ORIGINAL ARTICLE

Effects that passive cycling exercise have on muscle strength, duration of mechanical ventilation, and length of hospital stay in critically ill patients: a randomized clinical trial

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ABSTRACT

Objective: To evaluate the effects that passive cycling exercise, in combination with conventional physical therapy, have on peripheral muscle strength, duration of mechanical ventilation, and length of hospital stay in critically ill patients admitted to the ICU of a tertiary care university hospital. **Methods:** This was a randomized clinical trial involving 38 patients (≥ 18 years of age) on mechanical ventilation who were randomly divided into two groups: control (n = 16), receiving conventional physical therapy; and intervention (n = 22), receiving conventional physical therapy and engaging in passive cycling exercise five days per week. The mean age of the patients was 46.42 ± 16.25 years, and 23 were male. The outcomes studied were peripheral muscle strength, as measured by the Medical Research Council scale, duration of mechanical ventilation, and length of hospital stay. **Results:** There was a significant increase in peripheral muscle strength (baseline vs. final) in both groups (control: 40.81 ± 7.68 vs. 45.00 ± 6.89; and intervention: 38.73 ± 11.11 vs. 47.18 ± 8.75; p < 0.001 for both). However, the range of increase in strength was higher in the intervention group than in the control group (8.45 ± 5.20 vs. 4.18 ± 2.63; p = 0.005). There were no significant differences between the groups in terms of duration of mechanical ventilation or length of hospital stay. **Conclusions:** The results suggest that the performance of continuous passive mobilization on a cyclical basis helps to recover peripheral muscle strength in ICU patients.

(ClinicalTrials.gov Identifier: NCT01769846 [http://www.clinicaltrials.gov/])

Descriptors: Physical therapy modalities; Intensive care units; Early ambulation; Muscle strength.

INTRODUCTION

Currently, as a result of increasing technological advances, critically ill patients have prolonged ICU stays, which predisposes to the incidence of complications arising from immobility.[1] Prolonged immobility is harmful, with rapid reduction in muscle mass and bone mineral density, as well as impairment in other body systems; these manifestations are evident within the first week of bed rest,[2] which can contribute to functional decline and reduced quality of life.[3] Among immobility-related complications are malnutrition, increased rates of nosocomial infection,[4] changes in sleep quality,[5] and prolonged hospital stay.[6]

Development of generalized muscle weakness is a complication that affects 30% to 60% of ICU patients[6] and can persist for six months to as long as two years

after ICU discharge,[7,8] consequently impacting physical functioning in such patients.[8] In addition, patients with reduced peripheral muscle strength have a longer duration of mechanical ventilation (MV).[9] However, these deleterious effects of immobility can be reversed or mitigated by physical therapy,[10,11] which contributes to decreased length of stay in the ICU and hospital.[12] Studies demonstrate that early mobilization of critically ill patients is considered a safe approach[13] that is aimed at preserving muscle mass and reducing muscle weakness after hospital discharge and that facilitates resumption of activities of daily living.[14,15] According to Hodgson et al.,[16] early mobilization is defined as the intensification and early application (within the first 2 to 5 days of critical illness) of the physical therapy that is administered to critically ill patients. However, the major reported

barrier to performing early mobilization continues to be sedation, which, despite being necessary in some cases, limits the work of the physical therapist in the functional recovery of patients.[17,18]

In this context, passive mobilization is a strategy that the physical therapist has to prevent functional decline in critically ill patients. Although it has been widely used by professionals,[19,20] its effects in terms of the clinical recovery of patients have yet to be well established.

To date, cycle ergometers have been one of the most widely studied adjuvant tools in the treatment provided by physical therapists to ICU patients.[21-23] The use of early passive cycling exercise (< 72 h on MV) is safe and is associated with few hemodynamic changes even in more critically ill patients.[21] However, as already stated, little is known about the effects that passive mobilization (performed with a cycle ergometer or with a therapist) have on the clinical recovery of patients. Therefore, the objective of the present study was to evaluate the effects that passive cycling exercise, in combination with conventional physical therapy, have on the recovery of peripheral muscle strength, duration of MV, and length of hospital stay in ICU patients.

