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Use of Actigraphy to Characterize Inactivity and Activity in Patients in a Medical ICU

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Abstract

Background: In the intensive care unit (ICU), inactivity is common, contributing to ICU-acquired weakness and poor outcomes. Actigraphy may be useful for measuring activity in the ICU.

Objectives: To use actigraphy to characterize inactivity and activity in critically ill patients.

Methods: This prospective observational study involved 48-hour wrist actigraphy in medical ICU (MICU) patients, with activity data captured across 30-second epochs. Inactivity (zero-activity epochs) and activity (levels of non-zero activity) were summarized across key patient (e.g., age)

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Conflict of Interest

The authors have no conflicts of interest to declare

and clinical (e.g., mechanical ventilation status) variables, and compared using multivariable regression.

Results: Overall, 189,595 30-second epochs were collected in 34 MICU patients. Zero-activity comprised 122,865 (65%) of epochs. Inactivity was 24% and 13% more prevalent, respectively, in patients receiving mechanical ventilation (versus none, $p<0.001$) and in the highest (versus lowest) organ failure score tertile ($p=0.03$). Ambulatory (versus non-ambulatory) patients exhibited more activity (26 more movements per epoch, $p<0.001$), while those in the highest (versus lowest) organ failure score tertile exhibited less activity (19 fewer movements per epoch, $p=0.03$). Significant inactivity/activity differences were not observed when evaluated based on age, sedation, or restraint status.

Conclusions: Actigraphy demonstrated that MICU patients are profoundly inactive, including those who are young, non-sedated and non-restrained. Hence, ICU-specific, non-patient-related factors may contribute to inactivity, an issue requiring further investigation.

Keywords

actigraphy; activity; inactivity; critical illness; ICU; mobilization

INTRODUCTION

Critically ill patients often experience prolonged bedrest and inactivity, placing them at risk for adverse short- and long-term outcomes including intensive care unit (ICU)-acquired weakness (ICU-AW).¹ It is estimated ICU-AW is associated with 30% higher in-hospital and 13% higher 1-year mortality.² Many factors contribute to ICU-AW, including sedative infusions, neuromuscular blockade, glucocorticoids, and critical illness itself.^{2,3} Efforts to mobilize patients early may help prevent ICU-AW, reduce length of stay, and improve functional status after discharge.^{4,5} Despite this literature, many barriers impede mobilization efforts, including incomplete knowledge of its benefits, a lack of champions, and inexperience.^{1,3,6,7} Nevertheless, early mobilization efforts are gaining traction, and are recommended in ICU clinical practice guidelines.⁸

Despite guideline-supported efforts, tools to measure activity in the ICU are limited. Measurement of activity is important, as it can inform mobility practices and identify inactive patients who may benefit from mobilization. Most ICU mobility tools involve direct observation by trained observers, which involves activity measurement over discrete, rather than continuous time periods, and is infeasible on a large scale.⁹

As an alternative measurement tool, actigraphy involves use of an accelerometer to log patient activity, usually with a wristwatch-like device. Actigraphy is generally well tolerated, low cost, and, most importantly, provides continuous and objective activity data not provided by other tools.¹⁰⁻¹⁴ While actigraphy has been used for decades to evaluate activity and estimate sleep,¹⁵⁻¹⁸ prior studies involving actigraphy in critically ill patients mostly involved small convenience samples, utilized manufacturer-provided software for sleep-wake estimation, or presented broad descriptions of patient activity.^{13,19-21} Though it is commonly believed that critically ill patients are generally inactive, to build knowledge in

this area, we performed an exploratory analysis of data from a feasibility study of actigraphy in MICU patients.²² The original study was performed to assess the feasibility of continuous monitoring by actigraph over a prolonged period of time in a continuous sample of MICU patients. By examining zero- and non-zero activity levels across patient- and ICU-specific variables, our objective is to utilize actigraphy to identify factors associated with inactivity and low activity, and to highlight critically ill patient subpopulations who would most benefit from mobility interventions. The overarching goal of this work is to advance research on methods to design, motivate, evaluate, and sustain interventions aimed at promoting mobility in critically ill patients.

THEORY AND CALCULATIONS

We hypothesized that actigraphy would demonstrate that MICU patients are inactive and have low non-zero activity levels, in particular those who are older, with higher organ failure scores, or requiring sedation, restraints, or mechanical ventilation.

MATERIALS AND METHODS

This exploratory analysis was performed as a part of a prospective observational study evaluating the feasibility of 48-hour wrist actigraphy in consecutively enrolled patients in a Medical Intensive Care Unit (MICU).²² The original study was performed to assess the feasibility of continuous monitoring by actigraph over a prolonged period of time in a consecutive sample of MICU patients. All enrolled patients or surrogates provided oral informed consent. The UCLA institutional review board approved the study.

Study Setting and Participants

This study occurred in an academic MICU with 24 private rooms and a nurse-to-patient ratio of 1:2. Potentially eligible patients were identified from the daily MICU census. All patients aged 18 and older were considered eligible for enrollment. Patients who were moribund, awaiting transfer out of the MICU, awaiting procedures involving the wrist, with no available wrist (e.g., due to lines placed in the hand or arm), or unable to provide informed consent in English were excluded.

