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Critical care

A feasibility study investigating the use of a thigh-worn accelerometer to measure physical activity in patients recovering from critical illness

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Background

Rehabilitation of patients recovering from critical illness has been a focus of clinical research, however heterogeneity exists in the measurement of physical recovery. Wearable technology offers a simple, unobtrusive method of continuous activity monitoring. However, studies have reported issues with placement of wrist and ankle devices in critically ill patients.

Aim

To evaluate the feasibility of a thigh-worn accelerometer to measure the physical activity of patients recovering from critical illness.

Methods

A prospective observational feasibility study was conducted within a 33-bedded critical care unit over nine weeks. Thigh-worn activPAL^{TM} accelerometers were applied to patients for the duration of their critical care admission.

Results

A total of 12 participants were recruited. Median (IQR) device wear time was 268.35 (299.15) hours or 99.58% of their critical care admission. A priori feasibility success criteria of three days of wear time for more than ten hours were achieved in every participant. Device removal primarily occurred for recharging.

Conclusion

The practical application of a thigh-worn accelerometer may be feasible in this population for the duration of admission. As this was a small, single centre study additional research is necessary to further inform and determine the feasibility of this device.

INTRODUCTION

The consequences of critical illness are multifaceted, and can include significant physical deconditioning, acquired weakness and reduced functional capacity.[1] Physical activity is advocated for survivors of critical illness, initiated early in their critical care stay,[2] although currently there is little agreement regarding the optimum frequency and type of interventions.[3] Outcome measures largely focus on specific functional milestones that are not necessarily representative of the patient's consistent level of function.[4] As an alternative, measurements of overall physical activity beyond rehabilitation sessions, could facilitate a more accurate representation of a patient's recovery trajectory[5] and provide more meaningful data in order to tailor rehabilitation interventions.[6]

Wearable technology provides a simple, unobtrusive and objective approach to continuous activity monitoring.[7] Wearable devices for activity monitoring take many forms, measuring different variables to capture both physiological and activity data.[8] They provide continuous data regarding activity, without any additional effort from the patient or staff. Wearable device application during critical illness poses unique challenges with various aspects of feasibility discussed in the literature such as wear time, comfort, adverse events and ease of data interpretation.[4,9,10] Wrist and ankle devices are common, however these may not be appropriate for patients during critical illness who are administered medications and invasively monitored using their limbs. Limb oedema, line insertions and dressings

have been identified as complications associated with use in this population.[4,9,10] An alternative is a thigh-worn device, which has been examined within inpatient populations but not within critical care.[11] These devices can distinguish between lying/sitting and standing postures, which is of significance in the investigation of sedentary behaviours and low-level rehabilitation.[12] These devices provide objective activity data capturing acceleration and thigh position information, generating a near continuous picture of patient position and activity unable to be measured using subjective methods.

Investigation of feasible activity measurement tools in this population could provide valuable information for researchers and clinicians, and is currently lacking.[7] To date, studies have only captured data over relatively short periods of time. Consequently, it is unclear if wearable devices are a feasible data collection tool throughout critical care admission. This should be examined due to the unique challenges posed in this environment. Although arm and ankle devices have been studied to some extent within critical care,[4,9,10,13] no study has examined the feasibility of a thigh-worn device as an alternative.

AIM

This study aimed to investigate the feasibility of using a thigh worn accelerometer to measure physical activity levels of patients recovering from critical illness whilst in critical care.

METHODS

APPROVALS

The study was approved by the Wales Research Ethics Committee 3 (reference: 18/WA/0086) (IRAS: 238464). Both University College London (UCL) Joint Research Office (ID:18IR06) and Cardiff and Vale Research and Development office (ID:7237) reviewed this study and gave their approval. The study was registered with UCL data protection (reference: Z6364106/2018/02/52) prior to data collection.

PARTICIPANTS

This feasibility study was a single-centre, prospective observational study. It was conducted within the 33-bed critical-care unit at University Hospital of Wales, Cardiff; a tertiary referral centre with a case mix of general medical, surgical, neurosurgical and trauma patients. Screening of potential participants was completed through routine daily reviews of new patients admitted to the unit. Inclusion and exclusion criteria are summarised in Table 1.