METHODS

This was a randomized clinical trial, with blinding of outcome assessment, conducted in the ICU of the Santa Maria University Hospital of the Federal University of Santa Maria, in the city of Santa Maria, Brazil, between January and July of 2015. The study was approved by the local research ethics committee (Protocol no. CAAE 07201712.8.0000.5346). All participants or their family members gave written informed consent before inclusion in the study.

This ICU has 16 beds, of which 10 are general intensive care beds and 6 are cardiac unit beds; it predominantly admits neurological, clinical, and surgical patients. Physical therapy is made available 12 h/day in the cardiac unit and 18 h/day in the general ICU. The physical therapist-to-patient ratio in the ICU as a whole is 1:8, whereas the nurse-to-patient ratio is 1:5 and the nursing technician-to-patient ratio is 1:2.

Our study included 49 patients (≥ 18 years of age; convenience sample) who were on MV; were maintained at a light level of sedation, as assessed by the Richmond Agitation-Sedation Scale[24] (score −2); and were hemodynamically stable. We excluded patients who were receiving palliative care, amputees, patients with leg fractures, and patients with neuromuscular disease, neurological disease, and/or ICU-acquired muscle weakness, as well as patients who were unable to use a cycle ergometer because of preexisting joint and/or musculoskeletal disorders.

The patients recruited for the study were assessed by clinical records, demographic information, clinical history, primary reason for ICU admission, and the Acute Physiology and Chronic Health Evaluation II (APACHE II) score.[25]

Patients were allocated from a computer-generated table of random numbers, and a randomization sequence was generated using Random Number Generator Pro 2.00 software (Segobit; Issaquah, WA, USA). All participants received the intervention by two physical therapists. Blinded assessments were performed by a single physical therapist, who was also responsible for the randomization.

Peripheral muscle strength in arms and legs was measured by the score on the Medical Research Council (MRC) scale,[26] before and after the implementation of the study protocol, by a single, previously trained rater. Muscle strength was initially assessed on the first day the patient was cooperative and responsive (Richmond Agitation and Sedation Scale score = −1) and then on the last day of ICU stay.

The patients who met the inclusion criteria were allocated to the intervention group (IG) or the control group (CG). The CG patients received conventional physical therapy, whereas the IG patients received conventional physical therapy and engaged in passive exercise on a leg cycle ergometer (MOTOmed letto 2; RECK-Technik GmbH & Co.KG, Betzenweiler, Germany). This device offers the possibility of performing the exercise passively, in the supine position, even if the patient is under sedation. Therefore, 20-min sessions of passive cycling exercise at a fixed rate of 20 cycles/min were performed 5 days per week, until the last day of ICU stay. In order to ensure that true passive exercise was performed, the device screen, which allows the visualization/analysis of the training session and detects active movements, was constantly monitored during the protocol.

Conventional physical and respiratory therapy were provided by the ICU physical therapists twice daily, for approximately 30 min, 7 days per week. The protocol included vibrocompression maneuvers; lung hyperinflation by the mechanical ventilator; and tracheal aspiration, when necessary; as well as passive and active-assisted motor exercises for arms and legs, depending on the clinical course of patients.

In order to ensure the clinical stability of the patients during and after the protocol, cardiovascular parameters, such as SpO_2, HR, mean arterial pressure, systolic blood pressure, and diastolic blood pressure, were continuously monitored noninvasively with a multiparameter monitor (DX 2022; Dixtal Biomédica, Manaus, Brazil).

The following parameters were used as the criteria for discontinuing the protocol: hemodynamic instability (mean arterial pressure < 60 or > 125 mmHg); SpO_2 < 88%; HR > 130 bpm or < 40 bpm; and signs of respiratory distress.

