Admission Handgrip Strength as an Independent Predictor of In-Hospital Mortality in Critically ill Adults: A Prospective Observational Study

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Abstract

Aim: Handgrip strength (HGS) is an emerging non-invasive biomarker that reflects neuromuscular integrity, physiological reserve, and nutritional status. While reduced HGS has been linked to adverse outcomes in various clinical populations, its prognostic value in critically ill ICU patients remains underexplored. Given these considerations, this study aims to rigorously evaluate the potential of admission HGS as a prognostic marker for in-hospital mortality among critically ill ICU patients.

Methods: We conducted a prospective observational cohort study in a tertiary care ICU to evaluate whether the HGS at admission predicts in-hospital mortality. Adult patients (≥18 years) with evaluable HGS were included in the study. HGS was measured within 24 hours of admission using a standardized dynamometry protocol and expressed as sex-specific z scores. Multivariable penalized logistic regression was used to assess the association between HGS and mortality, adjusting for demographic, clinical, inflammatory (CRP), and renal (creatinine and urea) markers. The model performance was evaluated using the AUC, calibration plots, and Brier score.

Results: A total of 200 patients from the ICU were enrolled; 98 (49.0%) died during hospitalization. Admission HGS was significantly lower among non-survivors (mean 4.7 ± 2.8 kg vs. 14.6 ± 4.8 kg, $p < 0.001$). Each 1-SD decrease in HGS was associated with a 14-fold increase in mortality risk (adjusted OR 13.97, 95% CI: 6.08–36.24). Mortality rates differed markedly across HGS tertiles (lowest: 98.5%, middle: 45.5%, highest: 3.0%; p-trend < 0.001). The predictive model demonstrated excellent discrimination (AUC: 0.987; optimism-corrected AUC: 0.972) and calibration (Brier score: 0.095).

Conclusions: Handgrip strength measured at ICU admission is a strong and independent predictor of in-hospital mortality. Given its simplicity and prognostic accuracy, HGS may serve as a valuable bedside tool for early risk stratification in critical care settings.

Keywords: Handgrip strength; ICU mortality; prognostic biomarker; critical illness; muscle weakness

1. Introduction

Despite significant advancements in intensive care medicine, in-hospital mortality among critically ill patients remains alarmingly high, often surpassing 40% depending on the severity of the patient's condition and underlying comorbidities.[1,2]. This underscores the need for reliable, accessible, and early prognostic indicators to guide clinical decision-making and improve outcomes in the ICU.

Handgrip strength (HGS), a non-invasive and cost-effective indicator of muscular function and overall physiological reserve, has recently garnered attention as a potential bedside prognostic marker.[3,4] Declines in HGS have been associated with increased morbidity and mortality in various clinical populations, including geriatric, oncologic, and surgical cohorts.[5,6] Although the predictive value of HGS has been well established in outpatient and subacute care settings, its utility in critically ill ICU populations remains insufficiently explored.

In the ICU, muscle weakness, often referred to as ICU-acquired weakness, is multifactorial in origin, arising from systemic inflammation, catabolic stress, metabolic dysregulation (e.g., hyperglycemia and renal impairment), and prolonged immobilization.[7,8] These factors not only accelerate skeletal muscle degradation but also diminish neuromuscular function, which may be readily captured by the reduction in HGS. Thus, HGS may serve as a surrogate marker for both acute illness severity and underlying physiological frailty.

This prospective observational study aimed to evaluate the prognostic significance of HGS measured within 24 h of ICU admission. Specifically, we examined the association between admission HGS and in-hospital mortality, while also exploring the correlations between HGS and key inflammatory and metabolic biomarkers. By

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elucidating these relationships, this study seeks to position HGS as a valuable and practical tool for early risk stratification and individualized clinical management in the ICU.

