



EARLY DETECTION OF INTENSIVE CARE UNIT-ACQUIRED WEAKNESS USING HANDHELD DYNAMOMETRY AND LIMB GIRTH MEASUREMENTS IN MEDICAL AND SURGICAL INTENSIVE CARE UNIT PATIENTS: A PROSPECTIVE OBSERVATIONAL STUDY

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ABSTRACT

Background: Intensive Care Unit-Acquired Weakness (ICU-AW) is a frequent complication of critical illness resulting from neuromuscular dysfunction and skeletal muscle wasting. Early recognition of muscle deterioration remains challenging because standard diagnostic techniques may be resource-intensive and impractical for routine bedside assessment. Simple, objective, and reproducible methods suitable for routine ICU practice are therefore required. **Objective:** To evaluate changes in muscle strength and limb girth during the first week of intensive care admission using handheld dynamometry and anthropometric measurements as simple bedside indicators of early muscle deterioration associated with ICU-acquired weakness. **Methods:** A prospective observational study was conducted in a tertiary care teaching hospital between December 2024 and May 2025. Adult patients admitted to medical and surgical ICUs who remained clinically stable for at least 72 hours were enrolled. Dominant-hand grip strength and bilateral quadriceps strength were assessed using a calibrated handheld dynamometer. Mid-arm, mid-forearm, mid-thigh, and mid-calf circumferences were measured using a standardised measuring tape. Assessments were performed on Day 3 and repeated on Day 8 of ICU stay. Changes between assessments were analysed using a paired Student's t-test. **Results:** Forty-two patients were recruited, of whom 33 completed the study. Mean age was 48.5 ± 15.9 years, and 57% were male. Dominant-hand grip strength decreased by 28.9%, while right and left quadriceps strength declined by approximately 15.6% and 15.0%, respectively (both $p < 0.01$). Significant reductions were also observed in arm, forearm, thigh, and calf circumferences (all $p < 0.01$), indicating progressive muscle wasting during the observation period. **Conclusion:** Clinically significant reductions in muscle strength and limb girth occurred during the first week of ICU admission. Handheld dynamometry combined with serial limb circumference measurements represents a practical, inexpensive, and reproducible bedside approach for identifying early muscle deterioration and patients who may be at risk of ICU-acquired weakness.

KEYWORDS : Intensive Care Unit-Acquired Weakness; ICU-AW; Handheld Dynamometry; Muscle Strength; Limb Girth; Critical Illness; Rehabilitation

INTRODUCTION

Intensive Care Unit-Acquired Weakness (ICU-AW) is a common neuromuscular complication affecting critically ill patients admitted to intensive care units. It is characterised by generalised, symmetrical weakness that develops in the absence of pre-existing neuromuscular disease and results from critical illness polyneuropathy, critical illness myopathy, or a combination of both.^{1,4} ICU-AW is recognised as an important contributor to prolonged mechanical ventilation, delayed mobilisation, extended hospitalisation, impaired functional recovery, limited mobility, and reduced quality of life among survivors of critical illness.^{4,6,10,14}

The incidence of ICU-AW varies according to illness severity, duration of ICU stay, diagnostic criteria, and patient population, with reported prevalence ranging from 25% to more than 50% in critically ill adults.^{2,8,10,14} Patients with sepsis, multiorgan dysfunction, prolonged immobilisation, hyperglycaemia, corticosteroid exposure, and systemic inflammation are particularly susceptible.^{2,4,6,13,18} Neuromuscular impairment begins early during critical illness because of accelerated protein catabolism, mitochondrial dysfunction, impaired microcirculation, oxidative stress, and activation of proteolytic pathways, leading to rapid loss of muscle mass and contractile function.^{6,7,13,14}

Loss of skeletal muscle strength occurs rapidly during the first week of ICU admission and may precede clinically apparent muscle atrophy.^{7,12,14} The quadriceps muscles are especially vulnerable because of prolonged immobilisation and reduced weight-bearing activity, whereas handgrip strength provides a convenient measure of voluntary muscle function.^{7,12,16} Early recognition of these changes is important because timely rehabilitation interventions, including early mobilisation, resistance exercise, nutritional optimisation, and multidisciplinary rehabilitation, may attenuate functional decline.^{8,9,22}

