BALNEO RESEARCH Balneo and PRM Research Journal
English Edition
e ISSN 2734 - 8458 p ISSN 2734 - 844X ROMANIAN ASSOCIATION OF BALNEOLOGY

Research article

Effects of Adjunct Low-Level Laser Therapy and Neuromuscular Electrical Stimulation on Pulmonary Rehabilitation in the Intensive Care Unit: A Retrospective Study

Rahmad [1,2,3], Atika Lailana Qomarianty [2], Samiah Rachmawati [2,3], Erinda Rahma Mulia [2,3], Bethasiwi Purbasari [3], Yanuar Rahmat Fauzi [3], Arie Zainul [2,3], Irawaty Djaharuddin [4], Yose Waluyo [4,*], Vinny Alif Damara [3], Adilla Shafryantyo Purnomo [3]

1. Postgraduate Doctoral Program, Faculty of Medicine, Hasanuddin University, Makassar, Indonesia;
2. Saiful Anwar General Hospital, Malang, Indonesia;
3. Faculty of Medicine, Brawijaya University, Malang, Indonesia;
4. Faculty of Medicine, Hasanuddin University, Makassar, Indonesia

* Correspondence: yose.waluyo@med.unhas.ac.id

Citation: Rahmad, Qomarianty A.L., Rachmawati S., Mulia E.R., Purbasari B., Fauzi Y.R., Arie Zainul2,3, Djaharuddin I., Waluyo Y., Damara V.A., Purnomo A.S. – Effects of Adjunct Low-Level Laser Therapy and Neuromuscular Electrical Stimulation on Pulmonary Rehabilitation in the Intensive Care Unit: A Retrospective Study *Balneo and PRM Research Journal* **2025**, *16(4): 914*

Academic Editor(s):
Constantin Munteanu

Reviewer Officer:
Viorela Bembea

Production Officer:
Camil Filimon

Received: 29.10.2025
Published: 30.12.2025

Reviewers:
Andreea Vladulescu - Trandafir
Doinita Oprea

Publisher's Note: Balneo and PRM Research Journal stays neutral with regard to jurisdictional claims in published maps and institutional affiliations.

Abstract: This study explores the effects of adjunctive low-level laser therapy (LLLT) and neuromuscular electrical stimulation (NMES) on the duration of mechanical ventilation (MV), ICU length of stay (LOS), and mortality in ICU patients undergoing pulmonary rehabilitation (PR). A retrospective study was conducted on 110 mechanically ventilated patients at Saiful Anwar General Hospital in 2024, divided into four intervention groups: PR only, PR+LLLT, PR+NMES, and PR+LLLT+NMES. Duration of MV and ICU LOS were analyzed using the Kruskal–Wallis test, and mortality using the Chi-square test, followed by post hoc analysis. Results showed no significant difference in duration of MV between interventions (p 0.125). ICU LOS differed significantly be-tween interventions (p 0.044), with a shorter stay in the PR-only group compared to PR+NMES (p 0.014). Mortality also differed significantly between interventions (p 0.000), with lower rates in PR+NMES and PR+LLLT+NMES (p 0.012 & p 0.006) compared to other groups. Adjunctive NMES alone or combined with LLLT may contributes to better survival in mechanically ventilated ICU patients despite longer ICU stay and ventilator durations.

Keywords: pulmonary rehabilitation, low-level laser therapy, neuromuscular electrical stimulation, mechanical ventilation, length of stay, mortality

1. Introduction

Intensive Care Unit (ICU) patients frequently need mechanical ventilation for breathing support. Long-term mechanical ventilation use can result in various complications, such as diaphragmatic muscle atrophy, decreased pulmonary function, and increased morbidity and mortality [1]. Pulmonary rehabilitation (PR) in the ICU is an essential intervention aimed at maintaining and improving respiratory function. One crucial strategy to maintain and improve respiratory function in the intensive care unit is pulmonary rehabilitation.