The statistical analysis was performed with the IBM SPSS Statistics software package, version 20.0 (IBM Corporation, Armonk, NY, USA). Variables were tested for normality with the Shapiro-Wilk test. Continuous variables were expressed as mean and standard deviation or as median and interquartile range, whereas

categorical variables were expressed as absolute and relative frequencies. The paired Student's t-test or the Wilcoxon test was used for intragroup comparisons between the pre- and post-implementation periods. The unpaired Student's t-test or the Mann-Whitney U test was used for intergroup comparisons. The level of statistical significance was set at p < 0.05.

RESULTS

In the study period, 58 patients were admitted to the adult ICU of the institution. Of those, 49 met the inclusion criteria and were randomized to the CG (n = 23) or the IG (n = 26). Subsequently, 7 and 4 patients in the CG and the IG, respectively, died. Therefore, the final sample consisted of 38 patients, of whom 16 were in the CG and 22 were in the IG (Figure 1). Table 1 shows the general characteristics of the sample. We found that the primary reason for ICU admission was respiratory-related. Duration of sedation, time to first treatment, and time to first muscle strength assessment were similar in the two groups. The median number of sessions (interquartile range) in the CG and the IG was 30.0 (26.5-53.0) and 36.0 (30.0-59.0), respectively. During the study period, there was no need to discontinue the protocol, nor were there any adverse events during or after its administration.

Table 2 presents the duration of MV, length of ICU stay, and length of hospital stay in the two groups studied. There were no significant differences between the groups in terms of length of ICU stay (p = 0.824), duration of MV (p = 0.715), or length of hospital stay (p = 0.794).

Figure 2 shows the MRC scale scores obtained before and after the implementation of the study protocol. There was a significant increase in peripheral muscle strength, as assessed by the MRC scale, in both groups (control: 40.81 ± 7.68 vs. 45.00 ± 6.89; and intervention: 38.73 ± 11.11 vs. 47.18 ± 8.75; p < 0.001 for both) after the implementation of the protocol. In the comparison of the differences shown by the groups between the pre- and post-implementation periods, the IG showed a significantly greater increase in the MRC scale scores than did the CG (8.45 ± 5.20 vs. 4.18 ± 2.63; p = 0.005).

DISCUSSION

The present study is the first randomized clinical trial to analyze the effects that a passive cycling exercise program, in combination with conventional physical therapy, have on peripheral muscle strength, duration of MV, and length of hospital stay in critically ill ICU patients. An increase in peripheral muscle strength, as assessed by the MRC scale, occurred in both groups (CG and IG); however, the increase in strength was greater in the IG. There were no differences between the groups in terms of length of ICU stay, duration of MV, or length of hospital stay.

Our results corroborate those of a study by Dantas et al.,[27] who also found no differences in duration of MV or length of hospital stay between a control group receiving conventional physical therapy and a group receiving early mobilization, which was based on a systematic mobility protocol but did not include leg cycling exercise.