Actigraphy and Patient Data

As part of the feasibility study, each enrolled patient underwent 48-hour wrist actigraphy recording using the Phillips Respironics Actiwatch Spectrum Pro (Andover, Maryland, USA). Actigraphy recording began at 12:00 on the day of enrollment, or soon thereafter, with activity levels recorded by the device every 30 seconds (one epoch). We chose the 12:00 start time and 48-hour duration to balance the desire to record one complete day and night with the fact that some participants would be the ICU for a short period of time.

After consent was obtained, actigraphs were placed on each patient's right wrist, or if unavailable (i.e., due to arterial line), the left wrist. Each day, trained research personnel confirmed appropriate positioning of the actigraph devices on each enrolled subject. After up to 48 hours, actigraphs were removed and data were uploaded onto a computer for analysis. To identify time-based trends in inactivity and activity, during both the day and night, we

divided actigraph data into 4-hour time blocks, as follows: 06:00–09:59, 10:00–13:59, 14:00–17:59, 18:00–21:59, 22:00–01:59, and 02:00–05:59.

Patient baseline (pre-ICU) and ICU variables of potential interest were collected during this study, based on prior research and our own clinical experiences. From the electronic medical record, these variables included age, gender, body mass index, and admission diagnosis. Over the 48-hour recording period, we collected daily Sequential Organ Failure Assessment (SOFA) organ failure scores, along with sedation, restraint, and mechanical ventilation status. Patients and/or surrogates also reported patients' ambulatory status prior to admission. Sedation, restraint, and mechanical ventilation status were dichotomized into ever vs. never during the 48-hour actigraph recording period. Only patients providing wrist actigraph data during the allotted 48-hour period were included in this analysis; for these patients, there were no gaps in actigraph recordings or missing demographic or clinical data. Duplicate data entry was performed and abstracted data were audited by a third independent clinician to verify accuracy. Due to the design of original feasibility study, information on patient behaviors and patient care activities were not collected.

Statistical Analysis

Baseline and ICU data were evaluated using median and interquartile range for continuous variables and proportions for categorical variables. As a method to characterize inactivity and activity, we evaluated the proportion of epochs equaling zero activity (representing inactivity) and mean levels of non-zero activity (representing activity). Inactivity and non-zero activity levels were stratified by baseline and ICU variables. Subsequently, we estimated between-strata differences in inactivity and activity using univariable and multivariable logistic (to evaluate zero versus non-zero epochs) and Poisson regression models (to evaluate non-zero activity levels per epoch). Generalized estimating equations were used to account for repeated measures across subjects. Variance inflation factors were used to confirm the lack of multicollinearity in the multivariable model. Finally, we displayed zero-activity epochs using bar plots and non-zero activity levels using linear fit plots. For the initial feasibility study, a sample size of 35 was calculated for a feasibility proportion of 90%, with a 95% CI plus or minus 10%. All analyses were performed using STATA version 14.0 (College Station, TX).

RESULTS

Baseline and ICU Characteristics

Overall, 135 consecutive patients were screened from November 2014 to January 2015; 48 (36%) met eligibility criteria and 35 (73% of eligible patients) consented to participation (Figure 1). Thirty-four enrolled patients contributed actigraph data: 33 (97%) completed 48 hours, 1 (3%) completed 34.2 hours, 28 (82%) wore actigraphs on the right wrist and 3 (9%) on the left wrist (unknown wrist for 3 patients). Median (IQR) patient age was 60 (44, 69) years old, 17 (50%) were female, 21 (64%) non-Hispanic white race only, and 32 (91%) were ambulatory before ICU admission (Table 1). In the ICU, 14 of 34 (41%) patients were admitted with respiratory failure, and 11 (32%), 7 (21%), and 3 (9%) ever received mechanical ventilation, continuous sedative infusions, and wrist restraints, respectively.

Median (IQR) average daily SOFA score in the ICU was 5 (3, 9). No patients died during the recording period.

Inactivity (Zero-Activity Epochs)

Across 34 patients and 101 patient-days, we collected 189,595 30-second epochs of actigraphy-based activity data. Overall, 122,865 (65%) epochs had zero activity, with 61% zeroes (56,022 epochs out of 189,595) during normal waking hours (06:00 to 21:59).

Inactivity (zero-activity epochs), stratified by time-of-day and baseline and ICU characteristics, are depicted in Figure 2 and Table 2. Compared to 06:00–09:59, the mean proportion of zero-activity epochs was significantly higher from 22:00 to 01:59 and 02:00 to 05:59 (mean [95% CI] proportion zero-activity epochs 62% [55–70%] versus 72% [64–78%] and 76% [70–80%], respectively, adjusted differences [95% CI] = 9% [3–15%] and 14% [9–19%], multivariable $p=0.002$ and $p<0.001$) (Table 2). Additionally, patients in the highest (versus lowest) average daily SOFA score tertile were significantly more inactive (mean [95% CI] proportion zero-activity epochs = 77% [65–86%] versus 58% [48–52%], adjusted difference = 13% [2–24%], multivariable $p=0.03$), along with patients who were ever (versus never) mechanically ventilated (79% [65–89%] versus 58% [51–64%], adjusted difference = 24% [11–38%], multivariable $p<0.001$) (Table 2). Notably, there were no significant differences in inactivity by age, ambulatory status prior to ICU admission, or admission diagnosis category, or in patients who ever received continuous sedative infusions or restraints.