Pulmonary rehabilitation (PR) for ICU patients includes a variety of interventions, including conventional methods such as breathing exercises, chest physiotherapy, positioning techniques. Pulmonary rehabilitation can help accelerate the ventilator weaning, reduce ICU length of stay (ICU LOS), and minimize complications associated with respiratory muscle weakness. However, it is still unclear how it affects mortality [2]. Nonetheless, a number of factors, including the patient's baseline clinical status, start time of therapy, also the frequency and duration of therapy, influence the overall results associated with this therapy [3].

There are some adjunct modalities such as Low-Level Laser Therapy (LLLT) on the thorax and Neuromuscular Electrical Stimulation (NMES) on the diaphragm aimed to enhance PR in ICU patients. LLLT may increase tissue perfusion, lessen inflammation, and hasten the healing process [4]. NMES which produces passive muscle contractions without the need for voluntary patient effort by sending electrical impulses to certain muscles, like the diaphragm [5]. This therapy supports respiratory function during mechanical ventilation and helps maintain muscle mass and strength.

The combination of LLLT and NMES may provide more comprehensive benefits, covering both neuromuscular stimulation and tissue recovery. However, empirical data analyzing the clinical patterns of each therapy—both individually and in combination—remain limited, particularly within ICU settings in Indonesia.

This study aims to evaluate the differences in the implementation and effects of conventional pulmonary rehabilitation, LLLT, NMES, and their combination, along with clinical outcomes such as duration of mechanical ventilation, ICU length of stay, and patient mortality in ICU patients at Saiful Anwar General Hospital. These analytical findings may contribute to future evaluation and planning of ICU rehabilitation services.

2. Materials and Methods

This study employed a retrospective analytic comparative design. Data were collected from medical records of patients admitted to the Intensive Care Unit (ICU) at Saiful Anwar General Hospital between January and December 2024. Ethical approval was obtained from the Ethics Committee of Saiful Anwar General Hospital (Ethics Approval No: 400/249/K.3/102.7/2025). Inclusion criteria included adult patients (≥17 years) who received at least one form of rehabilitation therapy during mechanical ventilation. Patients were excluded from analysis if their medical records were incomplete.

Patients were categorized into four groups based on the type of therapy received: conventional PR only, PR with low-level laser therapy (PR+LLLT), PR with neuromuscular electrical stimulation (PR+NMES), and PR with both LLLT and NMES (PR+LLLT+NMES). Clinicians determined whether patients received the treatment based on individual clinical presentation. The conventional PR program was conducted once a day, with duration 30 – 60 minutes for each session, five days per week, included graded mobilization, breathing exercises, secretion mobilization (clapping, vibration, and/or postural drainage), range of motion (ROM) exercises, and appropriate patient positioning. LLLT was applied once a day for 10 minutes, 15 – 20 watt, five days per week, by directing LLLT to the patient's chest wall. NMES was administered once daily for 30 minutes with pulse frequency between 1 and 150 Hz and the pulse width to between 80 and 450 µs, five days per week, using pad electrodes applied to the diaphragm (intercostal 8 – 12 both sides) to deliver stimulation.

Collected data included patient demographic characteristics (age, gender, diagnosis, and comorbidities), as well as clinical parameters such as the Sequential Organ Failure Assessment (SOFA) score and the ICU Mobility Scale (ICU-MS), both measured at ICU admission and prior to discharge. Additional data included the duration of mechanical ventilation, ICU length of stay, and patient mortality.

Data were analyzed using IBM SPSS Statistics version 25. Descriptive statistics were used to summarize demographic and clinical characteristics. Normality of the data distributions was assessed using appropriate normality tests (e.g., Shapiro-Wilk test). Since the data were not normally distributed, the Kruskal–Wallis test was used to compare differences in ICU length of stay and duration of mechanical ventilation across groups. When significant differences were found ($p < 0.05$), the analysis was continued using Mann-Whitney post hoc test. Categorical variables such as mortality were analyzed using the Chi-square test (χ^2) to compare proportions among the four intervention groups. When the global test showed a significant difference ($p < 0.05$), pairwise post hoc (2×2) Chi-square or Fisher's Exact Tests were conducted to identify specific group differences, with Bonferroni correction applied to control for multiple comparisons.

