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Feasibility and safety of in-bed cycling for physical rehabilitation in the intensive care unit☆,☆☆

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ABSTRACT

Purpose: The purpose was to evaluate the feasibility and safety of in-bed cycle ergometry as part of routine intensive care unit (ICU) physical therapist (PT) practice.
Materials and methods: Between July 1, 2010, and December 31, 2011, we prospectively identified all patients admitted to a 16-bed medical ICU receiving cycling by a PT, prospectively collected data on 12 different potential safety events, and retrospectively conducted a chart review to obtain specific details of each cycling session.
Results: Six hundred eighty-eight patients received PT interventions, and 181 (26%) received a total of 541 cycling sessions (median [interquartile range {IQR}] cycling sessions per patient, 2 [1-4]). Patients' mean (SD) age was 57 (17) years, and 103 (57%) were male. The median (IQR) time from medical ICU admission to first PT intervention and first cycling session was 2 (1-4) and 4 (2-6) days, respectively, with a median (IQR) cycling session duration of 25 (18-30) minutes. On cycling days, the proportion of patients receiving mechanical ventilation, vasopressor infusions, and continuous renal replacement therapy was 80%, 8%, and 7%, respectively. A single safety event occurred, yielding a 0.2% event rate (95% upper confidence limit, 1.0%).
Conclusions: Use of in-bed cycling as part of routine PT interventions in ICU patients is feasible and appears safe. Further study of the potential benefits of early in-bed cycling is needed.

1. Introduction

Survivors of critical illness frequently report long-term physical impairments persisting up to 5 years after discharge [1,2]. Rehabilitation, such as physical therapy (PT) interventions in the intensive care unit (ICU), can improve patients' outcomes. A systematic review of randomized controlled trials (RCTs) of strategies to improve physical functioning of ICU survivors identified the importance of PT interventions in the ICU [3]. However, implementing evidence-based PT interventions, as part of routine clinical practice, can be challenging [4–6]. Such challenges include access to rehabilitation personnel and specialized equipment, and ICU patients' physiological stability [7–9].

Some rehabilitation interventions in critically ill patients require additional human resources. For example, a 330-patient study added a mobility team, consisting of a PT, registered nurse, and nurse assistant, to facilitate early mobility [10]. A 104-patient RCT of early rehabilitation used both a PT and occupational therapist for interventions [11]. With a projected increase in the number of critically ill patients requiring rehabilitation in the ICU [12] and a concurrent projected decrease in the number of PTs available to provide care [13–15], effective and efficient rehabilitation interventions are needed.

One promising technology that may be both effective and efficient for rehabilitation of critically ill patients is in-bed cycle ergometry ("cycling"). In a 90-patient, single-center RCT of in-bed cycling in the ICU vs usual care, those receiving cycling demonstrated better 6-minute walk distance, greater leg strength, and better Short Form 36 physical function scores at hospital discharge [16]. However, few ICUs have in-bed cycle ergometers [8]; thus, there are little data regarding use of cycling as part of routine care in the ICU. Following publication of the RCT of cycling [16], our ICU purchased an in-bed cycle ergometer (Reck MotoMed Letto) similar to that reported in the trial. Within an individual cycling session, as dictated by the patients' level of wakefulness, participation, and effort, this device

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Table 1
Patient characteristics, by cycling status, for 688 patients receiving physical therapy in the ICU