With the exception of age, pre-existing neuromuscular disease and unable to wear the activPAL^{TM}, the exclusion criteria were the same criteria used by the physiotherapy team to decide if a patient was appropriate for rehabilitation input. Determining if a patient was at risk of physical morbidity according to NICE[14] guidelines was completed using the short clinical assessment tool within the guidelines. Patients 'at risk' were included as their length of admission was likely to be longer, therefore allowing comprehensive assessment of the device.

Table 1. Inclusion and exclusion criteria

Inclusion criteria	Exclusion criteria
1. Age ≥18 years 2. 'At risk' of physical morbidity as determined by NICE (2009) guidelines 3. Advice from consultee for participation and patient re-consent if appropriate for continuing participation	1. Age < 18 years 2. Expected to die during admission 3. Unable to obtain consent/ advice 4. Pre-existing neuromuscular disease 5. Unable to wear device 6. Open abdomen 7. Active neurological event requiring intervention 8. Acute spinal cord injury 9. Lower extremity fractures 10. Bedbound prior to admission

NICE = National Institute for Health and Care Excellence

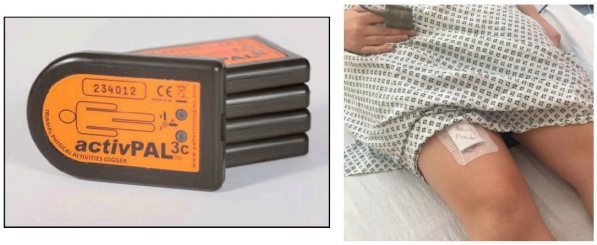

Figure 1. activPAL4^{TM} device and device in situ

INTERVENTION

The activPAL4^{TM} (PAL Technologies Limited) was the wearable device used in the study. This tri-axial accelerometer attaches to the thigh and records data in 15 second epochs. Using position and acceleration information it can differentiate between sitting/lying, standing and stepping. Step count is also recorded. Figure 1 shows the device and its position on the thigh.

The device was applied within 48 hours of admission to allow comprehensive evaluation of device feasibility at all stages of the critical care stay. Participants were not required to do anything different to their usual care apart from wearing the activPAL^{TM} device on their thigh for the duration of their critical care admission. Nursing staff completed standardised data collection sheets during the day shift at the same time as routine observations to document the participant's activity during the preceding hour.

Raw data from the devices were downloaded into Microsoft Excel^{TM} [version 16.13.1] and exported to IBM SPSS^{TM} [version 22] for analysis. As there was no hypothesis testing, no statistical tests were performed. Feasibility included successful recruitment and retention of participants, wear time (downloaded from the device), number of adverse events (as reported in the medical notes), reasons