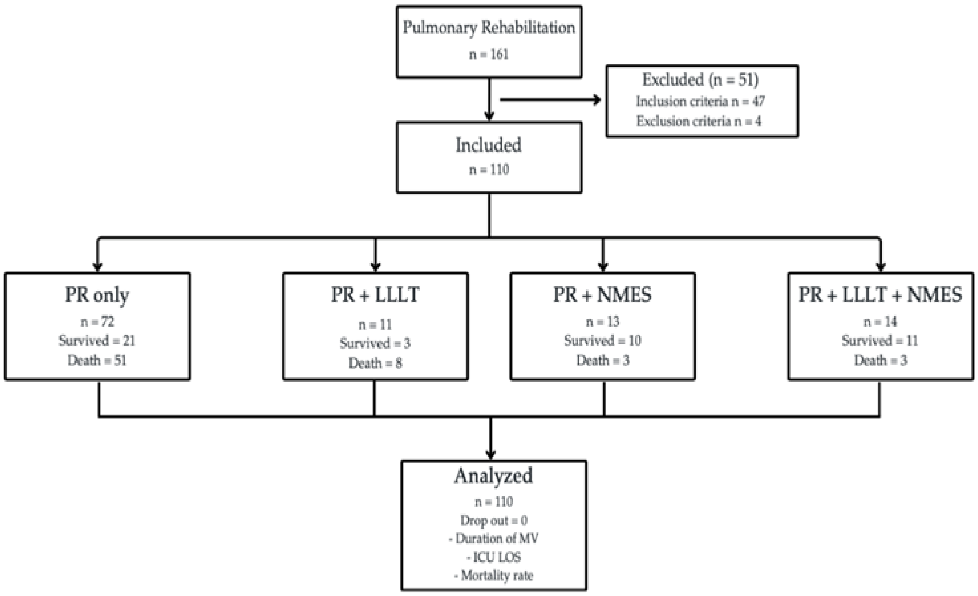

Figure 1. Patient Cohort Diagram

3. Results

A total of 110 patients were analyzed, consisting of 72 receiving conventional PR and 38 receiving adjunct interventions. The baseline demographic and clinical characteristics are presented in Table 1.

Table 1. Demographic and Clinical Characteristics of Patients

Variable	PR Only	PR+LLLT	PR+NMES	PR+LLLT+NMES
Sample size (n)	72	11	13	14
Age, mean (SD)	56.2 (15.9)	47.5 (16.3)	44.1 (21.3)	53.4 (15.6)
Gender, n (%)				
Male	42 (58.3)	7 (63.6)	8 (61.5)	7 (50)
Female	30 (41.7)	4 (36.4)	5 (38.5)	7 (50)
Diagnoses & Comorbidities, n (%)				
Cardiovascular	42 (58.3)	3 (27.3)	7 (53.8)	9 (64.3)
Respiratory	69 (95.8)	11 (100)	12 (92.3)	14 (100)
Neurology	51 (70.8)	8 (72.7)	12 (92.3)	10 (71.4)
Urinary/Nephrology	30 (41.7)	6 (54.5)	4 (30.8)	6 (42.9)
Hemato-Immuno-Oncology	49 (68.1)	8 (72.7)	12 (92.3)	9 (64.3)
Gastroenterohepatology	12 (16.7)	2 (18.2)	3 (23.1)	1 (7.1)
Endocrine/Metabolic	51 (70.8)	9 (81.8)	10 (76.9)	12 (85.7)
Electrolyte imbalance	37 (51.4)	4 (36.4)	6 (46.2)	8 (57.1)
Musculosceletal	11 (15.3)	0 (0)	0 (0)	2 (14.3)
Integumen	11 (15.3)	1 (9.1)	0 (0)	4 (28.6)

Variable	PR Only	PR+LLLT	PR+NMES	PR+LLLT+NMES
ICU Mobility Scale, n (%)				
Initial Assessment				
Scale 0	71 (98.6)	10 (90.9)	12 (92.3)	14 (100)
Scale 1	1 (1.4)	1 (9.1)	1 (7.7)	0 (0)
Scale >1	0 (0)	0 (0)	0 (0)	0 (0)
Final Assessment				
Scale 0	68 (94.4)	10 (90.9)	11 (84.6)	11 (78.6)
Scale 1	4 (5.6)	1 (9.1)	2 (15.4)	3 (21.4)
Scale >1	0 (0)	0 (0)	0 (0)	0 (0)
SOFA Score, mean (SD)				
Initial Assessment	7.1 (2.6)	6.9 (3.4)	7.5 (2.7)	6.5 (2.8)
Final Assessment	7.3 (2.9)	6.9 (3.4)	6.8 (3.4)	6.3 (2.8)