Current approaches to the assessment of ICU-AW include the Medical Research Council (MRC) sum score, electrophysiological studies, muscle ultrasound, computed tomography, magnetic resonance imaging, and muscle biopsy.^{3,4,6,15,18} Although these techniques provide valuable diagnostic information, several require specialised equipment, trained personnel, or patient cooperation and may therefore be difficult to implement routinely in many ICUs, particularly in resource-limited settings.^{3,4,15,16}

Handheld dynamometry has emerged as an objective, quantitative, and reproducible method for measuring voluntary muscle strength. It is portable and suitable for repeated bedside assessment.^{16,17,21} Similarly, serial limb circumference measurements obtained using a measuring tape provide a simple surrogate measure of peripheral muscle wasting.^{7,12,21} Although anthropometric measurements cannot distinguish muscle from oedema or adipose tissue, they remain attractive because of their simplicity and feasibility in routine clinical practice.^{12,16,21}

Most published studies have focused on mechanically ventilated patients with prolonged ICU stays. Limited evidence is available regarding the development of muscle weakness among clinically stable, non-ventilated patients admitted to both medical and surgical intensive care units.^{9,16,22} Identifying early deterioration in this population may facilitate prompt physiotherapy referral and rehabilitation before substantial muscle loss occurs.^{8,16}

Therefore, the present study aimed to evaluate changes in handgrip strength, quadriceps muscle strength, and peripheral limb girth during the first week of ICU admission using handheld dynamometry and standardised anthropometric measurements. We hypothesised that significant reductions in both muscle strength and limb circumference would occur within one week of ICU admission, supporting the use of these simple bedside tools for the early identification of muscle

deterioration associated with ICU-acquired weakness.^{7,12,16,21}

MATERIALS AND METHODS

Study Design and Setting

This prospective observational study was conducted between December 2024 and May 2025 in the Medical and Surgical Intensive Care Units of a tertiary care teaching hospital in Nagpur, Maharashtra, India.

The study adhered to the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) guidelines. Institutional Ethics Committee approval was obtained before commencement of the study. Written informed consent was obtained from all participants or their legally authorised representatives.

Participants

Adult patients aged 18 years or older admitted to either the Medical ICU or Surgical ICU were screened consecutively. Patients were eligible if their ICU stay was at least 72 hours, they were haemodynamically stable, had a Glasgow Coma Scale score of ≥ 13 , were able to understand and follow verbal instructions, and were suitable for physiotherapy assessment.

Patients receiving mechanical ventilation, heavy sedation, or muscle relaxants were excluded. Patients with progressive neurological disorders, peripheral neuropathy, myopathy, encephalopathy, major limb fractures, or severe musculoskeletal disorders affecting voluntary muscle assessment were also excluded.

Sample Size and Recruitment

Participants were recruited on an accrual basis as they became eligible during their ICU stay. No formal sample size estimation was performed.

Outcome Measures

The primary outcome measures were:

1. Dominant-hand grip strength.
2. Bilateral quadriceps muscle strength.

Secondary outcome measures were:

1. Mid-arm circumference.
2. Mid-forearm circumference.
3. Mid-thigh circumference.
4. Mid-calf circumference.

Assessments were performed on Day 3 (72 hours after ICU admission) and repeated on Day 8.

Muscle Strength Assessment

Muscle strength was measured using a calibrated handheld dynamometer. Calibration was verified before each assessment session according to the manufacturer's recommendations.

Participants were positioned in supported high sitting. Standardised verbal encouragement and identical positioning were used throughout the study. Three maximal voluntary contractions were recorded with one-minute rest intervals, and the average value was used for analysis.

All measurements were performed by the same trained physiotherapist to minimise intra-rater variability.

Limb Girth Measurement

Circumference measurements were obtained at the mid-arm, mid-forearm, mid-thigh, and maximum calf circumference using a non-elastic measuring tape. Standard anatomical landmarks were marked during the baseline assessment to ensure reproducibility during follow-up. Measurements were recorded to the nearest 0.1 cm.

Statistical Analysis

Data were analysed using IBM SPSS Statistics Version 15. Continuous variables were expressed as mean $\pm$ standard deviation, while categorical variables were summarised using frequencies and percentages.

Changes between Day 3 and Day 8 measurements were analysed using a paired Student's *t*-test. Statistical significance was defined as $p < 0.05$.

RESULTS

A total of 42 patients fulfilled the eligibility criteria and were enrolled

in the study. Nine participants were lost to follow-up because of transfer from the ICU, deterioration requiring mechanical ventilation, development of life-threatening complications, or death before the second assessment. Consequently, 33 patients completed the study and were included in the final analysis. The attrition rate was 21.4% (9/42).