2. Materials and Methods

2.1. Ethical considerations

The study protocol was approved by the Institutional Review Board of the participating tertiary care center (Approval Date: Aug 21, 2024; Decision No 2024-13/1) and conducted in accordance with the principles of the Declaration of Helsinki. Written informed consent was obtained from all participants or their legally authorized representatives prior to their enrollment.

2.2. Study design and setting

We conducted a prospective observational cohort study to investigate the prognostic significance of muscle strength in critically ill patients admitted to the ICU. The primary objective was to evaluate the association between admission handgrip strength and in-hospital mortality. The secondary objective was to examine the relationship between inflammatory/metabolic indices and both handgrip strength and mortality.

2.3. Study population

The exclusion criteria were as follows: age <18 years, pregnancy, pre-existing neuromuscular disorders (e.g., amyotrophic lateral sclerosis, multiple sclerosis, Guillain–Barré syndrome, advanced Alzheimer's disease), intubation or inability to cooperate at admission, and orthopedic conditions affecting the dominant hand.

Regarding sedation, patients receiving sedatives or neuromuscular blocking agents at the time of ICU admission were excluded. To ensure the reliability of muscle strength assessment, patients with potential residual sedation effects after discontinuation were also excluded. Additionally, patients admitted for malignancy-related conditions who were receiving active chemotherapy were excluded to eliminate the confounding effect of chemotherapy-induced muscle weakness.

2.4. Exposure: handgrip strength assessment

Handgrip strength (HGS) was measured within the first 24 hours of ICU admission by trained personnel using a calibrated hand dynamometer (Camry Hand Dynamometer; South El Monte, CA, USA). Prior to the measurement, the physician provided a detailed explanation of the procedure and performed a practical demonstration for the patient. Measurements were obtained from the dominant hand. Three trials were performed, and the maximum value (kg) was recorded as the final result. In patients with no documented hand dominance, the value from the stronger hand was used.

To account for physiological sex differences in muscle strength, HGS values were standardized into sex-specific z-scores, calculated as: $z_i = \frac{HGS_i - \mu_{sex}}{\sigma_{sex}}$ where HGSi is the individual patient's handgrip strength, and μ_{sex} and σ_{sex} are the mean and standard deviation of HGS in the corresponding sex group. Analyses were conducted per 1-SD decrease in sex-standardized HGS, and tertiles of z-scores (low, intermediate, and high) were used for descriptive comparisons.

2.5. Data collection and measurements

At admission, demographic variables (age, sex, and body mass index [BMI]) were noted. Handgrip strength was measured within 24 h using a standardized dynamometer protocol, as described above. The laboratory parameters included white blood cell count (WBC), hemoglobin, platelet count, serum urea, serum creatinine, and C-reactive protein (CRP). The clinical variables documented at baseline were the presence of comorbidities, delirium, and the use of inotropes/vasopressors.

2.6. Outcomes

The primary outcome was in-hospital mortality during index ICU admission. The survival status (alive or deceased) and time from admission to death (days) were obtained from hospital records.

2.7. Statistical analysis

Continuous variables are expressed as mean±standard deviation (SD) and median with interquartile range (IQR). Categorical variables are reported as counts and percentages. Baseline group differences were quantified using standardized mean differences (SMDs), and no formal hypothesis testing was performed for descriptive comparisons.

Normality was assessed using the Shapiro–Wilk test. Between-group comparisons of continuous variables were performed using the Mann–Whitney U test, where applicable, and categorical variables were analyzed using the chi-square test. Correlations between continuous variables were evaluated using Spearman's rank correlation.