As shown in Table 1, the group receiving only pulmonary rehabilitation had the highest number of participants (72 patients), while the other groups ranged from 11 to 14 patients. The highest mean age was observed in the PR-only group (56.2 years), whereas the youngest was in the PR+NMES group (44.1 years). Male patients predominated across nearly all groups, except the PR+LLLT+NMES group, which had an equal gender distribution (50%).

Patient diagnoses and comorbidities were categorized by organ system dysfunction. Respiratory disorders were predominant across all groups (92.3%–100%), with the PR+LLLT and PR+LLLT+NMES groups showing 100% prevalence. Neurological and Hemato-Immuno-Oncology disorders were also common, particularly in the PR+NMES group (92.3% for each category).

The ICU Mobility Scale (ICU-MS) was assessed twice. At baseline, most patients scored 0, indicating complete immobility, with 100% of patients in the PR+LLLT+NMES group at Scale 0. At the final assessment, a slight improvement was noted, especially in the PR+LLLT+NMES (21.4%) and PR+NMES (15.4%) groups.

The Sequential Organ Failure Assessment (SOFA) score was also evaluated twice. The highest mean baseline score was recorded in the PR+NMES group (7.5), while the lowest was in the PR+LLLT+NMES group (6.5). At the final assessment, all groups showed slight improvements except for the PR only group, which exhibited a minor increase in score (from 7.1 to 7.3).

Following the analysis of baseline characteristics, the comparison of clinical outcomes among the four intervention groups was conducted. The evaluated parameters included the duration of mechanical ventilation, ICU length of stay, and mortality rate, as summarized in Table 2.

Table 2. Comparison of Clinical Outcomes

	PR only	PR + LLLT	PR + NMES	PR + LLLT + NMES	*p*
Duration of MV (days, mean± SD)	19.6 ± 13.2	25.9 ± 24.8	28.2 ± 10.9	30.4 ± 32.4	0.125
ICU LOS (days, mean± SD)	21.5 ± 12.7¥	28.3 ± 22.8	30.4 ± 9.6	35.9 ± 29.3	0.044 ¥0.014
Mortality (%)	70.8	72.7	23.1*	21.4**	0.000 *0.012 **0.006

¥, *, ** post hoc test

The distribution and comparative trends of these clinical outcomes are further illustrated in Figure 2, which visually demonstrates the differences in mechanical ventilation duration, ICU length of stay, and mortality among the intervention groups.

The results show the comparison of clinical outcomes among the four intervention groups: PR only, PR+LLLT, PR+NMES, and PR+LLLT+NMES. The mean duration of mechanical ventilation (MV) was highest in the PR+LLLT+NMES group (30.4 ± 32.4 days) and lowest in the PR-only group (19.6 ± 13.2 days), but the differences were not significant ($p = 0.125$). ICU length of stay (LOS) was significantly shorter in the PR-only group (21.5 ± 12.7 days), demonstrating a significantly shorter ICU stay compared to the PR+NMES group (30.4 ± 9.6 days), with $p = 0.044$. The post hoc test for multiple comparisons confirms significant differences were only between the PR-only and PR+NMES group ($p = 0.014$). A significant difference was found in mortality rates (p = 0.000), where the combination group of PR+LLLT+NMES has a lower mortality rate. The PR+NMES (23.1%) and PR+LLLT+NMES (21.4%) groups had significantly lower mortality rates than the PR-only (70.8%) and PR+LLLT (72.7%) groups. This result is consistent with post hoc analyses ($p = 0.012$ and $p = 0.006$, respectively).

