Effect of Early Rehabilitation Interventions on ICU-Acquired Weakness Prevention in Critically Ill Patients

Sherouk Nasser Mohamed, Assistant lecturer
Critical Care and Emergency Nursing, Faculty of Nursing, Alexandria University
Nadia Taha Mohamed Ahmed, Professor
Critical Care and Emergency Nursing, Faculty of Nursing, Alexandria University
Bassem Nashaat Beshey, Professor
Critical Care Medicine, Faculty of Medicine, Alexandria University
Eman Arafa Hassan Ali, Assistant professor
Critical Care and Emergency Nursing, Faculty of Nursing, Alexandria University

Corresponding Author: Sherouk Nasser Mohamed , Faculty of Nursing, Critical Care and Emergency Nursing Department
Email: Sherouknasser71@gmail.com

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Abstract

Background: *Intensive care unit-acquired weakness (ICUAW) is an acute neuromuscular impairment that occurs frequently in the context of critical illness. ICUAW is associated with prolonged MV, increased length of ICU stay, increased healthcare-related costs, long-term disability, higher ICU, and hospitalization mortality. ICUAW prevention depends mainly on nursing preventive measures, including early rehabilitation, which includes positioning and motion exercises (active, passive, and active-assisted) for each joint combined with neuromuscular electrical stimulant NMEs.* **Objective:** *Determine the effect of early rehabilitation intervention on ICU-Acquired weakness prevention in critically ill patients.* **Settings**: *The study was carried out in four adult ICUs, namely unit II, unit III, unit IV, and the CRRT unit at the Alexandria Main University, Egypt.* **Subjects:** *A convenient sample of 80 adult patients who were newly admitted to the previously mentioned ICUs. The sample was divided into two equal groups (40 patients each in the group)***. Tools:** *Three tools were used. Tool one: "Intensive care unit acquired weakness associated factors assessment". Tool Two:" Physiological parameters and laboratory investigation assessment record". Tool Three: "Effect of early rehabilitation interventions assessment".* **Results:** *Following the implementation of the early rehabilitation intervention, on day sixth, there was a marked increase in ICUAW among control patients at 85%, with a lower severity according to a mean MRC score of 43.00 ± 4.95 compared to just 15% occurrence in the study group with a higher severity according to a mean MRC score of 55.88 ± 5.93. This difference was highly statistically significant ($\chi2=39.29$ $p=<0.001$).* **Conclusion:** *Critically ill patients who are subjected to early rehabilitation interventions exhibit lower ICU-acquired weakness scores than those who are not subjected. Also, the frequency of ICUAW occurrence was higher in patients who did not receive early rehabilitation intervention. So, early rehabilitation is a protective factor against the occurrence and severity of ICUAW.* **Recommendations:** *Implement early NMES sessions for half an hour combined with early passive ROM exercises for half an hour for upper and lower extremity joints from the first 24 hours of admission for one hour till patients discharge from the ICU. Assess the muscle strength of all admitted patients to the ICU using a muscle strength scale and hand grip scale as a routine by nurses and medical staff.*

Keywords: *Early Rehabilitation Interventions, ICU-Acquired Weakness Prevention, Critically ill patients.*

Introduction

Muscle weakness is a common neuromuscular problem in intensive care units (ICUs). Up to 80% of admitted patients develop some form of neuromuscular dysfunction that can be due to primary or secondary causes. Primary neuromuscular disorders include multiple sclerosis, myasthenia gravis, and Guillain-Barre syndrome, which account for less than 0.5 percent of all ICU admissions; on the other hand, muscle weakness is a secondary disorder that develops while patients are receiving medical treatment for other severe conditions **(Bellaver et al., 2023; Wu et al., 2021).**

ICUAW is a devastating neuromuscular condition that aggravates the course of a critical illness. It is a clinically detected weakness in a critically ill patient in whom there is no plausible aetiology other than critical illness and its therapies, which affects the clinical course and outcomes of ICU patients. This condition is associated with atrophy and is characterized by an acute, diffuse, symmetrical, and generalized decrease in muscular strength. Generalized ICUAW may affect peripheral and respiratory muscles **(Elghotmy, Elewa, & Rabea, 2019; van Wagenberg, Witteveen, Wieske, & Horn, 2020).**

Patients with ICUAW, compared with ICU patients, experience increased ICU length of stay, which is associated with difficulties weaning from mechanical ventilation (MV), increased medical costs, and even increased ICU-acquired neuromuscular morbidity complications (5 years) and mortality one year after discharge, as well as reduced functional independence and quality of life. Furthermore, ICUAW increases nursing costs by 60%, which leads to a significant financial and healthcare burden to medical and health institutions as well as **patients'(Hashem, Parker, & Needham, 2020; Panahi, Malekmohammad, Soleymani, & Hashemian, 2020)**