Recently, Witcher et al.,[28] in a retrospective study conducted in a neurological ICU, demonstrated that the implementation of an early mobilization program did not change duration of MV, length of ICU stay, or length of hospital stay, a finding that is similar to that of the present study. Schweickert et al.,[14] in a
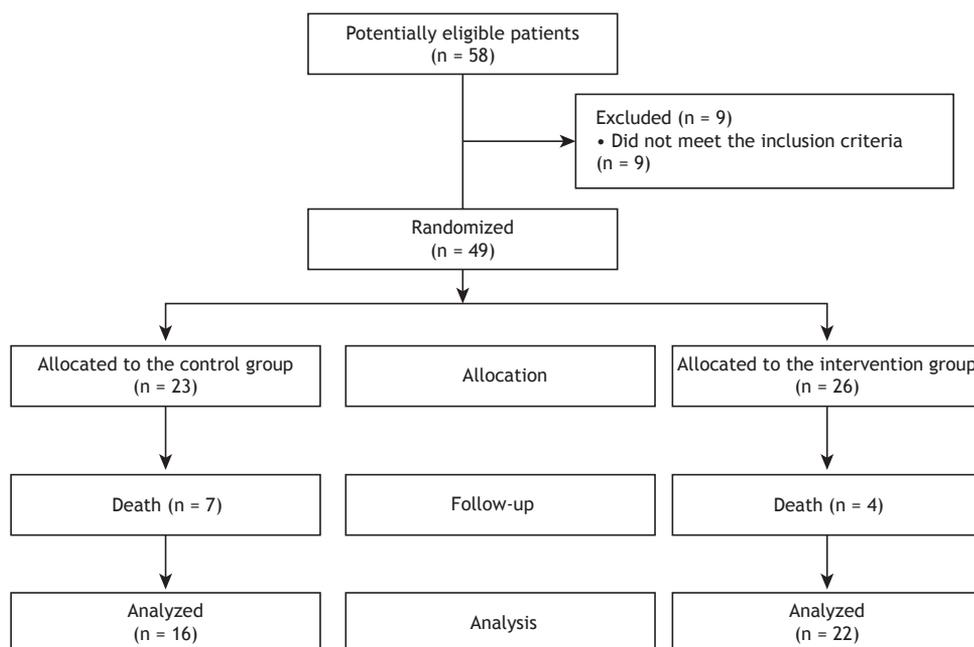

Figure 1. Flowchart of the study.

**Table 1.** Patient clinical and demographic characteristics.[a]

Variable	Control group (n = 16)	Intervention group (n = 22)
Age, years	45.13 ± 18.91	44.64 ± 19.23
Male gender, n (%)	7 (43)	16 (72)
Glasgow Coma Scale score	13. 33 ± 2.91	14.21± 3.62
APACHE II score	18.12 ± 6.36	17.34 ± 6.72
Duration of sedation, days	4 (3-7)	4 (2-7)
Primary reason for ICU admission, n (%)*		
Neurological	3 (18.75)	2 (9.09)
Respiratory	5 (31.25)	6 (27.27)
Abdominal	3 (18.75)	3 (13.64)
Cardiac	0 (0.00)	4 (18.18)
Other	5 (31.25)	7 (31.82)
Time to first session, days	2 (1-3)	3 (2-5)
Time to first assessment by the MRC scale, days	2.5 (2.5-2.5)	2.5 (2.0-2.5)
Duration of the protocol, days	15 (12-30)	12 (7-25)

APACHE II: Acute Physiology and Chronic Health Evaluation II; and MRC: Medical Research Council (scale). [a]Values expressed as mean ± SD or as median (interquartile range), except where otherwise indicated. *All comparisons were performed by using the Student's t-test, except where otherwise indicated (Mann-Whitney U test).

Table 2. Length of hospital stay, length of ICU stay, and duration of mechanical ventilation in the control and intervention groups.[a]

Variable	Control group (n = 16)	Intervention group (n = 22)	p
Length of hospital stay, days	46 (25-75)	38 (17-73)	0.794*
Duration of mechanical ventilation, days	15 (10-44)	18 (8.5-37)	0.824*
Length of ICU stay, days	18 (12-35)	22 (10-28)	0.715**

[a]Values expressed as median (interquartile range). *Student's t-test. **Mann-Whitney U test.
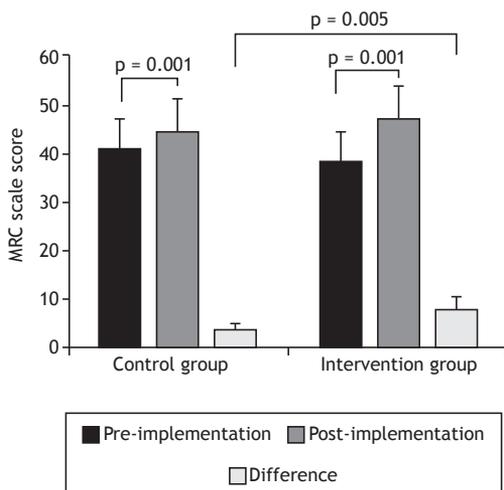
Figure 2. Peripheral muscle strength, as measured by the Medical Research Council (MRC) scale, before and after the implementation of the study protocol. Student's t-test.

pioneering, prospective randomized controlled trial, submitted 49 ICU patients on MV to an early active and passive mobilization program for 28 days. Those authors demonstrated that, at hospital discharge, the intervention group had achieved earlier functional independence, as well as having required 2.4 fewer days of ventilatory support, than had the control group, an outcome that did not occur in our study.