Table 1

Baseline characteristics by in-hospital mortality

Variable	Alive (n=102)		Death (n=98)		SMD
	Mean±SD	Median (IQR)	Mean±SD	Median (IQR)	
Male sex, n (%)	52 (51.0%)		54 (55.1%)		-0.08
Age (years)	64.7±15.4	68.0 (55.0–74.8)	65.3±13.8	68.0 (61.0–74.0)	-0.04
BMI (kg/m^2)	25.8±3.7	25.4 (23.7–27.0)	25.7±2.6	26.0 (24.0–27.0)	0.03
Any comorbidity, n (%)	94 (92.2%)		90 (91.8%)		0.01
Delirium, n (%)	13 (12.7%)		42 (42.9%)		-0.67
Inotrope use, n (%)	19 (18.6%)		84 (86.6%)		-1.36
Handgrip strength (kg)	14.6±4.8	13.7 (10.8–18.2)	4.7±2.8	4.1 (3.1–5.9)	2.51
WBC (10^9/L)	10.1±6.1	9.1 (6.5–11.8)	17.3±13.8	13.5 (5.9–25.5)	-0.67
Hemoglobin (g/dL)	9.8±2.0	9.3 (8.4–10.7)	9.1±1.8	8.9 (7.7–9.9)	0.37
Platelets (10^9/L)	210.8±113.9	205.5 (131.2–271.8)	130.2±113.6	100.0 (45.2–173.8)	0.71
Urea (mg/dL)	64.3±49.2	49.5 (33.0–85.9)	108.9±64.9	95.5 (54.1–150.7)	-0.78
Creatinine (mg/dL)	1.6±1.5	0.9 (0.6–2.2)	2.1±1.3	2.0 (1.0–2.7)	-0.34
CRP (mg/L)	46.4±44.9	33.0 (15.7–69.5)	173.5±104.4	143.0 (109.8–223.2)	-1.58

Continuous variables are presented as mean±SD and median (IQR); categorical variables as n (%). SMD = standardized mean difference. No formal hypothesis testing was performed for baseline characteristics; group differences are expressed as standardized mean differences (SMD), with values ≥0.1 considered potentially meaningful.

Univariate logistic regression analyses were first conducted to identify predictors of in-hospital mortality. Variables with clinical relevance or significant univariate associations were entered into the multivariable models. Penalized logistic regression was employed to robustly handle the complex interplay of multiple predictors of mortality, ensuring more reliable estimates by minimizing the risk of overfitting the data. Model performance was assessed using discrimination (area under the receiver operating characteristic curve [AUC]), calibration plots, and Brier scores. Internal validation was performed using bootstrap resampling methods.

All analyses were two-sided, with $p<0.05$ considered statistically significant. Statistical analyses were conducted using SPSS version 26.0 (IBM Corp., Armonk, NY, USA) and R version 4.3.

3. Results

3.1. Study population

A total of 200 critically ill adults were included, of whom 98 (49.0%) died during index hospitalization. The mean age was 65.0±14.6 years, and 53% of the patients were male. The baseline characteristics stratified by survival status are summarized in Table 1. Non-survivors exhibited markedly lower handgrip strength, higher inflammatory and renal markers, lower platelet counts, and more frequent delirium and inotrope use, with large standardized mean differences (SMD > 0.5) for these variables.

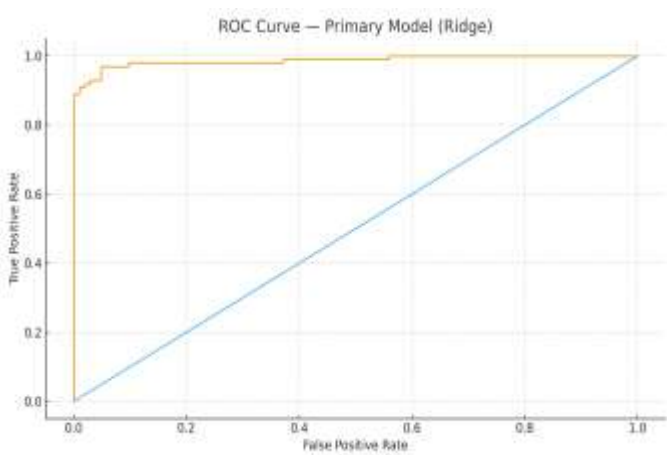
3.2. Association between handgrip strength and mortality

Admission handgrip strength was a strong, independent predictor of in-hospital mortality. In the penalized logistic regression model, each 1-SD decrease in sex-standardized handgrip strength was associated with a 14-fold increase in the odds of death (adjusted OR 13.97, 95% CI 6.08–36.24). The conventional logistic regression yielded consistent findings, although with wider confidence intervals (adjusted OR 58.2, 95% CI 9.94–340.83; Table 2).