The mean age of the overall study population was 48.5 ± 15.95 years, and 57% were male. Twenty-five patients were admitted to the Medical ICU and eight to the Surgical ICU.

Changes in Muscle Strength

Significant reductions in muscle strength were observed between Day 3 and Day 8 of ICU admission.

Dominant-hand grip strength declined from 10.30 ± 5.90 kg to 7.39 ± 3.29 kg, representing a 28.9% reduction ($p = 0.01$).

Right quadriceps strength decreased from 15.15 ± 6.06 kg to 12.79 ± 6.75 kg, while left quadriceps strength declined from 15.21 ± 6.05 kg to 12.93 ± 6.68 kg. The corresponding reductions were approximately 15.6% and 15.0%, respectively (both $p < 0.001$). (Table 1)

Changes in Limb Girth

Serial anthropometric assessment demonstrated significant reductions in limb circumference at all measurement sites.

Mean mid-arm circumference decreased from 24.64 ± 2.50 cm to 23.93 ± 2.88 cm, while mid-forearm circumference declined from 22.20 ± 1.98 cm to 21.44 ± 2.16 cm. The percentage reductions were 2.9% and 3.4%, respectively (both $p < 0.001$). (Table 2)

Right mid-thigh circumference decreased from 37.03 ± 2.99 cm to 36.02 ± 2.91 cm, and left mid-thigh circumference decreased from 37.27 ± 3.03 cm to 36.01 ± 2.91 cm. Mid-calf circumference declined from 31.22 ± 2.50 cm to 30.39 ± 2.08 cm. The corresponding percentage reductions were 3.3%, 3.4%, and 2.6%, respectively (all $p < 0.001$). (Table 3)

Collectively, these findings demonstrate measurable reductions in both muscle strength and peripheral limb circumference within the first week of ICU admission.

DISCUSSION

The present prospective observational study demonstrated that clinically stable adult patients admitted to medical and surgical intensive care units experienced significant declines in both muscle strength and peripheral limb girth within the first week of ICU admission. Dominant-hand grip strength decreased by approximately 29%, right and left quadriceps strength decreased by approximately 16% and 15%, respectively, and limb circumference decreased by 2.6–3.4%. These findings suggest that measurable neuromuscular and anthropometric deterioration occurs early during critical illness.^{7,12,14,16,21}

ICU-AW has emerged as an important complication among critically ill patients and is increasingly recognised as a determinant of prolonged mechanical ventilation, delayed mobilisation, longer hospital stay, increased healthcare utilisation, and persistent physical disability after hospital discharge.^{4,6,10,14} Contemporary literature indicates that the prevalence of ICU-AW ranges from 25% to more than 50%, depending on illness severity, duration of critical illness, diagnostic criteria, and patient population.^{2,5,10,14} Although previous studies have frequently focused on mechanically ventilated patients, the present findings demonstrate measurable muscle deterioration in patients who were not mechanically ventilated at enrolment, suggesting that immobilisation and systemic illness may contribute to early muscle dysfunction.^{7,14,16}

The nearly 29% reduction in handgrip strength observed in the present study represents the greatest decline among the measured strength parameters. Handgrip dynamometry provides a quantitative measure of voluntary muscle strength and can be used for repeated bedside assessment.^{16,17,21} Unlike manual muscle testing, handheld dynamometry provides numerical values that may allow clinicians to monitor changes in muscle performance over time.^{16,21} The present findings therefore support its potential use as part of routine ICU physiotherapy assessment for monitoring early muscle deterioration.^{16,21}

Quadriceps strength declined by approximately 15–16% over the five-

day observation period. This finding is clinically relevant because the quadriceps muscles are important for standing, transfers, and ambulation. Previous physiological studies have shown that lower-limb muscles undergo rapid disuse atrophy during immobilisation because of reduced mechanical loading, accelerated protein degradation, mitochondrial dysfunction, impaired muscle regeneration, and systemic inflammatory responses associated with critical illness.^{6,7,12,13} Early reduction in quadriceps strength may contribute to delayed functional recovery and impaired mobility after ICU discharge.⁸ Consequently, routine assessment of lower-limb strength may help identify patients who require early mobilisation and targeted rehabilitation interventions.^{8,9}