Non-Zero Activity Levels

Overall, 66,721 epochs did not equal zero, with a mean \pm SD non-zero activity level of 55 \pm 70 (healthy adult = 132 \pm 141) (Figure 3, Table 3). Non-zero activity levels were significantly higher in patients who were ambulatory prior to ICU admission (mean \pm SD non-zero activity level per epoch = 57 \pm 71 versus 31 \pm 35, adjusted difference [95% CI] = 35 [21 to 51], multivariable $p<0.001$), and in the highest (versus lowest) average daily SOFA score tertile (39 \pm 57 versus 58 \pm 71, adjusted difference [95% CI] = – 22 [–43 to –2], multivariable $p=0.03$). Notably, non-zero activity levels did not differ significantly by age, BMI category, admission diagnosis category, time-of-day, or in patients who ever received mechanical ventilation, continuous sedative infusions, or restraints.

DISCUSSION

This evaluation was performed as a secondary exploratory analysis of a feasibility study of actigraphy in medical ICU (MICU) patients, with the goal of characterizing inactivity and activity among critically ill subpopulations. Our analysis of nearly 190,000 30-second epochs of actigraph data demonstrated that MICU patients are profoundly inactive, registering zero movements for two-thirds of the time recorded, including 61% during waking hours. Moreover, when patients were moving, their non-zero activity levels were lower than previously-used activity cutoffs for sedentary behavior.^{23,24} Notably, activity levels were low for all patients, including those who were younger and who never received mechanical ventilation, continuous sedative infusions, or restraints during the actigraphy

recording period. This finding was surprising, as most patients (91%) were able to walk before ICU admission. These findings suggest that ICU hospitalization itself contributes to inactivity for critically ill patients, irrespective of patient-specific factors.

While our study involved a MICU population, prior studies involving actigraphy-based activity measurement in the critically ill have occurred in general ICU populations¹³ and in those recovering from cardiac surgery^{25,26} and neuromuscular blockade.²⁷ Similar to our findings, these prior studies demonstrated low daytime,^{13,25,28,29} nighttime,^{25,28,29} and mean 24-hour^{21,26,27} activity levels, ranging from 25 to 418, 2 to 19, and 9 to 1455 movements per 15 to 60 second epoch, respectively, along with 44 to 71% daytime and 74 to 91% nighttime zeroes.^{25,29}

Building on prior research, we introduced non-zero activity levels as a simple, but potentially important metric of movement intensity. We demonstrated that even with epochs with zero activity removed from the equation, patients generally exhibited low activity levels. Our method of measuring both inactivity and non-zero activity, rather than mean activity alone, could help more clearly define patient activity patterns, movement intensity, and associated outcomes. Not surprisingly, patients with the highest organ failure scores, and those receiving mechanical ventilation tended to be more inactive and when they moved, they moved less. While our study did not differentiate voluntary from involuntary (i.e., tremors) patient movement and movement related to patient-care activities, given the low levels of activity in the study, removing these movements would result in even lower activity levels.

Notably, we were surprised to observe that younger, less sick, non-mechanically ventilated, non-sedated, and non-restrained patients were also vulnerable to inactivity and low activity; these patients were profoundly motionless when compared to non-ICU inpatients and older community-dwelling adults.^{19,30–36} While our study was not powered to identify all subgroup differences, the raw values suggest relatively small differences across many subgroups. Prior studies involving actigraphy defined “sedentary” behavior as 200 movements per 60 second epoch, far exceeding the activity counts of nearly all of our ICU patients, even with zeros removed.^{23,24} Given all the data describing associations between low activity and post-intensive care syndrome, this finding reinforces the need for early mobility efforts in the ICU, including in younger and non-mechanically ventilated patients with lower acuity illness. Barriers in this population are less likely to be related to patient illness such as hemodynamic instability or excessive devices, and highlight institutional and process issues such as limited staff, difficulty in coordination can contribute to low activity states. Such priorities have support from recent ICU clinical practice guidelines, and have been associated with reduced mechanical ventilation duration, ICU length of stay and improved post-ICU functional outcomes.^{3,8,37–39}

As expected, we observed more inactivity during the nighttime hours (22:00 to 01:59 and 02:00 to 05:59) as compared to daytime hours. In our initial feasibility study we utilized manufacturer-provided software to demonstrate that 72% of epochs were defined as sleep, including 80% of nighttime (22:00 to 06:00) and 67% of daytime (07:00 to 19:00) epochs.²² However, this 24-hour “sleep” amount was unlikely to reflect true sleep, and in this analysis

we therefore did not attempt to differentiate between sleep and wake.^{19,22} Notably, zero-activity and low non-zero activity occupied the majority of the 24-hour day, suggesting that robust circadian patterns of inactivity and activity were absent and small daytime and nighttime differences were not clinically meaningful. Recent attention has highlighted circadian rhythm misalignment as a common, deleterious and potentially modifiable problem in critically ill patients.^{40–42} However, measuring circadian rhythms, whether via polysomnography or laboratory biomarkers, is extremely complicated in the ICU setting.^{14,19,43–45} In non-ICU patients, advanced analyses of actigraphy-based patterns of rest and activity have been used to measure circadian rhythm alignment and misalignment.^{11,17,19,25,46–51} To better understand and improve circadian rhythm misalignment in the ICU, future investigations could build on existing actigraphy-based investigations, including more advanced analyses of inactivity and non-zero activity levels.