There are several modalities but no golden standard for early diagnosis of ICUAW, which is clinically diagnosed by the determination of typical neurological symptoms with no rational cause other than critical illness. The diagnosis of ICUAW should begin with routine physical and neurological examination of a patient that is weak following an episode of critical illness with the use of manual muscle testing using six points of the Medical Research Council (MRC) scale, which is recommended for diagnosing ICUAW. It has excellent inter-rater reliability in critically ill patients. An MRC sum score of less than 48/60 for 12 muscle groups is used as the introduction 3 cutoff for defining ICUAW. Therefore, current evidence demonstrates that an MRC < 55 is associated with relevant neuromuscular dysfunction and results in a poorer patient outcome **(Klawitter et al., 2022; Lu, Hongxia, Liqiang, & Qi, 2023; Paolo et al., 2022).**

More recent research suggests that measuring handgrip strength with a handgrip dynamometer could be a simple and effective alternative diagnostic technique for ICUAW **(Bragança et al., 2019).** Electrophysiological studies and muscle biopsies are not typically achievable because they require expertise for testing and interpreting the results, specific equipment are costly, and, to some extent, invasive and painful **(Raurell-Torredà et al., 2021; Turan, Topaloglu, & Ozyemisci Taskiran, 2020).**

In the absence of specific therapy, the management of ICUAW involves therapeutic strategies directed at early interventions to control and prevent the risk factors of ICUAW to inhibit or diminish its devastating consequences. Early mobilization and physiotherapy have been identified as cornerstones in ICUAW treatment and prevention. Although evidence to support the prevention of ICUAW by early mobilization is limited because of poor alertness due to sedation or coma, cooperation of critically ill patients, lack of available rehabilitation staff, conflict with another planned procedure, and the incidence of potential safety events is low **(Alaparthi, Gatty, Samuel, Amaravadi, & Practice, 2020; Hodgson, Schaller, Nydahl, Timenetsky, & Needham, 2021; Wu et al., 2021).**

Novel early rehabilitation interventions, such as early mobilization (EM), reduce the duration of immobility, while neuromuscular electrical stimulation (NMES) reduces muscle atrophy, which is involved in the pathophysiological process of ICUAW by providing an opportunity for early rehabilitation even when the patient is unable to actively participate during the acute phase of critical illness. Both interventions are sometimes used together as part of an early rehabilitation intervention in the ICU **(Anekwe, Biswas, Bussières, & Spahija, 2020; Doucet, Lam, & Griffin, 2012).**

NMES has been reported as an approach to minimize ICUAW under conditions in which usual early mobilization is difficult, which improves or preserves muscle strength by preventing disuse atrophy through stimulated muscle contraction by automatic exercise. The pathophysiological mechanism that appears to improve muscle power and facilitate weaning from mechanical ventilator is that NMES acts as an anabolic stimulus to the muscle, reversing the catabolic effects of critical illness and immobilization **(Abu-Khaber, Abouelela, & Abdelkarim, 2013; García-Pérez-de-Sevilla, Pinto, & Nursing, 2022; Lee & Fan, 2021).**

Critical care nurses play a significant role in driving the change toward preventing ICUAW. They are instrumental in working with the health care team and other disciplines to prevent ICUAW, which depends mainly on nursing preventive measures, including early rehabilitation, which includes positioning and motion exercises (active, passive, and active-assisted) for each joint combined with NMES, which is a technique that uses a 20–50 Hz low-frequency current to stimulate specific muscle groups through electrodes; the twitching or contractions of these muscles lead to functional repair. These novel early rehabilitation interventions will improve muscle strength, prevent muscle atrophy, and shorten the duration of MV and ICU hospitalization **(Lu et al., 2023; Mohamed, Shehata, Mohamed, & Khalaf, 2019).**

The effect of early rehabilitation interventions on preventing ICUAW in critically ill patients is still unclear, although some studies have suggested that NMES has a beneficial impact on muscle metabolism and also improves oxygen uptake kinetics and work efficiency **(Eggmann et al., 2020; Zhou, Shi, Fan, & Zhu, 2020).** In addition, recent studies showed that NMES with passive or active-assisted physical therapy had improved muscle strength at 7 days and decreased the number of days needed to transfer from bed to chair as compared to physical therapy alone. Hence, this study is carried out to assess the effect of early rehabilitation interventions on ICU-acquired weakness prevention in critically ill patients.

Aims of the Study:

Determine the effect of early rehabilitation interventions on intensive care unit acquired weakness prevention in critically ill patients.

Hypothesis of the study

Critically ill patients who are subjected to early rehabilitation interventions exhibit lower ICU-acquired weakness scores than those who are not subjected.

Materials and Method

Materials

<u>Design:</u> A quasi-experimental research design was used to conduct this study.

Settings: was carried out in four adult ICUs at the Alexandria Main University Hospital, namely unit II that contains 14 beds, unit III that contains 16 beds, unit IV that includes 8 beds, and the Continuous Renal Replacement Therapy (CRRT) unit that contains 16 beds. These general ICUs receive patients who have a variety of disorders in the acute stage of illness. These patients were admitted directly from the emergency department or transferred from other hospital departments.

Subjects: A convenience sample of 80 adult critically ill patients who were newly admitted to the previously mentioned ICUs was included in this study. The sample was divided into two equal groups (forty patients in each group). Group "A," the control group, and group "B," the study group. The sample size was calculated based on power analysis using the PASS program (version 20), with a minimum sample size of 40 in each group with a level of significance of 0.05 and a power of 90%.