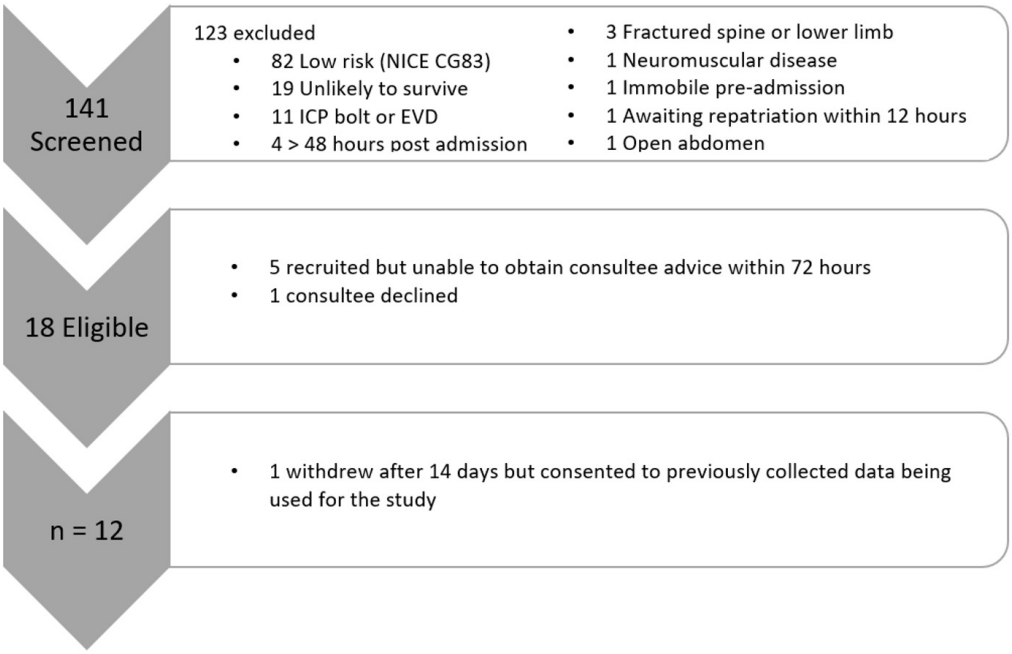

Figure 2. Recruitment flow chart

EVD = external ventricular drain, ICP = intracranial pressure, NICE CG83 = National Institute of Health and Care Excellence clinical guideline 83

for device removal and percentage agreement between device-recorded and nurse-observed activity. Feasibility outcomes were compared against a-priori criteria for success. They were based on data from previous studies and the recommended data needed for analysis of physical activity.[15, 16] A wear time of ten hours per day and at least three days of data were considered as the criteria for feasibility success.

RESULTS

Data were collected between April and June 2018. Of 141 patients screened for participation, 12 were successfully recruited (Figure 2). One device was removed during preparation for discharge and lost, therefore no data were available. Analysis is based on 11 participants.

The demographic characteristics of the sample are displayed in Table 2. Due to the small sample size, non-parametric summaries were calculated.

WEAR TIME

The median (IQR) duration of device wear time was 268.34 (299.15) hours. This equated to a median (IQR) percentage wear time of 99.58% (5.69) of critical care admission. Adequate wear time was achieved for every participant (Figure 3). In total, there were nine days in which sufficient wear time was not reached. Initial application of the device late in the day was responsible for six of these days.

No adverse events occurred. In total devices were removed on nine separate occasions, most commonly for recharging (n=3). Reasons for unplanned device removal (n=6) included imaging procedures, surgery and independent removal secondary to agitation. One device was removed from a participant before they were placed in a prone position. Additionally, it was noted that some activity was recorded in participants who were sedated and not moving.

Table 2. Sample demographics

Demographic characteristics	
Gender, n (%)	
Female	9 (75)
Male	3 (25)
Age (years), median (IQR)	56.67 (14.33)
APACHE II score, median (IQR)	23.50 (11.75)
Ventilation status, n (%)	
Mechanically ventilated	12 (100)
Admitting diagnosis, n (%)	
Respiratory failure	4 (33.3)
OOHCA	3 (25)
Seizures	2 (16.7)
Pneumonia	1 (8.3)
Urosepsis	1 (8.3)
VATS	1 (8.3)
Ventilated days, median (IQR)	9.00 (6.75)
Critical care LOS (days), median (IQR)	11.79 (10.62)

APACHE II = acute physiology and chronic health evaluation 2, IQR = interquartile range, LOS = length of stay, OOHCA = out of hospital cardiac arrest, VATS = video-assisted thoracoscopic surgery

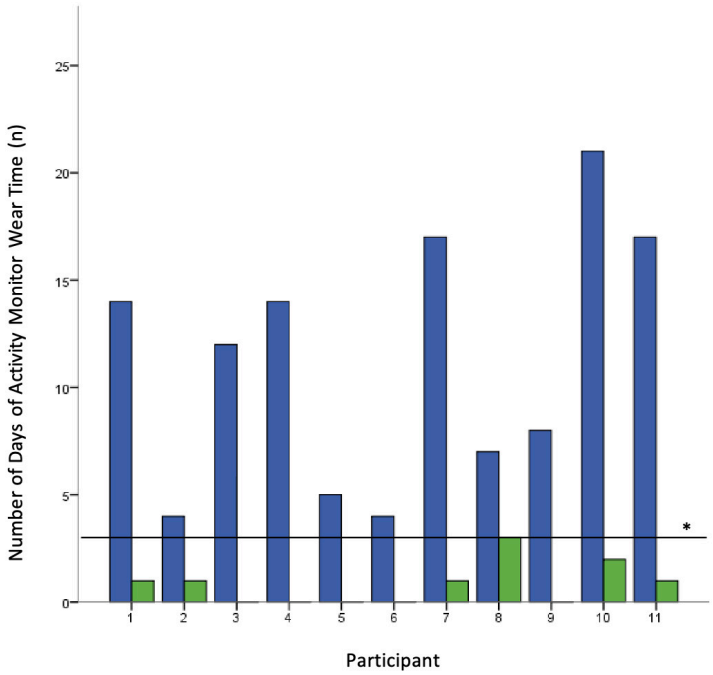

Figure 3. Bar chart showing number of days device wear above and below 10 hours

* Line represents a priori feasibility success criteria of 3 days
Blue bar = Days above 10 hours wear time
Green bar = Days below 10 hours wear time
Adverse events and device removals