Mortality gradients across tertiles of handgrip strength were striking: 98.5% in the lowest tertile, 45.5% in the middle tertile, and only 3.0% in the highest tertile (p for trend <0.001).

Figure 1

ROC curve — primary model (ridge)



The penalized logistic model incorporating admission handgrip strength achieved an AUC of 0.987 (optimism-corrected 0.972) for predicting in-hospital mortality.

3.3. Model performance

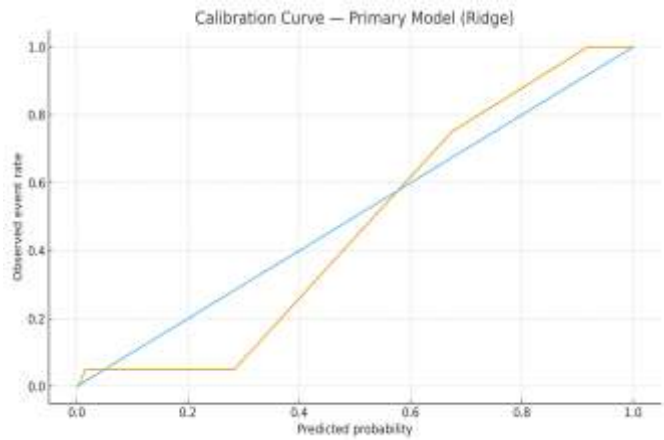
The penalized model demonstrated excellent discrimination, with an apparent AUC of 0.987 and an optimism-corrected AUC of 0.972 (Figure 1). Calibration was satisfactory, with the predicted and observed risks closely aligned (Figure 2). The overall Brier score was low (0.095), which supports the model accuracy.

3.4. Sensitivity analyses

The findings were robust when handgrip strength was expressed as sex-specific z-scores, when patients who died within 48 h were excluded, when creatinine was replaced with urea as the renal marker, and when delirium or inotrope use was omitted from the adjustment set. All sensitivity analyses confirmed a strong and independent association between lower handgrip strength and increased mortality.

Figure 2

Calibration curve — primary model (ridge)



The penalized logistic regression model incorporating admission handgrip strength showed good agreement between the predicted probabilities and observed outcomes. The calibration plot, constructed using bootstrap-corrected estimates and grouped by deciles of predicted risk, demonstrated close alignment with the 45° reference line, indicating satisfactory calibration across the full risk spectrum.

Table 2

Association between HGS and in-hospital mortality

Variable	Adj OR	95% CI (low)	95% CI (high)	p
Intercept	0.0	0.0	9.7	0.139
HGS (per 1 SD decrease)	58.2	9.94	340.83	<0.001
Age (per year)	0.93	0.88	0.99	0.0162
Male sex	2.03	0.43	9.65	0.371
BMI (kg/m^2)	0.98	0.82	1.18	0.857
Any comorbidity	0.87	0.07	10.36	0.912
log(CRP+1)	8.71	2.37	32.03	0.00113
log(Creatinine+1)	0.2	0.03	1.28	0.0895
WBC (10^9/L)	1.11	1.0	1.23	0.0552
Hemoglobin (g/dL)	1.15	0.79	1.67	0.474
Delirium	0.16	0.02	1.08	0.0599
Any inotrope	15.76	2.27	109.55	0.00532

Adjusted odds ratios derived from multivariable models including age, sex, BMI, comorbidity, CRP, creatinine, WBC, hemoglobin, delirium, and inotrope use. HGS expressed as sex-specific z-scores (per 1-SD decrease). Ridge logistic regression provided the primary robust estimate for HGS (Adj OR 13.97, 95% CI 6.08–36.24); Wald estimates from conventional logistic regression are shown above for all covariates.