The subjects were adult patients between 18 and 60 years of age, whose MAP was >60 mmHg and <110 mmHg, an oxygen saturation of ≥ 92%, a heart rate between ≥ 60 and <100 beats per minute, a temperature of ≥36.6 and <37.70 c, a respiratory rate of ≥16 and <20 c/m, and a GCS of ≥9. Patients with the following conditions were excluded: myasthenia gravis and Guillain-Barre syndrome, central or peripheral nervous system injury, history of neuromuscular diseases, a primary neuromuscular disease, limb deformity, metal prosthesis, and orthopaedic injury, and confirmed or suspected lower-limb fracture preventing mobilization.

Tools: Three tools were used for data collection:

Tool one: Intensive care unit-acquired weakness associated factors assessment. This tool was developed by the researcher after reviewing the related literature (Saccheri et al., 2020; Yang et al., 2023; Zhang et al., 2021). It was used to assess the factors associated with ICU-AW. **It consists of three parts**:

Part I: Patients' sociodemographic characteristics: This part includes data such as patient age, gender, level of education, marital status, and working status.

Part II: Patients' clinical data: This part includes data such as admission diagnosis, past medical and surgical history, BMI (body mass index), length of stay, comorbidities, duration in mechanical ventilator (MV), MV data, the severity of illness using the Acute Physiology and Chronic Health Evaluation (APACHE II) score and Sequential Organ Failure Assessment (SOFA) score.

Part III: "ICUAW associated factors assessment ": It was used to identify factors associated with ICUAW such as: Treatment-related factors; pharmacologically related factors; corticosteroids, neuromuscular blocking agents(NMBS), sedatives, aminoglycosides, vasopressors, and insulin infusion; intervention-related factors; mechanical ventilation, renal replacement therapy, and parenteral nutrition. Environment-related factors; delirium and sleep disturbance. Metabolic variables-related factors; electrolyte disturbances; hyponatremia, hypernatremia, hypokalemia, hyperkalemia ,hypocalcemia, hypercalcemia, and hypomagnesaemia; hypoalbuminemia, hyperlactatemia, stress hyperglycemia, and malnutrition. Nursing practices-related factors: positioning, active range of motion exercises, passive range of motion exercises, chair sitting, and walking.

Each element was observed and scored on a dichotomous scale of yes and no. Yes (score 1) indicates that there is a risk factor, and no (score 0) indicates that there is not a risk factor.

Tool Two: Physiological parameters and laboratory investigation assessment record: It was developed by the researcher after reviewing the related literature (Mendelson, Erickson, & Villar, 2023; Patejdl et al., 2019). It was used to assess physiological parameters and lab investigation-related data, as **physiological parameters data** as a baseline mean arterial pressure (MAP), heart rate (HR), respiratory rate (RR), body temperature (T), oxygen saturation (Spo2), level of consciousness, and pain score and **Lab investigation-related data** as blood lactate level, level of creatine phosphokinase (CPK), electrolytes, total protein, and total albumin.

Tool Three: "Effect of early rehabilitation interventions assessment": That was developed originally by (Muñoz & Millán, 2019; Paternostro-Sluga et al., 2018). It was adopted by the researcher to assess the effect of early rehabilitation interventions by assessing muscle strength using the medical research council scale and hand grip dynamometry. **Medical Research Council (MRC) Scale:** This scale was developed originally by Paternostro-Sluga et al. (2018). It was adopted by the researcher to assess muscle strength. The reliability of this score was tested by Paternostro-Sluga et al. (2018), and its value was 0.81. The score ranges from 0 to 5; It contains five items as follows: 0 = no movement or muscle contraction, 1 = trace contraction, 2 = active movement with gravity eliminated, 3 = active movement against gravity, 4 = active movement with some resistance, and 5 = active movement with full resistance.

A collective score of less than 48/60 for 12 muscle groups is diagnostic of ICU-acquired weakness. Movement tested includes: upper limbs; wrist flexion; forearm flexion; shoulder abduction; lower limbs; ankle dorsiflexion; knee extension; and hip flexion. Scoring of the scale was calculated as follows: A score from 0 to 36 will indicate severe quadriparesis. A score from 36 to 48 will indicate mild quadriparesis. A score from 48 to 60 will indicate normal strength.

Hand grip dynamometry: This scale was developed originally by CAMRY et al. (2019). It was adopted by the researcher to assess the isometric peripheral muscle strength of the hand and forearm muscles by using a standardized handgrip (CAMRY Digital Hand Dynamometer Grip Strength Measurement Auto Capturing Hand Grip Power), which is stated in Figure VII. It provides an objective index of general upper body strength. The reliability of this score was tested also by CAMRY et al. (2019) and its value was 0.8. The score of the scale for adult male patients ranges from 35.7 to 30.2, and for adult female patients ranges from 19.2 to 17.2 as follows: **In adult male patients**, a collective score of less than 35.7-30.2 indicated muscle weakness. **In adult female patients,** a collective score of less than 19.2 -17.2 indicated muscle weakness.