Our study was motivated, in part, by rising interest in ICU-based mobility efforts aimed at preventing adverse outcomes associated with prolonged bedrest.^{1,5,38,39,52–54} While such efforts are of interest to clinicians, quantification of their impact is difficult, especially when utilizing patient- or staff-reported activity levels. Past reviews of activity measurements in patients have demonstrated agreement of actigraphic or accelerometer based measurements of activity with respect to observation,^{14,47,55} EEG,⁴⁷ and PSG.^{12,31,43,56} Recent research has demonstrated that wrist accelerometer-based movements not only correlate with observer-recorded patient behavior maps,⁵⁷ but also energy expenditure and functional outcomes.^{58,59} Hence, wrist accelerometers are now available that can decipher positions and movements (i.e., lying, sitting, standing, and walking) based on activity patterns.²⁴ However, the device used in our study did not have such capabilities, thus preventing us from better understanding the content and characteristics of specific characteristics of recorded activity periods. Nevertheless, given its affordability and ability to non-invasively and continuously track activity, actigraphy poses an attractive option large-scale use in critically-ill patients and, with the development of more advanced interpretation algorithms, a valuable tool to inform ICU mobility efforts. Nevertheless, given its affordability and ability to non-invasively and continuously track activity, actigraphy poses an attractive option large-scale use in critically-ill patients and, with the development of more advanced interpretation algorithms, a valuable tool to inform ICU mobility efforts.

Using actigraphy, our analysis made apparent that inactivity is a serious issue in critically ill patients, given the high frequency of zero-activity epochs and low non-zero activity intensity overall. Several studies have explored the culture of immobility in the critical care environment.^{1,3,6,7} Though barriers to mobility are generally perceived to be low by providers, patient, environment, cultural and process-related barriers are common and often hinder these efforts.^{1,6,7} Actigraphy, particularly in real-time, may enlighten providers regarding the extent of patient immobility, which could in turn motivate rehabilitation interventions. Additionally, large-scale activity data could stress to health system leadership the importance of patient mobility, helping to jumpstart efforts to address barriers, including formation of interdisciplinary teams, identification of champions, and staff-wide education on safety and benefits of early mobility.⁶⁰

Key strengths of our study including enrollment of consecutive ICU patients, epoch-by-epoch analysis, and a separate analysis of zero and non-zero activity epochs. In addition, we introduce a novel tool in analyzing activity patterns by actigraphy – the percentage of zero vs. non-zero activity. However, our study also has limitations, including a small sample size (thus impacting the power to detect all important effects) and a relatively short 48-hour recording duration. Additionally, with use of one actigraph model, our findings were confined to the specific sensitivities of that device. To minimize device-related bias, we analyzed gross activity levels instead of using processed software-based activity metrics, and placed the devices according to standard practice. Future efforts could evaluate different actigraphs for measurement differences. Next, because patients were not observed during the recording period, our study could not distinguish between voluntary and involuntary (i.e., in setting of tremor) patient movements and movements associated with patient care. While our research staff diligently monitored actigraphs for position and placement, future efforts could include direct observation to differentiate actual from artifactual movement. Nevertheless, despite these limitations, our study provides a foundation for future studies involving actigraphy to evaluate patient inactivity and activity in the ICU setting. Further research is necessary in this area to evaluate what activity levels may be optimal in the critical care setting. We emphasize that more studies such as this may inform future research in ICU activity and mobility.

CONCLUSION

We performed a detailed analysis of ~190,000 30-second epochs of actigraphy data from 34 MICU patients, and demonstrated that nearly all patients were profoundly inactive, with ~60% of 30-second epochs equaling zero movements. When moving, patients exhibited markedly low levels of non-zero activity. Importantly, we observed profound inactivity and low activity at all times of the day, and in patients with lower acuity illness, including those who were younger and never received continuous sedative infusions or restraints. These findings suggest that irrespective of patient-specific factors, ICU hospitalization alone contributes to inactivity and low activity, highlighting an intriguing area of investigation and improvement.

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Highlights:

- Medical ICU patients demonstrate profound inactivity, and are making no movements about 2/3 of the time
- Activity levels were lowest in patients who were non-ambulatory prior to ICU admission and in patients with the highest severity of illness
- Inactivity was more prevalent in patients receiving mechanical ventilation and in sicker patients
- Sedation status, age, or presence of restraints did not contribute to differences in activity level