In addition to reductions in muscle strength, statistically significant decreases were observed in upper- and lower-limb circumference. Although the absolute reduction in limb girth was smaller than the reduction in muscle strength, these findings suggest progressive peripheral tissue loss during the first week of ICU admission.^{7,12} Functional impairment may precede measurable structural muscle loss because neuromuscular dysfunction can develop before substantial muscle atrophy becomes clinically apparent.^{6,7,12,14} This may explain why the decline in muscle strength exceeded the reduction in limb circumference in the present study. Serial anthropometric measurements may therefore complement strength testing by providing a simple bedside measure of changes in limb circumference.^{7,12,21}

Several techniques have been proposed for assessing ICU-AW, including Medical Research Council sum scoring, electrophysiological studies, muscle ultrasound, computed tomography, magnetic resonance imaging, bioelectrical impedance analysis, and muscle biopsy.^{1,3,4,6,15,18} While these methods provide valuable information, their widespread clinical use may be limited by cost, specialised equipment, technical expertise, patient cooperation, or logistical constraints.^{3,4,15,16} Bedside muscle ultrasonography has gained attention because it allows repeated assessment of muscle thickness and architecture without radiation exposure.^{12,15} However, ultrasonography remains operator dependent and may not be universally available, particularly in low- and middle-income countries.^{15,16} In contrast, handheld dynamometry and anthropometric measurements require relatively little equipment and can be performed repeatedly, making them potentially useful in routine intensive care settings.^{16,21}

An important feature of the present study was the inclusion of patients from both medical and surgical ICUs who were clinically stable and not mechanically ventilated at the time of assessment. Previous investigations have frequently evaluated patients with prolonged ventilation or severe multiorgan failure.^{7,22} The finding of measurable muscle deterioration in a relatively less severely ill population suggests that surveillance of muscle function should not necessarily be restricted to mechanically ventilated patients.^{14,16,18} Early identification of muscle deterioration may provide an opportunity to initiate interventions such as progressive mobilisation, resistance exercise, nutritional optimisation, and multidisciplinary rehabilitation.^{8,16,22}

The present study has several potential clinical implications. First, serial handheld dynamometry provides an objective quantitative measure that may identify deterioration in muscle performance.^{16,21} Second, limb circumference measurement provides an inexpensive measure of changes in peripheral girth that can be incorporated into routine physiotherapy documentation.^{7,12,21} Third, combining these assessment methods may provide a practical approach to monitoring patients in settings where advanced diagnostic modalities are unavailable.^{16,21} Such an approach may facilitate timely physiotherapy assessment and rehabilitation planning.^{8,16}

The study also has limitations. The sample size was relatively small, and formal sample size estimation was not performed. Approximately 21.4% of enrolled participants were lost to follow-up because of transfer, clinical deterioration, or death, which may have influenced the generalisability of the findings. Muscle ultrasound, Medical Research Council sum scores, and electrophysiological testing were not performed for comparison; therefore, diagnostic accuracy or agreement with established ICU-AW assessment methods could not be evaluated.^{1,3,15,16} In addition, long-term functional outcomes after hospital discharge were not assessed.⁸ Future multicentre studies involving larger patient populations should compare handheld dynamometry and anthropometric measurements with established

assessment methods and evaluate their predictive validity for long-term physical function, quality of life, and hospital outcomes.^{15,16}

Overall, the findings support the potential use of handheld dynamometry and serial limb circumference measurements as practical bedside methods for monitoring early muscle deterioration during ICU admission. Their simplicity, relatively low equipment requirements, and feasibility for repeated assessment make them potentially useful in intensive care settings where advanced diagnostic technologies may be unavailable or impractical.^{16,21} Early recognition of muscle deterioration may facilitate timely rehabilitation strategies aimed at preserving muscle function and improving recovery following critical illness.^{8,16,2}

CONCLUSION

This prospective observational study demonstrated significant reductions in handgrip strength, quadriceps strength, and peripheral limb circumference during the first week of ICU admission among the studied patients.

These findings indicate that measurable muscle deterioration occurs early during critical illness, including among patients who were not mechanically ventilated at the time of assessment.

Handheld dynamometry and serial limb circumference measurements are simple and feasible bedside assessment methods that may assist clinicians in identifying early muscle deterioration and patients who may be at risk of ICU-acquired weakness.

Future multicentre studies with larger sample sizes should evaluate these assessment methods against established ICU-AW assessment standards, including Medical Research Council sum scores, muscle ultrasonography, and electrophysiological investigations, and should assess their relationship with long-term functional outcomes and health-related quality of life.