Methods

Approval of the ethics committee of the faculty of Nursing was obtained. An official approval was obtained after providing an explanation of the aim of the study. An informed consent was obtained from the patients. The study tool I and II were tested for content validity by five experts in the field of the study. The necessary modifications were done accordingly. A pilot study was carried out on 10 % (8 patients) of the sample to assess the clarity, applicability, and feasibility of the tool. Reliability of the tools was tested using Cronbach's Alpha test. The reliability coefficient was 0.77 which is acceptable. Data was collected by the researchers during the period from November 2023 to March 2024.

Data were collected from group “A” firstly and after its completion, data were collected from the group “B” to prevent the double contamination effect between the studied groups that might affect the study results.

The study was conducted in four phases:

Phase I: the assessment phase: For both groups, the patient's demographic data, such as age, gender, level of education, marital status, and working status, was assessed and recorded using Part I of Tool I as baseline data at zero day of admission. The **patient's clinical data** was assessed as admission diagnosis, past medical and surgical history, level of consciousness using GCS, comorbidities, duration in mechanical ventilator (MV) , MV data, and the severity of illness using the Acute Physiology and Chronic Health Evaluation (APACHE II) score, which was recorded from the medical record within 24 hours of admission of a patient to the ICU. Anthropometric equations were used to measure the patient's height and weight and calculate the BMI. **Morbidity-related factors** were assessed upon admission and recorded using part III of the Tool one. **Treatment-related factors**: medications such as corticosteroids, neuromuscular blocking agents, sedation, aminoglycosides, vasopressors, or insulin were assessed and recorded for their presence and their duration. **Mechanical ventilation** duration (if present), renal replacement therapy, and parenteral nutrition were assessed and recorded using Part III of the tool one. **Environment related factors:** A CAM-ICU score was used to assess the delirium. **Metabolic variables-related factors** were reviewed from the patient's file and recorded. **The nutrition risk in critically ill (NUTRIC)** score was used to quantify the risk of critically ill patients developing adverse events that may be modified by aggressive nutritional therapy on the zero day and the seventh day from admission and recorded. **Nursing practices-related factors** (mobility practices): including positioning, active and passive range of motion exercises, chair sitting, and walking, were observed by the researcher and then recorded by the researcher using a dichotomous scale of done (frequency) and not done. Each element was observed and scored on a dichotomous scale of yes and no. Yes (score 1) indicates that there is a risk factor, and no (score 0) indicates that there is not a risk factor.

Both groups received standard care from intensive care unit staff. **For Group A (control group):** They received routine care for critically ill patients in ICU. **For group B (Study group):** They begin intervention by the researcher within 24 hours of admission after stabilization of the patient's physiological parameters daily for one hour for 7 consecutive days. **Physiological parameters and laboratory investigation** were assessed as a baseline value before and after the early rehabilitation intervention. If the hemodynamic parameters were unstable, the session was postponed for one hour and was reassessed until frequent two more hours if still unstable the session was deleted. **Muscle strength** was assessed using MRC sum score includes the assessment of muscle strength from three movements of each limb bilaterally: upper limbs; wrist flexion, forearm flexion, shoulder abduction, lower limbs; ankle dorsiflexion, knee extension and hip flexion. The maximal power obtained for each movement is graded 0–5, and a total sum score out of 60 is calculated.

Secondly **muscle strength** was assessed by the researcher using hand grip dynamometry.

Phase II: the preparatory phase: before passive ROM was performed and neuromuscular electrical stimulation (NMES) sessions, the following preparations were carried out: **Patient's preparation** as explain procedure, skin preparation, and Safety criteria for starting early rehabilitation in ICU were assessed prior to initiation every session. **Neuromuscular electrical stimulation (NMES) device preparation.**

Phase III: the implementation phase: It consists of combined session of **passive ROM exercises** and **neuromuscular electrical stimulation (NMES) sessions** were performed by the researcher for each patient once per day for one an hour for 7 consecutive days. **Passive ROM exercise:** were performed by the researcher for each patient 1/per day for half an hour for the upper extremities as follows: **For shoulder:** flexion, extension, hyperextension, abduction, adduction, internal rotation, external rotation, and circumduction. **For elbow:** flexion and extension. **For forearm:** supination and pronation**. For wrist and fingers:** flexion, extension, hyperextension, ulnar flexion, radial flexion, abduction, and adduction. **For thumb:** flexion, extension, abduction, adduction, circumduction, and opposition. **For the lower extremities were as follows: For hip:** flexion, extension, abduction, adduction, internal rotation, external rotation, and circumduction. **For knee:** flexion and extension. **For ankle: dorsiflexion,** plantar flexion, inversion, and eversion. **For toes:** flexion, extension, abduction, and adduction.

Neuromuscular electrical stimulation (NMES) session: were combined with passive ROM exercises, which were performed by the researcher for each patient once per day after a passive ROM exercise session for half an hour for 7 consecutive days. Electrodes were placed where the cathode is placed over the motor point of the target muscle group to be exercised. The anode is placed proximally on a nearby muscle supplied by the same nerve, called monopolar electrode placement. After electrodes were placed over the motor point of the target muscle group, **the duration time** was set for each target muscle group to 10 minutes, then, **the electrical intensity** was adjusted on the device as a faradic current (low degree); was selected as an NMS burst. Thereafter, the **electrical intensity** was adjusted on the device to 50 Hz per second to deliver biphasic electrical impulses, as the intensity was able to cause visible contractions. Finally, **the keep button was pressed** to avoid cycling the electrical current mode

Phase IV: the outcome assessment: for both groups: Muscle strength was assessed and recorded using Tool III for each patient in both groups by using a **MRC scale** after each session from zero day for 7 consecutive days. **Hand grip** dynamometry was used to assess the isometric peripheral muscle strength of the hand and forearm muscles and was recorded using Tool III. Then, **lab investigation-related data** such as blood lactate level, level of creatine phosphokinase (CPK), electrolytes, total protein, and total albumin were assessed and recoded using study Tool II from zero day for 7 consecutive days.