However, it is important to emphasize that, in the study by Schweickert et al.,[14] the control group did not receive any physical therapy intervention, whereas, in our study, the CG engaged in respiratory and motor exercises, and passive cycling exercise was the only difference between the CG and the IG.

A recent systematic review[29] concluded that there is evidence that ICU early mobilization programs are safe and improve the clinical outcomes of ICU patients. Our findings are consistent with those of this review, in which no significant adverse effects were found during physical therapy in the critically ill patients, and an increase in muscle strength was found in both groups.

Regarding our finding of a significantly greater increase in peripheral muscle strength in the IG than in the CG, it is important to mention a pioneering randomized study by Burtin et al.,[23] who also found increased quadriceps strength after active and passive mobilization combined with early cycling exercise. However, that study differs from ours in the following aspects: eligibility criteria (those authors included patients who had been on MV for more than 7 days, whereas, in our study, we included patients with a mean duration of MV of 2.5 days); and isometric strength assessment of a single muscle group (quadriceps) using a dynamometer.

Patients exposed to a period of immobilization in the ICU are predisposed to morphological muscle changes, which can lead to reduced muscle strength

and hypotrophy.[30] Koukourikos et al.[31] mentioned that muscle atrophy is one the most common and most important problems observed in critically ill patients, its prevention being the major focus in the ICU. The risk factors for this outcome include corticosteroid use, immobility, sepsis, and inadequate glycemic control. In this sense, those authors point to early mobilization as one of the strategies adopted to reduce the incidence of muscle weakness in the ICU. Increased peripheral muscle strength, which was demonstrated in our CG at ICU discharge, can be explained by the effectiveness of conventional physical therapy. One possible explanation for this finding is that, in our study, all patients received physical therapy during their ICU stay, which does not occur in centers in the United States [12] The only difference between the groups in our study was the performance of passive cycling exercise. Regarding our finding of a significantly greater muscle strength increase in the IG, which was demonstrated by higher scores on the MRC scale, Llano-Diez et al.[32] and Renaud et al.[33] state that passive exercise has a positive effect on the ability to generate muscle force, because it mitigates the deleterious effects of immobility by maintaining the architecture and intrinsic contractility properties of the muscle.

There are some limitations to our study that should be mentioned. First, our assessment was restricted to peripheral muscle strength in the ICU. Therefore, we cannot state whether the difference in muscle strength observed between our two groups would remain at hospital discharge. Second, although the cycle ergometer was used for passive exercise, it was impossible to ensure the total absence of muscle contraction by the patient (at the end of sedation) during the cycle ergometer protocol. In fact, in approximately 20% of the sessions in the IG, the visual resource available on the cycle ergometer detected active contraction. In these cases, the physical therapist immediately instructed the patients neither to contract their muscles nor to perform any effort with their legs. Therefore, we believe that such contractions were small in magnitude and may have had minimal influence on our results. We also emphasize that, although this active activity was caught by the equipment, most of the session occurred passively. Finally, we did not use objective measures of muscle strength, such as handgrip strength testing, in our assessment. However, it is important to emphasize that previous studies have demonstrated a good correlation between objective measures of muscle strength and manual muscle testing.[34]

In conclusion, early mobilization in the ICU, by implementing a passive cycling exercise protocol in patients on MV, can significantly increase peripheral muscle strength in such patients; however, it does not change duration of MV or length of hospital stay. Future studies of larger populations are needed to arrive at conclusions that are more definitive about this issue.

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