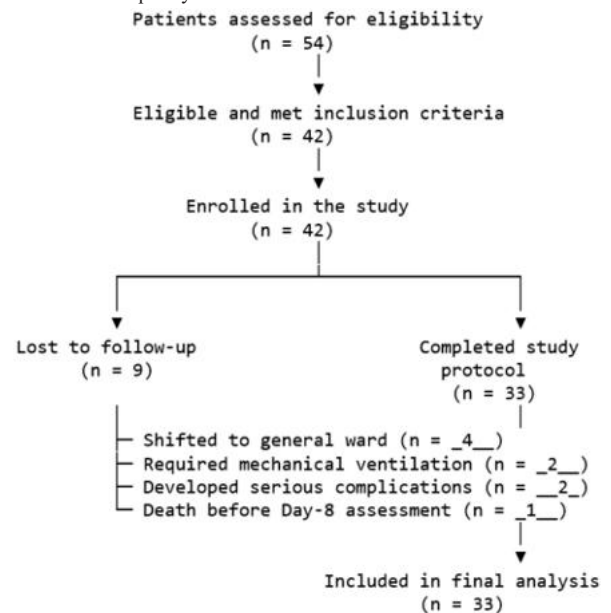


Figure 1. STROBE Flow Diagram of Participant Recruitment and Follow-up

Figure Legend

Flow diagram of participant recruitment, follow-up, and analysis according to the STROBE recommendations. Forty-two patients fulfilling the eligibility criteria were enrolled. Nine participants were lost to follow-up because of transfer to the general ward, requirement for mechanical ventilation, serious complications, or death before the Day-8 assessment. Thirty-three participants completed both assessments and were included in the final analysis.

Table 1 Changes in Peripheral Muscle Strength Between Day 3 and Day 8 in Critically Ill Patients (n = 33)

Variable	Day 3, mean ± SD	Day 8, mean ± SD	Mean difference	% change	p value
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Dominant-hand grip strength (kg)	10.30 ± 5.90	7.39 ± 3.29	-2.91	-28.9%	0.01
Right quadriceps strength (kg)	15.15 ± 6.06	12.79 ± 6.75	-2.36	-15.6%	<0.001
Left quadriceps strength (kg)	15.21 ± 6.05	12.93 ± 6.68	-2.28	-15.0%	<0.001

Legend: Values are presented as mean ± standard deviation (SD). Mean difference represents the change from Day 3 to Day 8 (Day 8 – Day 3), with negative values indicating a decline in muscle strength. Percentage change was calculated relative to the Day 3 value. Statistical significance was assessed using the paired *t*-test, with *p* < 0.05 considered statistically significant. Analyses included the 33 participants who completed both assessments.

Table 2 Changes in Upper-Limb Circumference Between Day 3 and Day 8 in Critically Ill Patients (n = 33)

Measurement	Day 3, mean ± SD	Day 8, mean ± SD	% change	p value
Mid-arm circumference (cm)	24.64 ± 2.50	23.93 ± 2.88	-2.9%	<0.001
Mid-forearm circumference (cm)	22.20 ± 1.98	21.44 ± 2.16	-3.4%	<0.001

Legend: Values are expressed as mean ± standard deviation (SD). Percentage change represents the relative change in circumference from Day 3 to Day 8, with negative values indicating a reduction in limb circumference. Statistical comparisons were performed using the paired *t*-test. A *p* value <0.05 was considered statistically significant. Data are presented for the 33 participants who completed both assessments.

Table 3. Changes in Lower Limb Circumference Between Day 3 and Day 8 in Critically Ill Patients (n = 33)

Measurement	Day 3 Mean ± SD	Day 8 Mean ± SD	% Change	p value
Right Mid-Thigh (cm)	37.03 ± 2.99	36.02 ± 2.91	-3.3%	<0.001
Left Mid-Thigh (cm)	37.27 ± 3.03	36.01 ± 2.91	-3.4%	<0.001
Mid-Calf (cm)	31.22 ± 2.50	30.39 ± 2.08	-2.6%	<0.001

Legend: Values are presented as mean ± standard deviation (SD). Percentage change indicates the relative reduction in lower limb circumference from Day 3 to Day 8. Negative values denote muscle wasting during the ICU stay. Statistical significance was assessed using the paired *t*-test, with *p* <0.05 considered statistically significant. Analyses include only the 33 participants who completed both assessments

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