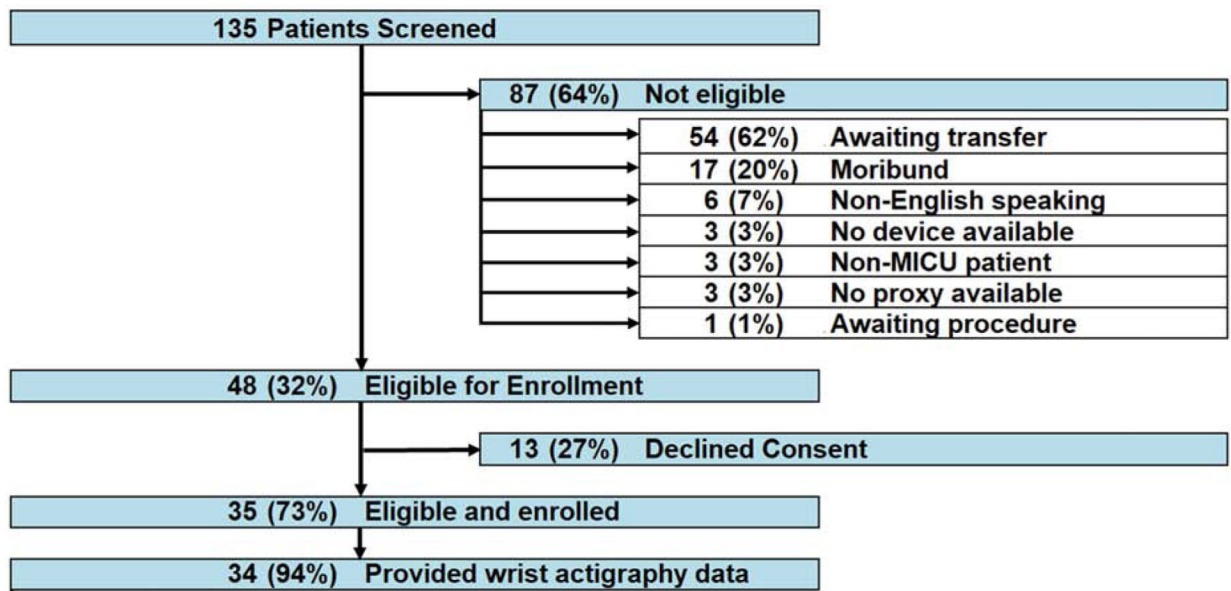


Figure 1.
Patient flow diagram

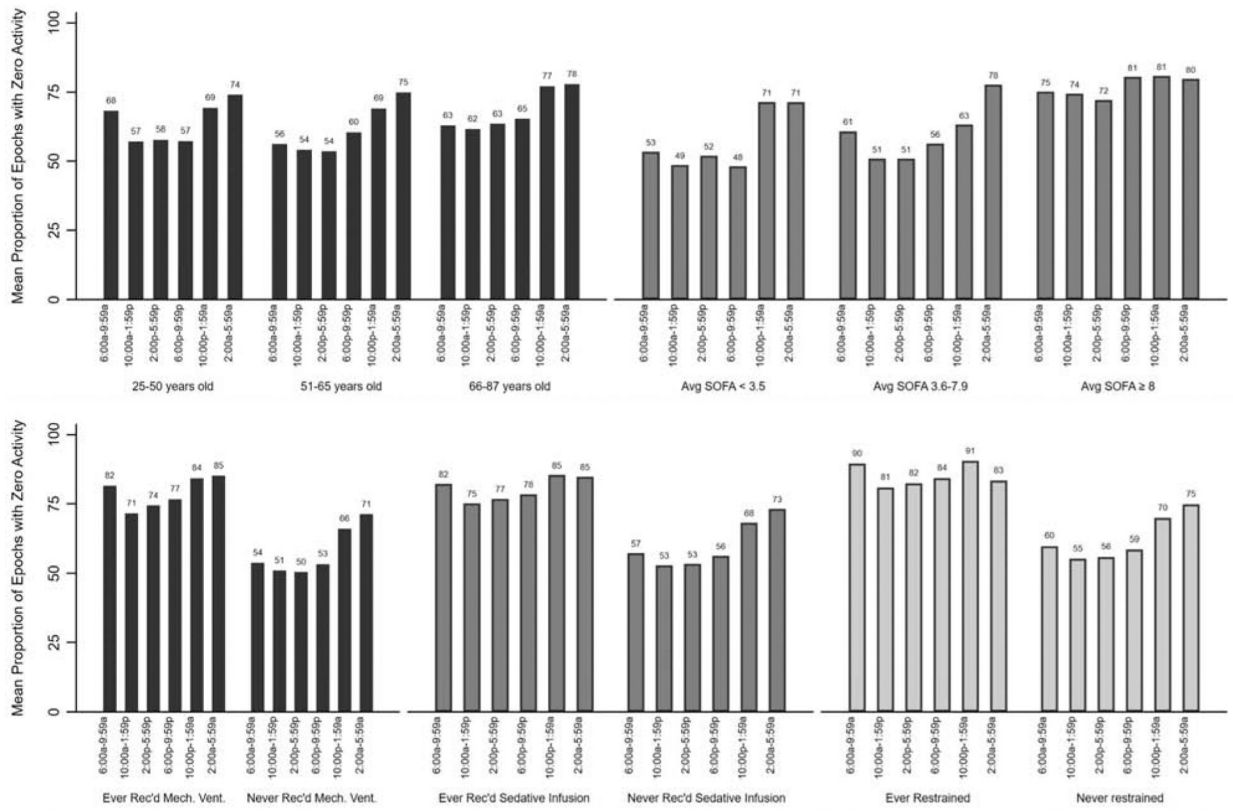


Figure 2.
Proportion of zero-activity epochs

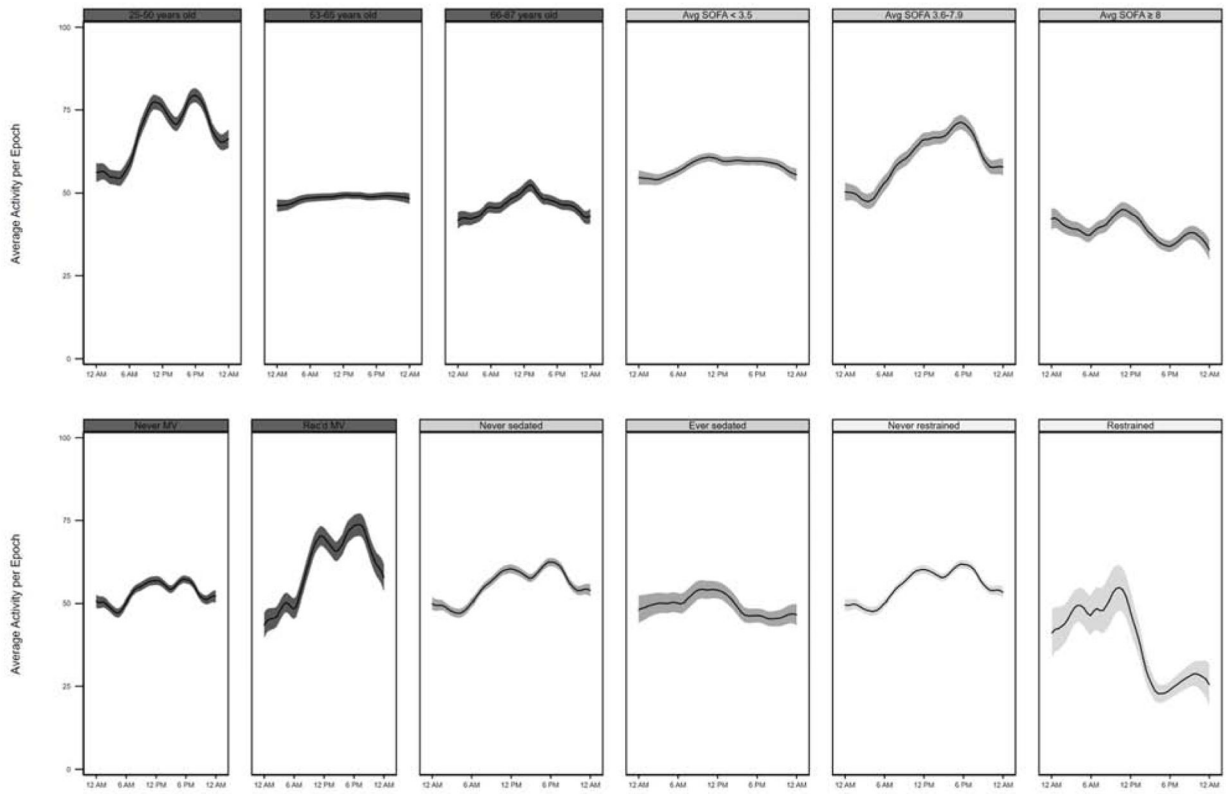


Figure 3. Actigraphy-based non-zero activity levels over the 24-hour day, expressed as a linear prediction plot with 95% confidence interval

Table 1.Patient Characteristics (*N* = 34)

Baseline Variables	
Age, median (IQR) ^a	60 (44,69)
Female, n (%)	17 (50%)
Non-Hispanic White Race, n (%)	21 (64%)
Ambulatory prior to ICU admission	32 (91 %)
BMI Classification^b	
Underweight (BMI <18)	3 (9%)
Normal (BMI 18–24.9)	13 (38%)
Overweight (BMI 25–29.9)	9 (26%)
Obese (BMI > 30)	9 (26%)
ICU Variables	
Admission Diagnosis Category	
Respiratory Failure	14 (41%)
Gastrointestinal	3 (9%)
Sepsis	7 (21%)
Cardiovascular	4 (12%)
Other ^c	6 (18%)
Average Daily SOFA Organ Failure Score, median (IQR) ^{a,c}	5 (3, 9)
Ever Mechanically Ventilated ^c	11 (32%)
Ever Received Continuous Sedative Infusion ^c	7 (21%)
Ever Restrained ^c	3 (9%)

Abbreviations: IQR = Interquartile Range; ICU = Intensive Care Unit; BMI = Body Mass Index; SOFA = Sequential Organ Failure Assessment

^aStratified by tertile in univariable and multivariable analyses

^bIncludes monitoring for procedures (2 of 34, 6%), renal (1 of 34, 6%), endocrine (1 of 34, 3%), and other (2 of 34, 6%)

^cDuring 48-hour actigraphy recording period only

Table 2.

