out of bed (minutes) related to the accelerometer wear time (minutes) and report it as average daily time out of bed (minutes/day) during the hospital stay while wearing the accelerometer. The time out of bed variable is defined as the sum of time spent standing and walking. Secondary outcomes were average daily time spent in bed (lying down), sitting, standing and walking (minutes/day).

2.7. Sample size

We aimed to include 108 participants in 6 cohorts of 18 each. This was pragmatically estimated, since we were unaware of any similar study that could be used to calculate a sample size. However, 108 patients in two groups of equal sizes would allow for approximately 90% power to detect a difference in average daily time out of bed of 30 min, with an estimated standard deviation of 45 min/day and a significance level of 0.05.

2.8. Statistical analyses

Only patients who had accelerometer recordings of at least 24 h were included in the analysis set. To assess comparability of the two groups (with vs without feedback) at admission, the baseline characteristics were compared using unpaired *t*-tests. The primary and secondary outcomes were tested for group differences using analysis of covariance (ANCOVA).

To test if the visual feedback intervention worked differently on the subgroups of patients (the CAS-walking score categorization) we added the mobility-level as a factor (3 levels), together with its interaction with group (group * mobility) to the ANCOVAs.

As sensitivity analyses we assessed if the cohort number (representing carry-over-effects from previous cohorts, seasonal or other contaminating effects) and the accelerometer wear time (exposure time) affected the results, we adjusted the ANCOVAs further for the cohort number, exposure time (in minutes) and for total hospitalisation time (in minutes).

All statistical tests were two-sided and statistical significance is claimed if the computed *p*-value is equal to or < 0.05.

3. Results

A total of 463 admissions were recorded from November 2017 to June 2018. Of those, 322 patients were not eligible for participation, the main reasons being expected stay < 24 h ($n = 88$), isolation ($n = 84$), and not being able to provide informed consent ($n = 64$). 141 patients gave informed consent and were included in the present study, with 72 being allocated to the visual feedback intervention and 69 to the control (no visual feedback). During participation, 3 withdrew their informed consent and 1 experienced an allergic reaction to the Band-Aid and was withdrawn from the study. Upon data analysis, 25 in feedback group and 19 in no feedback group were excluded due to recordings of < 24 h (see Fig. 1). These 44 patients were younger (mean 66 years) than those completing the study, but otherwise there were no differences (data not shown).

The clinical characteristics are presented in Table 1, according to group allocation. The most common diagnoses were pneumonia and COPD. The average accelerometer wear time was approximately 3.5 days (corresponding to 63% of average hospital stay), whereas the average length of stay was 7 to 8 days. This difference was due to some prolonged stays in a few patients affecting the average and due to accelerometer recordings being stopped after a max of 7 days. There were no statistically significant differences in patient characteristics (data not shown).

Across all included patients the visual feedback provided no statistically significant reduction in time spent out of bed compared to no visual feedback (Table 2). The feedback group spent 81 min per day out of bed and the no feedback group spent 64 min per day out of bed. The group difference was 18 min per day (95% CI -42 to 78; $P = .56$) numerically in favour of the visual feedback. There were no statistically significant group differences in the other measures of physical activity (Table 2).

However, the subgroup analyses revealed that patients with independent walking ability (CAS-walking score = 2) were 51 min (95% CI 0 to 102; $P = .049$) more out of bed when provided with visual feedback compared to the same subgroup of patients who did not receive feedback (Table 3). Further, the same subgroup spent statistically significantly more time standing during a day than when provided with visual feedback compared to the no feedback group (mean difference: 31 min/day (95% CI 4 to 59; $P = .027$) (Table 3). A similar tendency was seen for time spent walking, but this was not statistically significant (Table 3). Consequently, the independent mobility subgroup was similarly less inactive (Table 3).

The results were robust to the sensitivity analyses (with adjustment for cohort number, accelerometer wear time and total hospitalisation time) as the estimates only changed slightly (supplementary Tables S1& S2).

There were no recorded fall incidences in either group.

4. Discussion

This is the first study to combine information from accelerometers and providing a direct visual feedback around the clock to the patients, visitors and the staff in a hospital setting. Overall, we found no effect of the visual feedback of time spent in various physical activities on time spent out of bed in patients hospitalised at a pulmonary ward. However, the subgroup with independent walking ability spent 51 min/day more out of bed when provided with visual feedback group compared to the no-feedback group, which we find very promising.