4. Discussion

The present study compared the clinical outcomes of ICU patients who underwent pulmonary rehabilitation (PR) alone and in combination with adjunctive modalities—low-level laser therapy (LLLT), neuromuscular electrical stimulation (NMES), and their combination. The analysis revealed distinct outcome patterns across the four intervention groups. Although the mean duration of mechanical ventilation was longest in the PR + LLLT + NMES group and shortest in the PR-only group, this difference did not reach statistical significance. This finding suggests that while multimodal rehabilitation may be implemented in more severe or prolonged cases, its impact on ventilator duration may be influenced by patient heterogeneity and baseline clinical conditions rather than the intervention effect alone. This aligns with prior studies indicating that such interventions do not always yield significant benefit over standard care. The effectiveness of ICU rehabilitation therapies and the duration of mechanical ventilation are highly influenced by individual patient characteristics, such as age, sex, comorbidities, and illness severity [6-8].

Patients receiving LLLT or NMES are in more critically ill and at higher risk of developing muscle weakness, which may explain the longer ventilator use observed in this group. The PR-only group appeared to have shorter ventilator duration, which may be associated with better baseline conditions [9,10]. Weaning from mechanical ventilation has been reported to be influenced by disease severity and initial clinical status. Patients with milder illness, better pulmonary function, and preserved respiratory muscle strength are more likely to be weaned earlier. Lower baseline severity scores have been described as important predictors of successful weaning [11].

Research shows that not all ICU patients exhibit sufficient muscle contractile response to NMES. This response diminishes over time, particularly in patients with higher SOFA scores. Non-responders often require higher electrical currents and present with more severe muscle weakness at ICU discharge, indicating variations in NMES efficacy that may be related to disease severity and muscle condition [12]. Similarly, although LLLT is generally safe and effective, patient responses vary depending on ARDS severity, immune status, and tissue responsiveness [13].

Conversely, the length of ICU stay (ICU LOS) showed a statistically significant difference among the groups. The PR-only group exhibited a significantly shorter ICU stay than the PR+NMES group, with post hoc analysis indicating a meaningful reduction in LOS. The reduction in length of stay among patients treated with pulmonary rehabilitation alone appears to be related to their underlying septic condition and respiratory failure.

Although a combination of PR+LLLT+NMES is generally expected to help recovery and shorten ICU stays, this study observed the opposite pattern. The combination of PR+LLLT+NMES group has the longest LOS, possibly because the physician's decision to give this combination treatment to more severely critical patients. This may be related to factors such as illness severity, patient mobility, or complications during hospitalization. Patients with higher SOFA or APACHE II scores, severe comorbidities, or other critical conditions tend to stay longer in the ICU regardless of the treatment received. Longer ventilator use is also commonly associated with longer ICU stays. In addition, poor nutrition and ICU-acquired delirium can extend LOS. Other factors, such as hospital-acquired infections, side effects from treatment, or adverse events, may also contribute to prolonged hospitalization [14,15]. Furthermore, non-clinical issues such as delayed transfer to general wards may increase ICU LOS [14].

Clinical studies have reported that LLLT may help accelerate recovery and reduce ICU length of stay (LOS) in patients with pneumonia or COVID-19 [4]. However, large-scale trials specifically evaluating the added value of LLLT are still lacking. NMES as an additional therapy may be associated with reduced ICU LOS, although outcomes are influenced by patient-specific comorbidities [16]. In general, NMES may be associated with reduced ICU LOS, but the effects may vary if the intervention is delayed, given at low intensity, or administered to critically ill patients. Currently, there is insufficient clinical evidence to confirm that LLLT significantly reduces ICU LOS, and the combination of NMES and LLLT does not always show better results.

Moreover, a highly significant difference was observed in mortality rates. Patients receiving PR+NMES and PR+LLLT+NMES interventions exhibited markedly lower mortality compared to those who underwent PR-only or PR+LLLT interventions. These findings underscore the clinical relevance of integrating LLLT+NMES into pulmonary rehabilitation protocols, as it appears to confer survival advantages possibly related to enhanced respiratory muscle activation and prevention of ventilator-induced diaphragmatic dysfunction. This supports the notion that combined pulmonary rehabilitation using LLLT and NMES can improve survival rates in ICU patients, particularly those with severe respiratory impairment. LLLT may aid pulmonary tissue recovery, while NMES strengthens respiratory muscles and improves functional lung capacity [13,17,18].