Zero activity epochs in the ICU, as measured using actigraphy

	n (N=34)	Total Epochs (N=189,595)	Zero Activity Epochs, Proportion (95% CI) ^a	Unadjusted Difference (95% CI) ^b	P value	Adjusted Difference (95% CI) ^b	P value
Baseline Variables							
Age Tertile							
25–50 years old	12	66,196	64 (49, 77)	REF	REF	REF	REF
51–65 years old	11	61,471	62 (53, 70)	–2 (–17, 13)	0.79	–9 (–20, 2)	0.13
66–87 years old	11	61,928	68 (54, 80)	4 (–12, 21)	0.61	3 (–9, 15)	0.67
Gender							
Female	17	94,607	68 (57, 77)	REF	REF	REF	REF
Male	17	94,988	61 (52, 70)	–7 (–19, 6)	0.28	–2 (–14, 11)	0.78
Race							
White	21	117,884	62 (53, 71)	REF	REF	REF	REF
Non-white	13	71,711	69 (58, 78)	7 (–5, 19)	0.28	6 (–4, 15)	0.26
Ambulatory Prior to ICU							
No	2	9,822	70 (0, 100)	REF	REF	REF	REF
Yes	32	179,773	65 (57, 71)	–5 (–24, 14)	0.60	2 (–20, 23)	0.89
BMI Classification							
Underweight (BMI <18)	3	16,905	47 (18, 78)	–14 (–31, 2)	0.09	–12 (–36, 11)	0.30
Normal (BMI 18–24.9)	13	71,580	61 (49, 72)	REF	REF	REF	REF
Overweight (BMI 25–29.9)	9	50,496	74 (57, 86)	13 (–3, 28)	0.11	16 (0, 31)	0.05
Obese (BMI >30)	9	50,614	66 (54, 77)	5 (–9, 19)	0.50	12 (3, 22)	0.009
Admission Diagnosis Category							
Respiratory Failure	14	77,045	67 (56, 77)	REF	REF	REF	REF
Gastrointestinal	3	16,858	65 (8, 98)	–2 (–31, 26)	0.87	–2 (–28, 24)	0.90
Sepsis	7	39,739	67 (45, 84)	0 (–18, 18)	1.00	2 (–14, 17)	0.85
Cardiovascular	4	22,653	53 (27, 77)	14 (–3, 32)	0.10	–8 (–20, 4)	0.17
Other	6	33,300	64 (48, 78)	3 (–11, 17)	0.66	6 (–5, 18)	0.29
ICU Variables							
Time of day							
06:00–09:59	-	32,121	62 (55, 70)	REF	REF	REF	REF
10:00–13:59	-	27,813	60 (51, 68)	–3 (–9, 3)	0.36	–4 (–10, 2)	0.22
14:00–17:59	-	32,640	58 (50, 66)	–4 (–10, 2)	0.16	–5 (–11, 1)	0.11
18:00–21:59	-	32,640	61 (52, 69)	–2 (–8, 5)	0.62	–2 (–8, 4)	0.51
22:00–01:59	-	32,221	72 (64, 78)	9 (3, 15)	0.003	9 (3, 15)	0.002
02:00–05:59	-	32,160	76 (70, 80)	13 (7, 19)	<0.001	14 (9, 19)	<0.001
Average Daily SOFA Tertile							
0.0 – 3.5	13	72,683	58 (48, 52)	REF	REF	REF	REF

	n (N=34)	Total Epochs (N=189,595)	Zero Activity Epochs, Proportion (95% CI) ^a	Unadjusted Difference (95% CI) ^b	P value	Adjusted Difference (95% CI) ^b	P value
3.6 – 7.9	11	57,409	60 (46, 73)	2 (–12, 17)	0.74	–4 (–19, 12)	0.65
8.0 – 18.3	10	56,802	77 (65, 86)	19 (7, 32)	0.002	13 (2, 24)	0.03
Mechanically Ventilated							
Never	23	129,014	58 (51, 64)	REF	REF	REF	REF
Ever	11	60,581	79 (65, 89)	21 (9, 33)	0.003	24 (11, 38)	<0.001
Received Continuous Sedation							
Never	27	150,004	61 (54, 67)	REF	REF	REF	REF
Ever	7	39,591	81 (9, 38)	20 (7, 33)	0.01	–10 (–31, 10)	0.32
Restrained							
Never	31	172,632	63 (56, 69)	REF	REF	REF	REF
Ever	3	16,963	85 (63, 95)	22 (14, 31)	<0.001	–6 (–31, 19)	0.65
All Subjects ^c	34	189,595	65 (58, 71)				

Abbreviations: ICU = Intensive Care Unit; BMI = Body Mass Index; SOFA = Sequential Organ Failure Assessment

^aWithin-patient 95% confidence intervals

^bDerived using predictive margins of a logistic regression of zero versus nonzero activity epochs, using clustering to account for within-patient correlation of activity levels. Multivariable model involved all variables reported in this table. Expressed as marginal differences in proportion of zero activity levels.

^cFor reference, a healthy adult undergoing 24-hour actigraphy exhibits 49% zeroes, with 19% from 06:00–09:59, 41% from 10:00–13:59, 35% from 14:00–17:59, 31% from 18:00–21:59, 85% from 22:00–01:59, and 83% from 02:00–05:59.

Table 3.