Characteristic	All patients N = 688	Cycling n = 181	No cycling n = 507	*P* value
Demographics				
Age (y), mean [SD]	56.7 (14.1)	56.7 (16.6)	56.6 (16.0)	.977
Male, n (%)	332 (48.3)	103 (56.9)	229 (45.2)	.007
Black race, n (%)	350 (50.9)	82 (45.3)	268 (52.9)	.004
Location before hospital admission*				.476
Home (independent)	444 (64.6)	122 (67.8)	322 (63.5)	
Home (with caregiver assistance)	192 (27.9)	44 (24.4)	148 (29.2)	
Other	51 (7.4)	14 (7.8)	37 (7.3)	
Ambulatory before ICU admission, n (%)	604 (87.8)	155 (85.6)	449 (88.6)	.302
Location before MICU admission†				.005
Ward	252 (36.9)	61 (33.7)	191 (38.0)	
Emergency department	246 (36.0)	53 (29.3)	193 (38.4)	
Outside hospital	152 (22.3)	56 (30.9)	96 (19.1)	
Other	33 (4.8)	11 (6.1)	22 (4.4)	
MICU data				
ICU admission diagnosis, n (%)				.003
Respiratory failure	315 (45.8)	101 (55.8)	214 (42.2)	
Sepsis, nonpulmonary	114 (16.6)	25 (13.8)	89 (17.6)	
Gastrointestinal	91 (13.2)	15 (8.3)	76 (15.0)	
Nephrology	45 (6.5)	11 (6.1)	34 (6.7)	
Cardiopulmonary arrest	19 (2.8)	9 (5.0)	10 (2.0)	
Other	104 (15.1)	20 (11.0)	84 (16.6)	
Received mechanical ventilation during MICU stay, n (%)	430 (62.5)	149 (82.3)	281 (55.4)	<.001
Days from MICU admission to first PT session, median (IQR)	2 (1-3)	2 (1-4)	2 (1-3)	<.001
No. PT treatments in MICU, median (IQR) per patient	2 (1-4)	4 (3-9)	2 (1-3)	<.001
ICU mortality	52 (7.6)	28 (15.5)	24 (4.7)	<.001
MICU LOS, all patients, median (IQR) days	4 (2-8)	10 (5-17)	3 (2-6)	<.001
Hospital mortality	95 (13.8)	49 (27.1)	46 (9.1)	<.001
Hospital LOS, all patients, median (IQR) days	13 (7-24)	20 (12-35)	11 (6-19)	<.001
Discharge location among survivors, n (%)				<.001
Home (independent)	198 (33.4)	28 (21.2)	170 (36.9)	
Home (with caregiver assistance)	130 (21.9)	20 (15.2)	110 (23.9)	
Acute rehabilitation	72 (12.1)	27 (20.5)	45 (9.8)	
Subacute rehabilitation	78 (13.2)	27 (20.5)	51 (11.1)	
Other	115 (19.4)	30 (22.7)	85 (18.4)	

In this table, we compare characteristics of patients receiving physical therapy and in-bed cycle ergometry with those who did not receive cycle ergometry. For binary data, we calculated the proportion and 95% confidence interval. We used a *t* test for independent groups to compare continuous data [19] and used the χ^2 statistic (or Fisher exact test, as appropriate) to compare categorical data. JHH indicates Johns Hopkins Hospital.

* Sample size for cycling and noncycling, respectively: 180, 507.

† Sample size for cycling and noncycling, respectively: 181, 502.

allows patient activity to move back and forth between passive cycling (where the patient does not contribute to pedaling motion), active-assisted cycling (where the patient can augment the motorized cycle), and active cycling (with the option for a PT to add resistance to cycling). In this report, we evaluated the feasibility and safety of incorporating in-bed cycle ergometry as part of routine PT practice in the ICU.

2. Materials and methods

We identified all adult patients admitted to a 16-bed medical ICU (MICU) who received PT interventions between July 1, 2010, and December 31, 2011, from a prospectively collected clinical database of critical care physical rehabilitation. For all such patients, prospectively identified as receiving in-bed cycling as part of their PT intervention session, we retrospectively collected additional data on all cycling sessions, including the duration of sessions, whether active cycling occurred, and highest reported resistance used. We retrospectively collected additional data on the daily presence of femoral catheters in situ, receipt of mechanical ventilation, vasopressor infusions, continuous renal replacement therapy (CRRT), and sedative and opioid infusions on the days of cycling sessions, and Sequential Organ Failure Assessment (SOFA) scores on the day of ICU admission [17].

Using prospectively recorded safety events from a preexisting ICU rehabilitation clinical database, we identified whether any of the following 12 physiological abnormalities or potential safety events occurred during in-bed cycling: cardiovascular event (arrhythmia, hypertension [mean arterial pressure >140 mm Hg], hypotension [mean arterial pressure <55 mm Hg], or cardiorespiratory arrest), respiratory event (oxygen saturation <85% for >3 minutes), catheter (arterial, central venous, or dialysis/pheresis) removal, tube (artificial airway [endotracheal or tracheostomy], chest, or feeding) removal, or falls [18].