4. Discussion

In this prospective cohort study of critically ill ICU patients, we found that lower handgrip strength (HGS) at admission was strongly and independently associated with increased in-hospital mortality. Patients in the lowest HGS tertile had a nearly 100% mortality rate compared to only 3% in the highest tertile. Penalized logistic regression demonstrated a 14-fold increase in the odds of death per one standard deviation decrease in HGS, even after adjusting for CRP, creatinine, delirium, and inotrope use. These results support the utility of HGS as a powerful and independent prognostic marker in the ICU.

Our findings are consistent with those of earlier studies that identified reduced HGS as a strong predictor of adverse outcomes in critical care. In a multicenter cohort study, Ali et al. showed that both ICU-acquired weakness and low HGS were independently associated with higher in-hospital mortality, even after adjusting for illness severity (OR for HGS: 4.5, p=0.007).[9] Similarly, a recent COVID-19 ICU study found that low HGS was significantly associated with mortality, independent of CRP and oxygenation levels, reinforcing its role as a prognostic tool in acute respiratory infections.[10]

The prognostic value of HGS appears to be robust across various populations, including patients with sepsis, chronic kidney disease, and cardiac conditions. A systematic review and meta-analysis involving over 16,000 dialysis patients showed that low HGS increased the risk of all-cause mortality by nearly two-fold.[11] In community-dwelling adults, large cohort studies have repeatedly confirmed that lower HGS is associated with higher mortality, even after adjusting for demographic and socioeconomic confounders.[12,13]

Lamers et al.'s study examined the mortality of hospitalized geriatric patients and recorded hand grip strength using a hand dynamometer. The study evaluated 302 patients and found that muscle strength and muscle mass were associated with mortality.[14] Hu X et al.'s study examined 453 participants and found, consistent with the literature, a higher mortality risk in patients with sarcopenia.[15]

Saiphoklang et al.'s study evaluated patients in intensive care units who were ventilated. Handgrip strength yielded significant predictive value for extubation failure in mechanically ventilated patients, and reintubation rates were higher in patients with poor handgrip strength.[16]

Jeong W et al.'s study, however, obtained results with a high number of cases and long-term follow-up. Data from 9,102 participants were analyzed between 2006 and 2018. The study examined the relationship between handgrip strength and all causes of mortality. The study found that handgrip strength was associated with the risk of all-cause mortality.[17,18]

Physiologically, HGS reflects integrated neuromuscular, metabolic, and immune functions, making it a sensitive marker of resilience under critical illness stress. ICU-acquired weakness, often driven by systemic inflammation, mitochondrial dysfunction, and immobility, can develop rapidly and is associated with long-term disability and death.[9,19] The ease, reproducibility, and non-invasive nature of HGS measurement offer a practical advantage over many biochemical markers that require laboratory processing and are affected by fluid shifts, hemolysis, or acute-phase response.

From a clinical perspective, the simplicity and feasibility of HGS measurement make it a strong candidate for incorporation into ICU triage and monitoring protocols. Its predictive strength may help prioritize nutritional and rehabilitative interventions or inform discussions around prognosis with families. Moreover, in resource-limited settings, HGS can provide a low-cost alternative to complex scoring systems or advanced biomarkers.

4.1. Strengths and Limitations

Strengths

- Prospective design: The study prospectively assessed handgrip strength at a standardized time point (within 24 h of ICU admission), minimizing recall and measurement bias.
- Robust statistical modeling: The use of penalized logistic regression with internal bootstrap validation enhanced model reliability and mitigated the risks of overfitting and quasi-separation.
- Multidimensional data: Simultaneous analysis of inflammatory (CRP), metabolic (urea and creatinine), and clinical variables (delirium and inotrope use) enabled comprehensive adjustment for potential confounders.
- Clinical applicability: HGS was measured using a portable dynamometer following standardized protocols, which supports reproducibility and real-world implementation in diverse ICU settings.