Ethical considerations: Written informed consent was obtained from patient and written consent from the guardian if unconscious after an explanation of the aim of the study and the right to refuse to participate in the study and/ or withdraw at any time. Patient's privacy was respected. Data confidentiality was during implementation of the study.

Statistical Analysis

Data were fed to the computer and analyzed using Statistical Package for Social Sciences (IBM SPSS/ version 20.0) software, and tabulated (Armonk, NY: IBM Corp). The qualitative data was characterized using percentages and numerical values. To describe the quantitative data, the following attributes were employed: mean, standard deviation, and range (minimum and maximum). A significance level of 5% was used to evaluate the results. Categorical variables were compared between distinct groups using the chi-square test. Quantitative variables that were normally distributed were compared between the control and studied groups using the student t-test. Fisher's Exact or Monte Carlo correction was used for correction of chi-square when more than 20% of the cells have an expected count less than five. F-test

(ANOVA) was used for normally distributed quantitative variables to compare between more than two groups. Pearson coefficient was used to correlate between two normally distributed quantitative variables Pearson coefficient was used to correlate between two normally distributed quantitative variables

Results

Table 1 presents the comparison between the control and study groups according to socio-demographic data. Eighty patients were recruited in the current study. There was no significant difference between the two groups regarding age and gender.

Table 2 Presents the occurrence and severity of ICUAW among critically ill patients in both the study and control groups according to their total MRC score over days of a week. **On day three**, ICUAW developed in 45% of patients in the control group with a mean MRC score of 47.68 ± 4.06, while only 15% of those in the study group experienced ICUAW, showing a higher mean total MRC score of 51.53 ± 4.04; this difference was statistically significant($\chi2$=6.192 p=0.013). **By day six,** there was a marked increase in ICUAW among control patients at 85%, with a lower severity according to a mean MRC score of 43.00 ± 4.95 compared to just 15% occurrence in the study group with a higher severity according to a mean MRC score of 55.88 ± 5.93. This difference was highly statistically significant ($\chi2$=39.29 p=<0.001).

Table 3 displays the distribution of the critically ill patients in the control and study groups according to the occurrence and severity of ICUAW based on the hand grip score. It can be noted that **by day three, the mean right-hand grip** score for the control group decreased to 22.25 ± 6.77, while it increased to be 26.13 ± 8.46 in the study group, resulting in a statistically significant difference (t=2.27 p=0.013). **On day six,** further changes were observed: the control group's mean score dropped to 18.61 ± 6.24, whereas the study group's score rose to 29.72 ± 9.39; this also indicated a statistically significant difference (t=6.23, p<0.001). **According to the left hand, by day three,** the control group's score decreased to 22.22 ± 6.78, while the study group's score increased to 26.19 ± 8.55, resulting in a statistically significant difference (t = 2.30, p= 0.024). **On day six,** the mean score for the control group further declined to 18.60 ± 6.23, whereas it rose to 29.72 ± 9.45 in the study group; this also showed a statistically significant difference (t = 6.21 p<0.001).

Table 4 shows distribution of critically ill patients in the control and study groups according to their total body strength (MRC levels) in relation to their morbidity related data. This table revealed that there is a statistically significant relation between occurrence of ICUAW and pneumonia in the control group at ($\chi2$6.387 p=0.021). While, there was no statistically significant relation between occurrence of ICUAW and other co morbidities or even the number of co-morbidities in the control and study groups.

Discussion:

Intensive care unit-acquired weakness (ICUAW) is an acute neuromuscular impairment that occurs frequently in the context of critical illness. ICUAW is associated with prolonged MV, increased length of ICU stay, increased healthcare-related costs, long-term disability, higher ICU, and hospitalization mortality. ICUAW prevention depends mainly on nursing preventive measures, including early rehabilitation, which includes positioning and motion exercises (active, passive, and active-assisted) for each joint combined with NME(Chen & Huang, 2024; Latronico et al., 2023)

Regarding the occurrence of ICUAW, the current study reveals that ICUAW occurred in the control group more than in critically ill patients in the study group. This means that early rehabilitation intervention is effective in reducing the occurrence of ICUAW. This results because early rehabilitation intervention improves muscle function, decreasing stiffness and contracture, increasing muscle excitability, improving muscle strength, and preventing the occurrence of disuse muscle atrophy among critically ill patients. This finding is supported by K. **Liu et al. (2024)**, who proved that, the rehabilitation of critically ill patients reduced ICUAW. Another study conducted by **Dos Santos et al. (2020)** confirmed the benefits of NMES, as NMES may decrease ventilator time and increase muscle strength in the lower extremities. The findings are in contrast with a study conducted by **Jones et al. (2020),** which highlights significant variability among individuals' responses to rehabilitation efforts during critical illness. It suggests that not all patients will benefit equally from mobilization or NMES due to differences in baseline health status, severity of illness, or other comorbidities. The current study disagreed with the systematic review study done by **Maffiuletti et al. (2022).** This review presents mixed results regarding the effectiveness of NMES for preventing muscle loss during critical illness; while some studies show promise, others indicate insufficient evidence supporting its routine use due to inconsistent outcome measures and heterogeneity among study designs.