The lower mortality rate observed in the combination group could reflect the potential of structured multimodal rehabilitation, even with extended ICU care. On the other hand, high mortality rates in the PR-only and PR+LLLT groups may indicate that single or no additional therapies might not be adequate for patients with severe respiratory conditions. Previous studies show that single rehabilitation methods may be less effective in reducing mortality among ICU patients with multisystem complications [19].

A high SOFA score upon ICU admission is known to be a strong indicator for prolonged ICU length of stay (LOS) and increased mortality. On the other hand, a reduction in SOFA score during treatment is generally associated with better survival rates and shorter ICU stays [20]. Similarly, patients with low scores on the ICU Mobility Scale (ICU-MS) or Perme Score usually need more time to reach mobility targets and clinical stability, leading to longer use of mechanical ventilation and longer ICU stay. However, mortality remains influenced by each patient's clinical condition [21].

Patients in the PR+LLLT+NMES group were likely selected due to a higher risk of developing ventilator-induced diaphragmatic dysfunction (VIDD) or progressive respiratory muscle weakness. Despite lower baseline SOFA scores, they were predicted to deteriorate without early intervention. Previous studies state that additional interventions in patients at risk of neuromuscular respiratory injury can improve outcomes [22]. The longer ventilator use in this group shows a focused treatment strategy to maintain respiratory stability and allow recovery before weaning. The reduction in SOFA scores in this group indicates clinical improvement, which is also reflected in the lowest mortality rate. This contrasts with the PR-only group, which had shorter ventilator use but higher mortality due to clinical deterioration and possible organ failure.

The group receiving only conventional PR had the highest proportion of patients with an ICU Mobility Scale (ICU-MS) score of 0 and the shortest ventilator duration. However, the high mortality rate suggests that shorter ventilator use may not be due to recovery, but rather rapid clinical decline. Previous studies associate poor mobility with delayed respiratory recovery and a higher risk of complications from prolonged immobility, contributing to worse outcomes and higher mortality [23]. This group also had the shortest LOS, which likely reflects poor clinical condition rather than positive recovery outcomes. In contrast, the PR+LLLT+NMES group, with better mobility scores at discharge, had the longest ICU LOS, indicating longer but possibly more effective rehabilitation that contributed to a lower mortality rate.

Recent studies report that improved ICU mobility is associated with better organ function recovery and higher survival, even when ICU stays are longer due to intensive rehabilitation [24]. In this study, we found an increase in ICU-MS scores from 0 to 1 among patients in all groups suggests that this intervention effectively enhances mobilization capacity, specifically facilitating the progression from passive to active bed-based mobility.

The PR+LLLT+NMES group showed notable mobility improvement (from 100% to 78.6% at scale 0), suggesting the therapy helped clinical improvement even though mobility scores remained low. This therapy may have contributed to improved respiratory strength, enabling mobilization and better outcomes. Literature supports that ICU rehabilitation improves mobility and reduces mortality [25]. Low mobility is consistently a poor prognostic indicator in ICU patients.

5. Study Limitation

This study has several limitations, including its retrospective design, marked differences between sample size, and patient heterogeneity, which may affect the results and limit generalization. There were also no long-term follow-up data to assess recovery after ICU discharge. Future studies should use randomized designs with proportional samples size in each group, record ventilator-free days and functional outcome. However, the strength of this study is its analytical design comparing multiple ICU rehabilitation modalities, providing novel real-world data on LLLT and NMES. It offers valuable insight into clinical outcomes and highlights the potential survival benefit of combined therapy as a basis for future research.

6. Conclusions

Adjunctive NMES alone or combined with LLLT may improve survival in mechanically ventilated ICU patients despite longer ICU stay and ventilator durations. Although patients receiving NMES or combined therapy had longer durations of mechanical ventilation and ICU stay, these outcomes likely reflected higher baseline illness severity rather than limited therapeutic efficacy. Overall, multimodal rehabilitation incorporating LLLT and NMES may contributes to better survival outcomes in critically ill, mechanically ventilated patients.