DISCUSSION

This study aimed to investigate the feasibility of using a thigh worn accelerometer to measure physical activity levels of patients recovering from critical illness during critical care admission. To the author's knowledge this was the first study to specifically investigate this, adding to the current literature regarding wearable technology use in this population. The key findings were that device wear time satisfied a-priori feasibility criteria, no adverse events occurred and device removal was required to allow recharging or a small range of procedures.

Results suggest that achieving a wear time of sufficient duration to estimate activity levels may be feasible in a select number of patients in critical care (8.5% of those screened for the study were recruited). Owing to time and resource constraints the inclusion and exclusion criteria allowed the researcher to focus the study on participants who would likely to be participating in active rehabilitation during the early phase of their critical care admission. Any future study design would need to allow inclusion of a wider range of participants for a more comprehensive evaluation in this population.

Wear time criteria were achieved for every participant, although there were days when ten hours of wear time was not reached. Unplanned removals were only responsible for three of these occasions. Circumstances demanding device removal are unavoidable in critically ill patients who may require scans and surgery as part of their care. However, these did not significantly impact overall wear time as devices remained in situ for 99.58% of the time. Two previous studies evaluated device wear time in a critical care population. Beach et al.[9] and Kamdar et al.[4] reported a mean (SD) wear time of 4.4 (0.8) days and 46.5 (2.3) hours respectively equating to 97% wear time. As wear time in the current study was measured throughout admission, a longer median (IQR) wear time of 268.34 (299.15) hours was achieved. As the devices remained in situ throughout admission, the effect of short periods of removal on overall wear time were less potent.

In agreement with previous studies, no adverse events were reported, supporting the safety of device use within critical care.[4,9,10,13] In critical illness survivors, removal of limb-worn devices due to oedema has been reported.[5] This was not an issue for the activPAL^{TM}, which was applied to participants with different sized legs without needing to adjust the fit of the device. There were no requirements for the device to be moved for insertion of lines during the study as previously described.[4,9,10] The number of purposeful device removals was higher than previously reported for wrist and ankle devices in a critical care population. This is likely a reflection of the longer data collection phase for the current study. Participants were excluded from one study if they required any procedures necessitating device removal.[4] The current study may provide a more representative evaluation of instances during critical illness that impact upon the ability to wear an activity monitor.

Although not directly related to the study's primary aim, it was noted that as only a single device was used, distinguishing between sitting and lying positions was not possible, and on two occasions activity was detected in a partic-

ipant who was sedated. Sitting may form a significant part of a patient's rehabilitation and represent improvement in their recovery, therefore identification of both positions would be an important distinction to make. Occasions when activity was identified by the device while the patients were fully sedated require further investigation and raise concerns regarding its validity.

One important limitation of this study was the small sample size, which was primarily a result of time constraints. Reduced resources meant screening of 48 potential participants was not possible. Consequently, the sample was less likely to be representative of the population. As this was a single-centre study, external validity is reduced and results cannot be generalised to the wider critical care population.[17] Only a single thigh-worn device was employed, therefore no robust conclusions can be made about the feasibility of similar devices. In addition, qualitative aspects of feasibility were not investigated. This would have provided a more comprehensive evaluation of the device in this unique population and is an area for further research.

CONCLUSION

This study offers some preliminary information to researchers and clinicians seeking to utilise wearable devices to monitor physical activity in patients recovering from critical illness. Results suggest the practical application of this device is feasible throughout critical care admission. Generalisability to the wider critical care population is reduced due to the small sample and single-centre design. Additional research is warranted to further investigate the validity of this device in these patients and explore the feasibility of such devices to inform the rehabilitation of patients recovering from critical illness.