Limitations

- Selection bias: Patients unable to cooperate with HGS assessment due to sedation, neurological impairment, or severe agitation were excluded, potentially biasing the sample toward less critically impaired individuals.
- Single-center study: The study was conducted at a single tertiary care center, which may limit its generalizability to different hospital systems, geographic regions, or patient populations.
- Lack of pre-ICU functional data: Baseline frailty or sarcopenia prior to ICU admission was not formally assessed, which may have influenced HGS and confounded its prognostic interpretation.
- No longitudinal muscle monitoring: HGS was measured only at admission, and serial measurements could offer additional insight into the trajectory and response to interventions.
- Data on scoring systems like the Apache scale, which were available at the time of admission, were missing and therefore not included in the study.
- HGS was measured only at admission, and serial measurements could offer additional insight into the trajectory and response to interventions.
- Finally, illness severity scores (e.g., APACHE II) at the time of admission were not consistently available for all patients and, therefore, could not be included in the study

5. Conclusion

This prospective cohort study demonstrated that HGS measured within 24 h of ICU admission is a powerful and independent predictor of in-hospital mortality among critically ill adults. The robust inverse association between HGS and mortality persisted after adjusting for age, comorbidities, inflammatory markers, renal function, and clinical status, with patients in the lowest HGS tertile exhibiting an exceptionally high risk of death.

These findings highlight the clinical utility of HGS as a rapid, non-invasive, and low-cost tool for early risk stratification in intensive care settings. Incorporating HGS into ICU admission protocols may support more individualized decision-making, facilitate early intervention planning, and improve prognostic discussions with patients and their families.

Future studies should explore whether interventions targeting mus-

cle preservation or enhancement can improve outcomes in patients identified as high-risk with low HGS. Additionally, the validation of optimal cutoff values for ICU populations and their integration into prognostic scoring systems warrants further investigation.

5.1. Implications for Practice

- Early risk stratification: Handgrip strength (HGS) provides a rapid and objective method for identifying ICU patients at high risk of in-hospital mortality within 24 hours of admission. Integrating HGS into early clinical assessments may enable more proactive and tailored interventions.
- Low-cost, scalable tool: Unlike advanced biomarkers or imaging modalities, HGS measurement is simple, inexpensive, and feasible across all care settings, including resource-limited ICUs.
- Guiding multidisciplinary care: Patients with low HGS may benefit from early referral to nutrition, physiotherapy, and rehabilitation. HGS can serve as a trigger point for initiating muscle-preserving strategy.
- Enhanced prognostic discussions: HGS results may facilitate clearer communication with patients and families regarding prognosis, goals of care, and discharge planning.
- Monitoring treatment response: Serial HGS measurements could be used to monitor patient recovery or response to interventions targeting muscle mass and function.

Statement of ethics

The study protocol was approved by the Institutional Review Board(Bursa City Hospital) of the participating tertiary care center (Approval Date: Aug 21, 2024; Decision No 2024-13/1) and conducted in accordance with the principles of the Declaration of Helsinki. Written informed consent was obtained from all participants or their legally authorized representatives prior to their enrollment.

genAI

No artificial intelligence-based tools or generative AI technologies were used in this study. The entire content of the manuscript was originally prepared, reviewed, and approved by both authors.

Funding

This research received no specific grant from any funding agency in the public, commercial, or not-for-profit sectors.

Conflict of interest statement

The authors declare that they have no conflict of interest.

Availability of data and materials

The datasets used and/or analyzed during the current study are available from the corresponding author upon reasonable request.

Author contributions

NY is the major contributor in writing the manuscript. NY, NK, MDO involved in the design and conception of the study. NY, NK, MDO are involved in the collection of the data and clinical follow-up of the patients. All authors read and approved the final manuscript.

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