Author Contributions: Conceptualization, R., A.L.Q., S.R., E.R.M., and Y.W.; methodology, R., A.L.Q., and V.A.D.; software, A.L.Q. and A.S.P.; validation, R., A.L.Q., Y.W., and A.Z.; formal analysis, R., A.L.Q., and Y.W.; investigation, B.P., Y.R.F., and I.D.; resources, A.L.Q., V.A.D., and A.S.P.; data curation, R., S.R., and E.R.M.; writing—original draft preparation, R. and A.L.Q.; writing—review and editing, R., B.P., Y.R.F., A.Z., I.D., and Y.W.; visualization, R. and A.L.Q.; supervision, R. and Y.W.; project administration, R., A.L.Q., and Y.W. All authors have read and agreed to the published version of the manuscript.

Funding: This research received no external funding.

Institutional Review Board Statement: The study was conducted in accordance with the Declaration of Helsinki and approved by the Ethics Committee of Saiful Anwar General Hospital (Ethics Approval No: 400/249/K.3/102.7/2025).

Informed Consent Statement: Patient consent was waived because this study involved retrospective data collection from existing medical records without direct patient involvement.

Data Availability Statement: Not applicable.

Acknowledgments: No acknowledgments.

Conflicts of Interest: The authors declare no conflict of interest.

References

1. Goligher EC, Dres M, Fan E, et al. Mechanical Ventilation-induced Diaphragm Atrophy Strongly Impacts Clinical Outcomes. Am J Respir Crit Care Med. 2018;197(2):204-213. doi:10.1164/rccm.201703-0536OC
2. Yang Y, Zhang RJ, Yuan XN, et al. Clinical effect of pulmonary rehabilitation in patients with mechanical ventilation: A meta-analysis. Int J Artif Organs. 2024;47(2):96-106. doi:10.1177/03913988231218116
3. Li Z, Peng X, Zhu B, Zhang Y, Xi X. Active mobilization for mechanically ventilated patients: a systematic review. Arch Phys Med Rehabil. 2013;94(3):551-561. doi:10.1016/j.apmr.2012.10.023
4. Mokmeli S, Vetrici M. Low-level laser therapy as a modality to attenuate cytokine storm at multiple levels, enhance recovery, and reduce the use of ventilators in COVID-19. Can J Respir Ther. 2020;56:25-31. doi:10.29390/cjrt-2020-015
5. Xu C, Yang F, Wang Q, Gao W. Effect of neuromuscular electrical stimulation in critically ill adults with mechanical ventilation: a systematic review and network meta-analysis. BMC Pulm Med. 2024;24(1):56. doi:10.1186/s12890-024-02854-9
6. Nurhasty, SW., Nurachmah, E., Maria, R. Faktor Yang Berkontribusi Terhadap Terjadinya Penggunaan Ventilasi Mekanik Yang Memanjang Pada Pasien Paska Bedah Jantung. Jurnal Keperawatan Sekolah Tinggi Ilmu Kesehatan Kendal. 2020;12(2), pp. 287–300. doi: https://doi.org/10.32583/keperawatan.v12i2.735
7. Mori, H. et al. Predictors of prolonged mechanical ventilation identified at an emergency visit for elderly people: A retrospective cohort study. Medicine. 2020;99(49), p. e23472. doi: 10.1097/MD.0000000000023472.
8. Sumarlan, R. D., Setioputro, B., and Yunanto, R. A. Factors associated with duration of mechanical ventilation at Intensive Care Unit Dr. Soebandi: a retrospective study. Jurnal Ners. 2022;17(2), pp. 168-175. doi: http://dx.doi.org/10.20473/jn.v17i2.37864
9. Santoso RE, Madjid AS, Sedono R, Marcelia M. Impact of neuromuscular electrical stimulation (NMES) on duration of mechanical ventilation in ICU patients: A systematic review and meta-analysis. Anaesth. pain intensive care 2025;29(1):61-69. doi: 10.35975/apic.v29i1.1887
10. Jiroutková K, Duška F, Waldauf P. Should New Data on Rehabilitation Interventions in Critically Ill Patients Change Clinical Practice? Updated Meta-Analysis of Randomized Controlled Trials. Crit Care Med. Published online March 19, 2024. doi:10.1097/CCM.0000000000006259
11. Fossat G, Daillet B, Desmalles E, Boulain T. Does diaphragm ultrasound improve the rapid shallow breathing index accuracy for predicting the success of weaning from mechanical ventilation?. Aust Crit Care. 2022;35(3):233-240. doi:10.1016/j.aucc.2021.05.008
12. Grunow, J.J., Goll, M., Carbon, N.M. et al. Differential contractile response of critically ill patients to neuromuscular electrical stimulation. Crit Care 23, 308 (2019). https://doi.org/10.1186/s13054-019-2540-4
13. Fazza TF, Pinheiro BV, da Fonseca LMC, et al. Effect of low-level laser therapy on the inflammatory response in an experimental model of ventilator-induced lung injury. Photochem Photobiol Sci. 2020;19(10):1356-1363. doi:10.1039/d0pp00053a
14. Peres IT, Hamacher S, Oliveira FLC, Thomé AMT, Bozza FA. What factors predict length of stay in the intensive care unit? Systematic review and meta-analysis. J Crit Care. 2020;60:183-194. doi:10.1016/j.jcrc.2020.08.003
15. Almashrafi A, Elmontsri M, Aylin P. Systematic review of factors influencing length of stay in ICU after adult cardiac surgery. BMC Health Serv Res. 2016;16:318. doi:10.1186/s12913-016-1591-3
16. Mahran GSK, Mehany MM, Abbas MS, et al. Short-Term Outcomes of Neuromuscular Electrical Stimulation in Critically Ill Patients. Crit Care Nurs Q. 2023;46(2):126-135. doi:10.1097/CNQ.0000000000000445