Key points

1. The activPAL^{TM} accelerometer appears feasible to use with patients recovering from critical illness.
2. The lack of ability to distinguish between lying and sitting may limit its use within a critical care population.
3. Areas for further research, including validity of the activPAL^{TM} in this population have been highlighted.

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REFERENCES

1. Kang J, Jeong YJ, Yun SY, et al. Post-Intensive care syndrome experience among critical care survivors: A meta-synthesis of qualitative research. *Journal of Korean Critical Care Nursing*. 2017;10(3):13-30.

2. Needham DM, Feldman DR, Kho ME. The functional costs of ICU survivorship: collaborating to improve post-ICU disability. *Am J Respir Crit Care Med*. 2011;183(8):962-964. doi:10.1164/rccm.201012-2042ed

3. Connolly B. Describing and measuring recovery and rehabilitation after critical illness. *Current Opinion in Critical Care*. 2015;21(5):445-452. doi:10.1097/mcc.0000000000000233

4. Kamdar BB, Kadden DJ, Vangala S, et al. Feasibility of continuous actigraphy in patients in a medical intensive care unit. *Am J Crit Care*. 2017;26(4):329-335. doi:10.4037/ajcc2017660

5. Denehy L, Berney S, Whitburn L, Edbrooke L. Quantifying physical activity levels of survivors of intensive care: a prospective observational study. *Physical Therapy*. 2012;92(12):1507-1517. doi:10.2522/ptj.20110411

6. Connolly BA, Mortimore JL, Douiri A, Rose JW, Hart N, Berney SC. Low levels of physical activity during critical illness and weaning: The evidence–reality gap. *J Intensive Care Med*. 2017;34(10):818-827. doi:10.1177/0885066617716377

7. Verceles AC, Hager ER. Use of accelerometry to monitor physical activity in critically ill subjects: a systematic review. *Respir Care*. 2015;60(9):1330-1336. doi:10.4187/respcare.03677

8. Sylvia LG, Bernstein EE, Hubbard JL, Keating L, Anderson EJ. A practical guide to measuring physical activity. *Journal of the Academy of Nutrition and Dietetics*. 2014;114(2):199-208. doi:10.1016/j.jand.2013.09.018

9. Beach LJ, Fetterplace K, Edbrooke L, et al. Measurement of physical activity levels in the Intensive Care Unit and functional outcomes: An observational study. *Journal of Critical Care*. 2017;40:189-196. doi:10.1016/j.jcrc.2017.04.006

10. Winkelman C, Higgins PA, Chen YJK. Activity in the chronically critically III. *Dimensions of Critical Care Nursing*. 2005;24(6):281-290. doi:10.1097/00003465-200511000-00011

11. Baldwin C, van Kessel G, Phillips A, Johnston K. Accelerometry shows inpatients with acute medical or surgical conditions spend little time upright and are highly sedentary: Systematic review. *Physical Therapy*. 2017;97(11):1044-1065. doi:10.1093/ptj/pzx076

12. Byrom B, Stratton G, Mc Carthy M, Muehlhausen W. Objective measurement of sedentary behaviour using accelerometers. *Int J Obes*. 2016;40(11):1809-1812. doi:10.1038/ijo.2016.136

13. Grap MJ, Borchers CT, Munro CL, Elswick RK Jr, Sessler CN. Actigraphy in the critically ill: correlation with activity, agitation, and sedation. *American Journal of Critical Care*. 2005;14(1):52-60. doi:10.4037/ajcc2005.14.1.52

14. *Rehabilitation After Critical Illness (Clinical Guideline 83)*. National Institute for Health and Care Excellence (NICE); 2009.

15. Edwardson CL, Winkler EAH, Bodicoat DH, et al. Considerations when using the activPAL monitor in field-based research with adult populations. *Journal of Sport and Health Science*. 2017;6(2):162-178. doi:10.1016/j.jshs.2016.02.002

16. Trost SG, McIver KL, Pate RR. Conducting accelerometer-based activity assessments in field-based research. *Medicine and Science in Sports and Exercise*. 2005;37(11):S531-S543. doi:10.1249/01.mss.0000185657.86065.98

17. Hammond F. Multicentre Trials. In: Hammond FM, Malec JF, Nick TG, Buschbacher RM, eds. *Handbook for Clinical Research: Design, Statistics, and Implementation*. Springer Publishing Company; 2014. doi:10.1891/9781617050992