During hospitalisation, the focus is on treating the disease and generally physical inactivity is largely accepted. Several studies have reported that patients are bedridden for of 17–20 h per day during hospitalisation [1,10,11]. In Brown et al. from 2009 [1] the amount of time hospitalised patients spent lying was in average 20 h per day. This is in line with our study with patients generally were inactive (lying/sitting) for 22.7 h per day. Studies on the impact of bedrest have

demonstrated significant decreases in muscle strength and mass [1,13]. These physiological consequences contribute to the functional decline frequently observed after hospitalisation [14], including reduced ability to independent transferring, walking, and toileting that are fundamental activities of independent living [15]. In broader terms physical inactivity can act as an additional stressor besides that of the acute illness [14]. Indeed, bedrest has been deemed toxic to older adults and there have been repeated calls for hospital mobility actions [16].

Despite the well-established knowledge about mechanisms and outcomes, studies of hospital mobility interventions are very sparse. A randomised study from 2017 showed that an early rehabilitation program in survivors of critical illness led to an earlier discharge from the hospital, improved functional recovery, and was also cost-effective and safe [17]. In 2016 an in-hospital mobility program versus usual care was tested [16]. The mobility program consisted of assisted walking twice daily for 15-min and enabled patients to maintain their pre-hospitalization community mobility, whereas those in the control group experienced clinically significant declines.

The amount of time spent out of bed in a hospital setting necessary for secondary benefits to occur is not known. In Brown et al. [16] total mobilisation time was up to 40 min per day, which is similar to the subgroup effect observed in the present study of almost 1 h per day. This suggest that the present intervention could yield similar secondary effects on post-hospital functioning. Unfortunately, we did not assess these secondary benefits of less physical inactivity, but the observed reduction of physical inactivity holds a promising perspective. While the overall effect was not evident the intervention was successful at mobilising patients who had most to lose, i.e. those with independent mobility at admission.

It is not surprising that the intervention with visual feedback was effective in the subgroup with independent mobility, and not in the other subgroups who need assistance to transfer to/from bed and to locomote. The visual feedback may have motivated all patients, but those without resources to be more physically active had no opportunity to react on the motivation. The data suggest that patients with severe mobility limitations are unsuited for a technology assisted feedback intervention without professional backup. The technology may be a potential tool to identify patients who need assistance and/or additional motivation to avoid excess physical inactivity during hospitalisation.

This study focused on testing if a technology-based intervention would decrease time spent physically inactive during hospitalisation. The visual feedback was provided continuously throughout the hospital stay. This does not only provide an external motivation for the patients but may also be used actively by the hospital staff. The effects of the feedback intervention had a multifactorial component, of which some were not quantified by this study, but likely influencing both patients, staff and visitors. Among other things, the visual display may serve as simple visualisation, but also encourage the patients to work against a goal, and/or animate staff to encourage patients to move. The technology is most likely affecting a combination of mechanisms. In possible future applications, the information may also be used to better allocate physiotherapy resources to the patients with impaired mobility or those who do not respond to the feedback. The intervention is easy to implement. The mounting and activation of the accelerometers and feedback screens do not require specialist skills, and the technology has the potential to be incorporated into standard care at most hospital wards. An important note is that the present study focused on the use of technology to increase physical activity during hospitalisation. It is likely that the effects can be augmented if the technology is combined with other stimuli, such as education, advice, environmental considerations etc.

Because this study was performed in a pulmonary ward, it may not be generalizable across all types of wards or hospitals. Further, there were a substantial number of patients who were not eligible, which also limits generalisability to the general medicine population. However, the patient population had a significant burden of comorbidities, as indicated by their comorbidity count, and is fairly representative of the general population at the pulmonary ward. Medical procedures were not considered as a potential confounder as the patient characteristics are quite similar between the groups. We excluded patients a priori who had accelerometer recordings for < 24 h. These patients were not included until the day after the admission (e.g. admitted in the evening where study staff was not present). Inclusion of these patients may have altered the results but may also have introduced unwanted noise as the recordings will for some patients only relate to evening/night time and others to only to daytime.

Although this is a small study that needs replication, it provides evidence of the efficacy of a technology assisted physical activity intervention.

5. Conclusion

A technology assisted physical activity intervention with bedside visual feedback to encourage mobility was overall not effective at increasing time spent out of bed in hospitalised patients. However, the subgroup of patients with independent walking abilities increased the time spent out of bed and may benefit from this type of intervention. The subgroup findings are promising and need replication in larger populations before implementation can be recommended.

Author contributions

Drs Dall, Andersen and Henriksen had full access to all the data in the study and take responsibility for the integrity of the data and the accuracy of the data analysis. Study concept and design: Dall, Henriksen. Acquisition, analysis, or interpretation of data: Dall, Andersen, Povlsen. Drafting of the manuscript: Dall. Critical revision of the manuscript for important intellectual content: All authors. Statistical analysis: Henriksen. Obtained funding: Dall, Henriksen. Administrative, technical, or material support: Dall, Andersen, Povlsen. Study supervision: Henriksen.