For continuous data, we calculated the mean and standard deviation (SD), or median and interquartile range (IQR) if data were not normally distributed. For binary data, we calculated the proportion and 95% confidence interval. We used a *t* test for independent groups to compare continuous data [19] and used the χ^2 statistic (or Fisher exact test, as appropriate) to compare categorical data. We used IBM SPSS Statistics, version 22 (IBM, Armonk, NY), for analyses. The Johns Hopkins University Institutional Review Board, which waived the requirement for informed consent, approved our study.

3. Results

During the 18-month study period, 688 patients received at least 1 PT intervention session in the MICU, of whom 181 (26%) received cycling as part of their PT intervention session (Table 1). Of the 688 patients, the median (IQR) time from MICU admission to first PT intervention session was 2 (1-3) days, and the number of MICU PT intervention sessions per patient was 2 (1-4). Compared with patients who did not receive in-bed cycling during their MICU stay, patients who cycled were more likely to receive mechanical ventilation (82% [149] vs 55% [281], $P < .001$), received a greater number of PT intervention

Table 2
Characteristics of 181 patients receiving 541 in-bed cycling sessions in the MICU

Characteristic	Measurement
SOFA score at ICU admission*, mean (SD)	8.4 (3.8)
Cycling session data	
Days from MICU admission to first cycling session, median (IQR)	4 (2-6)
No. cycling sessions received in MICU, median (IQR) per patient	2 (1-4)
Duration of in-bed cycling, median (IQR) minutes per session per patient†	25 (18-30)
Duration of entire PT session, median (IQR) minutes per session per patient‡	47 (38-55)
Active cycling recorded, proportion of sessions§, n (%)	411 (94)

* SOFA: a composite score evaluating 6 organ systems used to assess the severity of organ dysfunction in the ICU [17]; patient sample size for SOFA score = 179.
† Sample size for duration of cycling = 171 patients and 473 sessions.
‡ Sample size for duration of PT session = 169 patients and 471 sessions.
§ Sample size for active cycling = 159 patients and 436 sessions.

sessions (4 [3-9] vs 2 [1-3], $P < .001$), and had a longer MICU length of stay (median [IQR] days, 10 [5-17] vs 3 [2-6], $P < .001$).

Of the 181 patients receiving cycling, the mean (SD) age was 57 (16) years, 103 (57%) were male, and 82 (45%) were black (Table 1). Before hospital admission, most patients could ambulate (155 [86%]) and lived independently at home (122 [68%]). The main categories for MICU admission were respiratory failure (101 [56%]), nonpulmonary sepsis (25 [14%]), or gastrointestinal issues (15 [8%]). The mean (SD) admission SOFA score was 8.4 (3.8), and median (IQR) time from MICU admission to first PT intervention and first cycling session was 2 (1-4) and 4 (2-6) days, respectively (Tables 1 and 2). Patients received 541 cycling sessions by 9 different PTs with a median ([IQR] number of PT intervention and cycling sessions of 4 (3-9) and 2 (1-4) per patient, respectively.

3.1. Feasibility of in-bed cycling

Patients received the following ICU therapies on 541 cycling days (Table 3): mechanical ventilation (432 [80%], of whom 268 [62%] had an oral endotracheal tube), vasopressor infusion (45 [8%]), and CRRT (36 [7%]). Infusions of a benzodiazepine, propofol, or opioid occurred on 128 (24%), 62 (11%), and 206 (38%) of all cycling days, respectively. Moreover, during cycling, femoral arterial, dialysis, and venous catheters, respectively, were in situ for 6 (1.1%), 1 (0.1%), and 8 (1.5%) sessions (2.8% of all sessions). Fig. 1 is an example of a patient receiving mechanical ventilation and in-bed cycling.

Of the 471 and 473 instances where the duration of the PT intervention session and cycling was reported, the median (IQR) was 47 (38-55) and 25 (18-30) minutes, respectively. Of the 436 instances where PTs recorded both active and passive cycling activity, the device reported active cycling (for any part of the cycling session) in 411 (94%) of all sessions. Of the 368 instances with available resistance data, the majority of cycling sessions (336 [91%]) had no resistance.