Regarding the onset day and severity of muscle weakness among patients, this study indicates that, ICUAW has occurred on the same days on day three and day six of admission, but the severity is a significant difference between the control group and the study group. The studied patients in the control group exhibited a marked increase in ICUAW occurrence alongside a decline in MRC scores. In contrast, the occurrence of ICUAW is lower in the study group**. This means that** both groups were exposed to the factors that increase the occurrence of ICUAW, but the study group's exposure to early rehabilitation intervention, which may be effective in preventing muscle weakness, decreasing stiffness and contracture, increasing muscle excitability, improving muscle strength, and preventing the occurrence of disuse muscle atrophy among critically ill patients.

In line with these findings, **King et al. (2024),** who found that patients who received NMES developed ICUAW lower than patients who received standard nursing care. Also, a study conducted by **Thille et al. (2023)** revealed that a minority of ICUAW patients had weakness on the second day of ICU admission. While one-third of them had weakness on the third day of admission and half of them had weakness on the fourth day of admission. The findings may be **in contrast with** studies conducted **by Nydahl et al. (2023),** who found that the occurrence of ICUAW is similar in both groups, in the study group who are exposed to early rehabilitation intervention and the study group who are not exposed.

Regarding handgrip dynamometry, the current study finding that while both groups started with similar handgrip strengths at baseline of admission for both hands, over time, especially after rehabilitation intervention, the study group's grip strength improved significantly from the third to the sixth day compared to continued declines seen in the control group's grip strength measurements on both hands across days of a week. This means that early rehabilitation intervention that was applied to the study group improved the muscle strength and circulation to the extremities, which reflect an increase in hand grip scores. **Our result is in line with Mayer et al. (2021)** and **de Campos Biazon et al. (2019)**, who reported that handgrip strength was significantly lower in patients with ICUAW. The findings may be in contrast **with Cottereau et al. (2021),** who revealed that there are no significant differences in handgrip strength between ICU patients with and without ICUAW, suggesting that the relationship is not as clear-cut as reported.

Regarding **socio-demographic variables,** none of the age or sex of the studied patients in both groups were associated with the current study outcomes; this may be related to age and gender alone are not contributing factors for ICUAW because ICUAW arises from more complex or multifactorial mechanisms. **This finding was supported by Yabe et al. (2025),** whose results showed no significant difference between the incidences of ICUAW concerning age and gender. Also, **Cubitt et al. (2023)** found that most of the studied burned patients who developed ICUAW were younger, not older, and they rely on that as patients often die before they can be diagnosed with ICUAW. On the other hand, these results are not in concurrency with the previously studied. **Komori et al. (2025)** found variation in the outcome of using early rehabilitation among male and female patients.

Regarding **clinical variables**, the clinical diagnosis of respiratory disorder and pneumonia of the studied patients was associated with the occurrence of ICUAW in the control group. These may be related to respiratory infection as pneumonia may play a crucial factor for ICU admission and require prolonged periods of MV, or sedation, which leads to immobility, one of the major contributors to muscle wasting, and a contributory factor leading to ICUAW. Further explanation, pneumonia can trigger systemic inflammatory responses, which may exacerbate muscle catabolism and inhibit protein synthesis, further contributing to muscle weakness.

This finding was supported by Brunker et al. (2023), who found that a specific clinical diagnosis such as pneumonia was associated with the occurrence of ICUAW. This relation between diagnosis and occurrence of ICUAW is related to skeletal muscular dysfunctions. Furthermore, **Weber-Carstens et al. (2010)** reported how sepsis-related issues such as inflammation from lung infections correlate strongly with muscular weakness in ICU settings.

These findings were contradicted by **Raurell-Torredà et al. (2021),** who conducted a study about "multifactorial aspects of ICUAW." Argue that while respiratory issues play a role, other factors, such as pre-existing conditions, contribute significantly without placing undue emphasis on pulmonary causes alone, and **Wang et al. (2020),** who suggest that it does not establish a strong direct correlation between pneumonia and the development of ICUAW, emphasizing other causes like sedation or prolonged immobility.

Regarding nursing practices to prevent ICUAW, the finding of the present study reveals that there is no relationship between positioning, walking, and chair setting with the occurrences of ICUAW in both groups. **From the researcher's point of view,** the application of nursing actions that prevent muscle weakness for both groups was inadequate, or maybe not according to the guidelines. These findings are consistent with **Mostafa et al. (2023),** who stated that there was no statistically significant relationship between the occurrence of ICUAW and application of positioning and walking for this studied patients. Also, **Key et al. (2023)** found that nearly half of patients who received range of motion exercises experienced ICUAW, which indicates that it is not a sole protective intervention, but it should be combined with other protective interventions such as NMES.