17. Panelli A, Grunow JJ, VERFUß MA, Bartels HG, Brass Z, Schaller SJ. Outcomes in critically ill patients after diaphragmatic stimulation on ventilator-induced diaphragmatic dysfunction: a systematic review. Eur J Phys Rehabil Med. 2023;59(6):772-781. doi:10.23736/S1973-9087.23.08031-0
18. Chen S, Jiang Y, Yu B, et al. Effect of transcutaneous neuromuscular electrical stimulation on prevention of intensive care unit-acquired weakness in chronic obstructive pulmonary disease patients with mechanical ventilation. Zhonghua Wei Zhong Bing Ji Jiu Yi Xue. 2019;31(6):709–13. doi:10.3760/cma.j.issn.2095-4352.2019.06.010
19. Dos Santos FV, Cipriano G Jr, Vieira L, et al. Neuromuscular electrical stimulation combined with exercise decreases duration of mechanical ventilation in ICU patients: A randomized controlled trial. Physiother Theory Pract. 2020;36(5):580-588. doi:10.1080/09593985.2018.1490363
20. Setareh, M., Alavi, NM., Atoof, F. Severity of illness affecting the length of stay and outcomes in patients admitted to intensive care units. Journal of Education and Health Promotion. 2019;10(1):p 142. doi: 10.4103/jehp.jehp_780_20
21. Luna ECW, Perme C, Gastaldi AC. Relationship between potential barriers to early mobilization in adult patients during intensive care stay using the Perme ICU Mobility score. Can J Respir Ther. 2021;57:148-153. doi:10.29390/cjrt-2021-018
22. Liu Y, Gong Y, Zhang C, et al. Effect of neuromuscular electrical stimulation combined with early rehabilitation therapy on mechanically ventilated patients: a prospective randomized controlled study. BMC Pulm Med. 2023;23(1):272. doi:10.1186/s12890-023-02481-w
23. Díaz MC, Ospina-Tascón GA, Salazar C BC. Respiratory muscle dysfunction: a multicausal entity in the critically ill patient undergoing mechanical ventilation. Arch Bronconeumol. 2014;50(2):73-77. doi:10.1016/j.arbres.2013.03.005
24. Hodgson CL, Tipping CJ. Physiotherapy management of intensive care unit-acquired weakness. J Physiother. 2017;63(1):4-10. doi:10.1016/j.jphys.2016.10.011
25. Jang MH, Shin MJ, Shin YB. Pulmonary and Physical Rehabilitation in Critically Ill Patients. Acute Crit Care. 2019;34(1):1-13. doi:10.4266/acc.2019.00444.