Table 3
Characteristics of catheters and ICU therapies in 181 patients receiving 541 in-bed cycling sessions in the MICU

	n (%) patients	n (%) sessions
Femoral catheters in situ during cycling		
Arterial	4 (2.2)	6 (1.1)
Dialysis	1 (0.6)	1 (0.1)
Venous	6 (3.3)	8 (1.5)
ICU therapies on days of cycling*		
Mechanical ventilation†	138 (76)	432 (80)
Vasopressor infusions	30 (17)	45 (8)
Continuous renal replacement therapy	20 (11)	36 (7)
Sedation and opioid status on days of cycling		
Benzodiazepine infusion	41 (23)	128 (24)
Propofol infusion	15 (8)	62 (11)
Opioid infusion	55 (30)	206 (38)

* Recorded at 6:00 AM on dates of cycling.
† Of 432 days with mechanical ventilation, 268 (62%) occurred with an endotracheal tube in situ, and 164 (38%) occurred with a tracheostomy in situ.

3.2. Safety of in-bed cycling

Among all 12 physiological abnormalities or potential safety events prospectively monitored with the 541 cycling sessions, only a single event occurred (0.2% event rate, 95% upper confidence limit = 1.0%). This event was dislodgement of a radial arterial line already scheduled for replacement due to unstable positioning and malfunction before cycling.

4. Discussion

To our knowledge, this evaluation of 181 consecutive patients receiving 541 in-bed cycling sessions as part of routine clinical care with PT interventions in the MICU is the largest-sized report to date. Medical ICU patients receiving (vs not receiving) in-bed cycling were more severely ill with more PT intervention treatments and a longer ICU length of stay. For those patients who received in-bed cycling, PTs included cycling in approximately half of all treatment sessions. The majority of in-bed cycling sessions occurred on days in which patients received mechanical ventilation. Cycling also occurred on days when patients received vasopressor infusions and CRRT, and had femoral vascular access devices in situ. The frequent use of cycling, as reported in our data, demonstrates that it is a feasible rehabilitation therapy intervention for ICU patients. In particular, this intervention may be most suitable for ICU patients who cannot tolerate out-of-bed activities, such as standing, transferring to chair, or walking. Safety events were rare (0.2% event rate) with only a single event (ie, dislodgement of a radial arterial catheter previously identified for replacement due to malposition and malfunction before cycling). Hence, these data suggest that cycling is feasible and safe as part of routine PT interventions in the ICU.

In-bed cycling is a promising technology to enhance rehabilitation in critically ill patients [9]. To date, 6 ICU studies have reported cycling in a total of 173 patients [16,20–24] with more than 600 sessions reported [16,21–24]. Of these 6 reports, there were 3 case series [21–23], 1 case-control study [24], and 2 RCTs [16,20], with sample sizes varying from 16 (24) to 90 (16) enrolled patients. These reports included evaluation of single cycling sessions [21–23], cycling as part of a rehabilitation therapy protocol [20], cycling added to usual-care PT interventions [16], and cycling augmented by electrical stimulation [24]. Reported cycling session duration was less than or equal to 5 [20,22], 20 [16,21], and greater than or equal to 30 minutes [23,24], and occurred during receipt of mechanical ventilation [16,20–24] and vasopressors [16,21–24]. Two studies using a control group compared cycling to usual care [16,20].

The largest study to date was a 90-patient, single-center RCT of 20 minutes of in-bed cycling delivered 5 days per week in addition to usual PT interventions [16]. This trial was conducted in Belgian medical-surgical patients, randomizing 45 patients to the cycling intervention with 425 cycling sessions received. Participants received a median (IQR) of 7 (4-11) sessions; 45% and 87% cycled actively during their first and last ICU cycling sessions, respectively [16]. Patients were randomized to cycling, on average, 14 days after ICU admission, with 84% mechanically ventilated at trial entry [16]. Patients randomized to cycling vs usual care had a greater median 6-minute walk test distance at hospital discharge (196 m vs 143 m, $P < .05$) as the primary outcome [16]. Those receiving cycling also had greater quadriceps force ($P < .05$) and Short Form 36 physical function scores ($P < .01$) at hospital discharge [16].

Similar to the RCT [16], our mean patient age was 57 years old, approximately 80% received mechanical ventilation, and patients cycled for a median of 25 minutes per session. In contrast, we studied exclusively medical ICU patients, whereas surgical patients accounted for almost 80% of those in the prior RCT (39% cardiac, 25% transplant, and 16%

Fig. 1. Example of patient receiving mechanical ventilation and in-bed cycling in the MICU.

thoracic) [16]. In our cohort, the mean time from MICU admission to first cycling session was 4.7 days, whereas in the RCT, cycling started after a mean of 14 days. In our study vs the prior RCT, both our ICU and hospital lengths of stay were shorter (median ICU length of stay, 10 vs 25 days; median hospital LOS, 20 vs 36 days). Hence, our data build on these prior studies in suggesting that it is feasible for PTs to initiate cycling, even within days of hospital admission, as part of routine care.