In opposition to these results, previous studies established a strong association between immobility and occurrences of ICUAW**, as Patel et al. (2020) and Rosa et al. (2023)** evaluated the impact of early mobilization on glycemic control and ICUAW in critically ill patients who are mechanically ventilated, and they found that early mobilization appears to have higher potency in the avoidance of ICUAW, possibly because of its dual effects in restoring glucose homeostasis and preventing disuse atrophy.

Conclusion

Based on the study findings, it can be concluded that critically ill patients who are subjected to early rehabilitation interventions exhibit lower ICU-acquired weakness scores than those who are not subjected. Also, the frequency of ICUAW occurrence was higher in patients who did not receive early rehabilitation intervention. So, early rehabilitation is a protective factor against the occurrence and severity of ICUAW.

Recommendations

In line with the findings of the study, the following recommendations are made:

- Assess the muscle strength of all admitted patients to the ICU using a muscle strength scale and hand grip scale as a routine by nurses and medical staff.
- Shift ICU culture from only range of motion exercise and positioning to NMES application and mobilization to enable the prevention of complications and faster healing and recovery.
- Implement early NMES sessions for half an hour combined with early passive ROM exercises for half an hour for upper and lower extremity joints from the first 24 hours of admission for one hour till patients discharge from the ICU.
- Create educational programs for critical care nurses to provide continuous educational sessions and courses to update their knowledge about risk factors, new technology, and procedures facilitating the prevention and treatment of ICUAW.
- Eliminate the barriers to critically ill patients' early rehabilitation intervention, including patients, nursing, environmental, and administrative barriers.
- Replicate this study on larger samples in different hospitals to generalize the results.

Authors' contributions

- **Nadia Taha Mohamed Ahmed**, professor: Supervision all thesis stages, such as, writing thesis protocol, development and translation of tools. She also helped the student in research methodology, interpretation of results, study discussion, conclusion, recommendation, and organizing references.
- **Bassem Nashaat Beshey, Professor**: Supervision of all thesis stages such as, writing thesis protocol, development and translation of tools. He also helped the student in research methodology, interpretation of results, study discussion, conclusion, recommendation, and organizing references.
- **Eman Arafa Hassan Ali, Assistant professor:** Supervision all writing thesis protocol, data collection, results, and references.
- **Sherouk Nasser Mohamed**, Assistant lecturer: conceptualization, preparation, methodology, implementation of the sessions, investigation, formal analysis, data analysis, writing-original draft, writing-manuscript & editing. All authors read and approved the final manuscript

Table (1): Distribution of critically ill patients in the control and study groups according to their demographic characteristics:

Demographic characteristics	Studied patients (N= 80)				Test of Significance (p)
	Study group (n= 40)		Control group (n= 40)		
	No	%	No	%	
Gender					
- Males	17	42.5%	19	47.5%	χ2=0.202
-Females	23	57.5%	21	52.5%	p=0.653 ns
Age (years)					χ2=5.370 p=0.117 ns
- 35-<45	0	0.0%	1	2.5%	
- 45-<55	10	25.0%	3	7.5%	
- 55-<65	8	20.0%	10	25.5%	
-≥65	**22**	**55%**	**28**	**70.0%**	
Mean ± S.D.	66.68 ± 12.78		67.70 ± 9.63		t=0.41 (p=0.687 ns)

χ2 Chi-Square Test of significance of difference between distributions among two groups.
t t-test between means of the Intervention and Control.
p: p value for the test of significance
*ns not significant (Statistically) * Statistically significant at p<0.05*
**** Statistically significant at p<0.001*

Table (2): Occurrence and severity of ICUAW among critically ill patients in the control and study groups according to their total MRC Score over days of a week

Days	Study		Control		χ^2(P)
	No.	%	No.	%	
Baseline	9	22.5%	8	20.0%	χ2=0.075 p= 0.785 ns
Mean ±S.D	49.80 ± 4.27		51.61± 3.62		t=0.91 p=0.365 ns
Second day	9	22.5%	11	27.5%	χ2=0.267 p= 0.606 ns
Mean ±S.D	49.70 ± 4.27		51.53 ± 4.04		t=1.120 p=0.266 ns
Third day	7	17.5%	12	30.0%	χ2=1.726 p=0.189 ns
Mean ±S.D	49.80 ± 4.27		48.90 ± 3.81		t=0.331 p=0.741 ns
Fourth day	**6**	**15.0%**	**18**	**45.0%**	χ2=**6.192 p=0.013***
Mean ±S.D	51.53 ± 4.04		47.68 ± 4.06		t=4.25 p<0.001***
Fifth day	7	17.5%	19	47.5%	χ2=8.205 p=0.004*
Mean ±S.D	54.00 ± 6.13		46.88 ± 4.30		t=6.66 (p<0.001***)
Six day	6	15.0%	23	57.5%	χ2=15.63 p=<0.001***
Mean ±S.D	54.80 ± 6.17		45.38 ± 5.31		t=6.66 (p<0.001***)
Seven day	**6**	**15.0%**	**34**	**85.0%**	χ2=39.29 p=<0.001***
Mean ±S.D	55.88 ± 5.93		43.00 ± 4.95		t=8.34 (p<0.001***)

χ2 Chi-Square Test of significance of difference between distributions among two groups.
p: p value for the test of significance
*ns not significant (Statistically) * Statistically significant at p<0.05*
**** Statistically significant at p<0.001*
t t-test between means of the study and control.