Sources of funding

This work was supported by the Department of Physical and Occupational Therapy at Bispebjerg-Frederiksberg Hospital, VihTek – Research and Test Center for Health Technologies in the Capital Region of Denmark, and grants from The Association of Danish Physiotherapists (Dr. Dall) and The Oak Foundation (Dr. Henriksen).

Declaration of Competing Interest

Dr. Henriksen reported membership of advisory board for Thuasne. No other disclosures were reported.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.ejim.2019.08.019.

References

[1] Brown CJ, Redden DT, Flood KL, Allman RM. The underrecognized epidemic of low mobility during hospitalization of older adults. J Am Geriatr Soc 2009;57:1660–5.
[2] Pedersen MM, Bodilsen AC, Petersen J, Beyer N, Andersen O, Lawson-Smith L, et al. Twenty-four-hour mobility during acute hospitalization in older medical patients. J Gerontol A Biol Sci Med Sci 2013;68:331–7.
[3] Suetta C, Hvid LG, Justesen L, Christensen U, Neergaard K, Simonsen L, et al. Effects of aging on human skeletal muscle after immobilization and retraining. J Appl Physiol (1985) 2009;107:1172–80.
[4] Ostir GV, Berges IM, Kuo YF, Goodwin JS, Fisher SR, Guralnik JM. Mobility activity and its value as a prognostic indicator of survival in hospitalized older adults. J Am Geriatr Soc 2013;61:551–7.

[5] Jones SW, Hill RJ, Krasney PA, O'Conner B, Peirce N, Greenhaff PL. Disuse atrophy and exercise rehabilitation in humans profoundly affects the expression of genes associated with the regulation of skeletal muscle mass. FASEB J 2004;18:1025–7.
[6] de Boer MD, Selby A, Atherton P, Smith K, Seynnes OR, Maganaris CN, et al. The temporal responses of protein synthesis, gene expression and cell signalling in human quadriceps muscle and patellar tendon to disuse. J Physiol 2007;585:241–51.
[7] Dean E. Effect of body position on pulmonary function. Phys Ther 1985;65:613–8.
[8] Marklew A. Body positioning and its effect on oxygenation–a literature review. Nurs Crit Care 2006;11:16–22.
[9] Nielsen KG, Holte K, Kehlet H. Effects of posture on postoperative pulmonary function. Acta Anaesthesiol Scand 2003;47:1270–5.
[10] Villumsen M, Jorgensen MG, Andreasen J, Rathleff MS, Molgaard CM. Very low levels of physical activity in older patients during hospitalization at an acute geriatric Ward: a prospective cohort study. J Aging Phys Act 2015;23:542–9.
[11] Karlsen A, Loeb MR, Andersen KB, Joergensen KJ, Scheel FU, Turtumoeygard IF, et al. Improved functional performance in geriatric patients during hospital stay. Am J Phys Med Rehabil/Assoc Acad Physiatrists 2017;96:e78–84.
[12] Foss NB, Kristensen MT, Kehlet H. Prediction of postoperative morbidity, mortality and rehabilitation in hip fracture patients: the cumulated ambulation score. Clin Rehabil 2006;20:701–8.
[13] Kortebein P, Ferrando A, Lombeida J, Wolfe R, Evans WJ. Effect of 10 days of bed rest on skeletal muscle in healthy older adults. Jama. 2007;297:1772–4.
[14] Volpato S, Onder G, Cavalieri M, Guerra G, Sioulis F, Maraldi C, et al. Characteristics of nondisabled older patients developing new disability associated with medical illnesses and hospitalization. J Gen Intern Med 2007;22:668–74.
[15] Suetta C, Andersen JL, Dalgas U, Berget J, Koskinen S, Aagaard P, et al. Resistance training induces qualitative changes in muscle morphology, muscle architecture, and muscle function in elderly postoperative patients. J Appl Physiol (Bethesda, Md: 1985) 2008;105:180–6.
[16] Brown CJ, Foley KT, Lowman Jr JD, MacLennan PA, Razjouyan J, Najafi B, et al. Comparison of Posthospitalization function and community mobility in hospital mobility program and usual care patients: a randomized clinical trial. JAMA Intern Med 2016;176:921–7.
[17] Gruther W, Pieber K, Steiner I, Hein C, Hiesmayr JM, Paternostro-Sluga T. Can early rehabilitation on the general Ward after an intensive care unit stay reduce hospital length of stay in survivors of critical illness?: a randomized controlled trial. Am J Phys Med Rehabil/Assoc Acad Physiatrists 2017;96:607–15.