Our data contribute to a growing body of literature supporting the safety of in-bed cycling with critically ill patients. Similar to other reports of rehabilitation activities in critically ill patients, safety events in our study were rare. A comprehensive review of 2.5 years of prospective data from our MICU rehabilitation program, with 1110 patient admissions and 5267 rehabilitation sessions, reported that physiological abnormalities or potential safety events occurred in only 0.6% of therapy sessions [18]. In our current report, of 541 cycling sessions, there was a single event prospectively identified (1 catheter dislodgement) with no unplanned extubation, and there were no cardiorespiratory physiological abnormalities as previously defined (see "Methods"). Similarly, in the cycling RCT, no severe physiologic adverse events occurred (eg, arrhythmias, myocardial ischemia, intolerable dyspnea); 16 sessions (4%) stopped early because of low oxygen saturation ($<$90%; n = 8) or blood pressure concerns (n = 8; systolic $>$180 mm Hg, n = 6; $>$20% decrease in diastolic, n = 2); however, all variables returned to baseline within 2 minutes of activity cessation [16]. Three patients in the cycling group withdrew: 2 because of cardiac instability and 1 because of an Achilles tendon rupture [16]. In all 6 cycling studies, authors reported no catheter or tube dislodgements [16,20–24].

Our study has potential limitations. Firstly, although we prospectively identified all cycling sessions and safety data, details about the cycling sessions were retrospectively collected from PT clinical notes; hence, we do not have data regarding why therapists chose cycling as part of their treatment session. Secondly, we did not collect daily organ failure scores or patient comorbidities. Previous research suggests that the time to initiation of PT interventions in the ICU is longer in patients with higher vs lower severity of illness and organ failure scores [25]. Moreover, patient comorbidities may impact exercise tolerance, and greater comorbidity is associated with poorer physical function [26]. Thirdly, we have no data on patients' physical functional outcomes at ICU initial assessment, ICU discharge, or hospital discharge, or data on patients' perceptions of in-bed cycling.

In-bed cycling was provided by PTs experienced with MICU rehabilitation and trained to provide in-bed cycling, which could impact the generalizability of safety data to other ICU settings where therapists are not experienced with ICU-based rehabilitation or in-bed cycling. To facilitate implementation of cycling, PTs in our institution learn about technical operation of the cycle ergometer (eg, patient set up, cycle functioning) and patient characteristics required for cycling (eg, maximum patient weight = 150 kg; ~75° and ~80° available knee and hip flexion, respectively; body habitus not interfering with cycling movement). Burtin et al [16] reported that a single 20-minute cycling session took approximately 30 to 40 minutes (including setup, takedown, and cleaning). Finally, although our study prospectively identified potential safety events and physiological abnormalities, we did not record "near-miss" events. Further research regarding near-miss events in this field is needed.

Our study also has several strengths. We had predefined, prospectively collected safety data available within a "routine care" practice environment; reported 18 months of clinical data from 9 different PTs; and studied the single largest number of patients and cycling sessions to date to help provide precision for the estimated safety event rate. We studied implementation of a new technology as part of routine PT interventions. Although cycling is a helpful rehabilitation tool for critically ill patients, the optimal timing for its initiation and the indications for its use are not yet known. Results from this single-center study suggest that therapists do routinely consider earlier use of in-bed cycling than in the prior RCT of this intervention [16]. More prospective research studying the use of early in-bed cycling is needed.

5. Conclusions

We evaluated a cohort of 181 consecutive patients receiving 541 in-bed cycling sessions as part of routine PT interventions in a single MICU. In this setting, cycling started relatively early during their ICU stay and

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generally occurred on days when patients were receiving mechanical ventilation. In this setting, in prospectively evaluating for 12 safety events during cycling, such events were rare (0.2%; 95% upper confidence interval, 1.0%). Hence, in-bed cycling as part of routine care PT sessions in the ICU appears feasible and safe. Further study of the potential beneficial effects of early in-bed cycling on patient outcomes is needed.

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