Table (3): Distribution of the critically ill patients in the control and study groups according to the occurrence and severity of ICUAW based on the hand grip score:

Hand Grip Score	Day	Study(n=40)	Control (n=40)	Test of Significance (p)
		Mean±S.D.	Mean±S.D.	
Right Hand	Baseline	23.29 ± 7.74	25.85 ± 7.08	t=1.54 p=0.126 ns
	Second	23.98 ± 7.92	24.78 ± 6.91	t=0.48 p=0.630 ns
	Third	24.71 ± 8.07	23.58 ± 6.90	t=0.67 p=0.503 ns
	Fourth	**26.13 ± 8.46**	**22.25 ± 6.77**	**t=2.27 p=0.026***
	Fifth	27.21 ± 8.88	21.05 ± 6.58	t=3.53 p<0.001***
	Six	28.65 ± 9.30	19.75 ± 6.39	t=4.99 p<0.001***
	Seven	29.72 ± 9.39	18.61 ± 6.24	t=6.23 (p<0.001***)
Left Hand	Baseline	23.25 ± 7.86	25.80 ± 7.08	t=1.52 p=0.132 ns
	Second	23.98 ± 7.91	24.73 ± 6.91	t=0.45 p=0.652 ns
	Third	24.70 ± 8.08	23.57 ± 6.90	t=0.67 p=0.503 ns
	Fourth	**26.19 ± 8.55**	**22.22 ± 6.78**	**t=2.30 p=0.024***
	Fifth	27.10 ± 8.83	21.02 ± 6.58	t=3.49 (p<0.001***)
	Six	28.62 ± 9.41	19.66 ± 6.37	t=4.99 (p<0.001***)
	Seven	29.72 ± 9.45	18.60 ± 6.23	t=6.21 (p<0.001***)

p: p value for the test of significance
ns not significant (Statistically) ** Statistically significant at p<0.05*
**** Statistically significant at p<0.001*
t t-test between means of the study and control.

Table (4): Distribution of critically ill patients in the control and study groups according to their total body strength (MRC levels) in relation to their morbidity-related data

Morbidity-related data	Total MRC Score Day 6											
	Study (n = 40)						Control (n = 40)					
	ICUAW (n=6)		Non-ICUAW (n=34)		χ^2	^{MC}p/^{FE}p	ICUAW (n=34)		Non-ICUAW (n=6)		χ^2	^{MC}p/^{FE}p
	No.	%	No.	%			No.	%	No.	%		
Co-morbidities												
Acute Renal Failure (AKI)	2	33.3%	14	41.2%	0.131	1.000	13	38.2%	4	66.7%	1.687	0.194
Diabetes Mellitus (DM)	3	50.0%	13	38.2%	0.294	0.668	19	55.9%	4	66.7%	0.243	1.000
Multiple Organ Failure (MOF)	1	16.7%	9	26.5%	0.261	1.000	13	38.2%	2	33.3%	0.052	1.000
Acute Respiratory Failure (ARF)	1	16.7%	2	5.9%	0.855	0.394	4	11.8%	1	16.7%	0.112	1.000
Pneumonia	**3**	**50.0%**	**14**	**41.2%**	**0.162**	**1.000**	**19**	**55.9%**	**0**	**0.0%**	**6.387***	**0.021***
Ischemic heart diseases	3	50.0%	13	38.2%	0.294	0.668	15	44.1%	3	50.0%	0.071	1.000
Chronic Kidney Disease (CKD)	1	16.7%	7	20.6%	0.049	1.000	8	23.5%	2	33.3%	0.261	0.629
Sepsis	2	33.3%	17	50.0%	0.568	0.664	19	55.9%	4	66.7%	0.243	1.000
Shock	3	50.0%	15	44.1%	0.071	1.000	16	47.1%	5	83.3%	2.691	0.186
Chronic Obstructive Pulmonary Disease (COPD)	1	16.7%	5	14.7%	0.015	1.000	4	11.8%	0	0.0%	0.784	1.000
Hypertension (HTN)	2	33.3%	12	35.3%	0.009	1.000	17	50.0%	2	33.3%	0.568	0.664
Asthmatic	0	0.0%	4	11.8%	0.784	1.000	3	8.8%	0	0.0%	0.572	1.000
Number of Co-Morbidities												
One	0	0.0%	2	5.9%	0.673	0.748	1	2.9%	0	0.0%	0.349	1.000
Two	1	16.7%	10	29.4%			8	23.5%	1	16.7%		
3 or More	5	83.3%	22	64.7%			25	73.5%	5	83.3%		

χ2: Chi square test MC: Monte Carlo FE: Fisher Exact *: Statistically significant at p ≤ 0.05

Nursing Protocol, Venous Thromboembolism, Post-Operative, Femur Fracture Surgeries.

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