Non-zero activity counts in the ICU, as measured using actigraphy

	<i>n</i> (N=34)	Non-Zero Epochs (N=66,721)	Mean (SD) Non-Zero Activity Level ^a	Unadjusted Difference (95% CI) ^b	<i>P</i> value	Adjusted Difference (95% CI) ^b	<i>P</i> value
Baseline Variables							
Age Tertile							
25–50 years old	12	23,811	69 (83)	REF	REF	REF	REF
51–65 years old	11	23,338	49 (61)	–21 (–40, –2)	0.01	–1 (–17, 15)	0.91
66–87 years old	11	19,572	47 (61)	–23 (–46, 1)	0.07	–1 (–24, 21)	0.90
Gender							
Female	17	30,085	62 (78)	REF	REF	REF	REF
Male	17	36,636	50 (62)	–13 (–31, 6)	0.16	–15 (–30, 0)	0.05
Race							
White	21	44,500	59 (72)	REF	REF	REF	REF
Non-white	13	22,221	49 (66)	–9 (–27, 9)	0.32	–12 (–25, 1)	0.06
Ambulatory Prior to ICU							
No	2	2,985	31 (35)	REF	REF	REF	REF
Yes	32	63,736	57 (71)	25 (14, 36)	<0.001	35 (20, 51)	<0.001
BMI Category							
Underweight (BMI <18)	3	8,949	85 (97)	28 (–9, 65)	0.13	6 (–27, 39)	0.74
Normal (BMI 18–24.9)	13	27,576	57 (67)	REF	REF	REF	REF
Overweight (BMI 25–29.9)	9	13,123	42 (55)	–14 (–30, 1)	0.07	–12 (–30, 5)	0.16
Obese (BMI > 30)	9	17,073	48 (64)	–9 (–24, 7)	0.29	–4 (–24, 16)	0.67
Admission Diagnosis Category							
Respiratory Failure	14	25,167	64 (81)	REF	REF	REF	REF
Gastrointestinal	3	5,915	56 (66)	–9 (–27, 11)	0.40	–9 (–46, 28)	0.64
Sepsis	7	12,980	49 (67)	–15 (–44, 15)	0.33	–18 (–39, 4)	0.11
Cardiovascular	4	10,738	58 (63)	–6 (–32, 21)	0.68	–11 (–27, 5)	0.18
Other	6	11,921	43 (54)	–21 (–39, –2)	0.03	–21 (–44, 3)	0.08
ICU Variables							
Time of day							
06:00–09:59	-	12,836	59 (76)	REF	REF	REF	REF
10:00–13:59	-	11,769	63 (83)	5 (–1.6, 11)	0.14	2 (–3, 7)	0.45
14:00–17:59	-	14,261	61 (75)	4 (–3, 11)	0.27	2 (–3, 6)	0.42
18:00–21:59	-	13,443	63 (83)	4 (–5.3, 13)	0.40	0 (–6, 7)	0.96
22:00–01:59	-	9,329	50 (65)	–4 (–13, 5)	0.38	–5 (–12, 3)	0.19
02:00–05:59	-	8,017	50 (67)	–6 (–13, 1)	0.07	–5 (–11, 2)	0.16
Average Daily SOFA Tertile							
0.0 – 3.5	13	30,605	58 (71)	REF	REF	REF	REF

	<i>n</i> (<i>N</i> =34)	Non-Zero Epochs (<i>N</i> =66,721)	Mean (SD) Non-Zero Activity Level ^a	Unadjusted Difference (95% CI) ^b	<i>P</i> value	Adjusted Difference (95% CI) ^b	<i>P</i> value
3.6 – 7.9	11	22,809	62 (75)	3 (–19, 26)	0.77	–3 (–26, 20)	0.78
8.0 – 18.3	10	12,876	39 (57)	–19 (–34, –4)	0.01	–22 (–43, –2)	0.03
Mechanically Ventilated							
Never	23	54,114	54 (66)	REF	REF	REF	REF
Ever	11	12,607	63 (87)	9 (–22, 40)	0.56	0 (–27, 28)	0.98
Received Continuous Sedation							
Never	27	59,101	56 (71)	REF	REF	REF	REF
Ever	7	7,620	49 (64)	–7 (–21, 7)	0.32	–9 (–43, 24)	0.60
Restrained							
Never	31	64,220	56 (70)	REF	REF	REF	REF
Ever	3	2,501	38 (62)	–19 (–32, –4)	0.01	2 (–34, 37)	0.93
All Subjects ^c	34	66,721	55 (70)				

Abbreviations: ICU = Intensive Care Unit; BMI = Body Mass Index; SOFA = Sequential Organ Failure Assessment

^aWithin-patient standard deviation

^bDerived using predictive margins of a Poisson regression of non-zero activity counts per epoch, using clustering to account for within-patient correlation of activity levels. All covariates included in multivariable Poisson model.

^cFor reference, a healthy adult undergoing 24-hour actigraphy exhibits 51% non-zero epochs with a mean±SD non-zero activity of 132±141 movements, with 138±143 movements from 06:00–09:59, 140±137 from 10:00–13:59, 108±108 from 14:00–17:59, 158±166 from 18:00–21:59, 38±75 from 22:00–01:59, and 143±149 from 02:00–05:59.