



Associations of energy, protein, and zinc intake adequacy with SOFA scores and length of hospital stay in patients with major burns at Ngoerah General Hospital, Denpasar

Hubungan kecukupan asupan energi, protein, dan seng dengan skor SOFA dan lama rawat inap pada pasien luka bakar mayor di RS Ngoerah, Denpasar

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Abstract

Major burn injuries induce hypermetabolic and hypercatabolic responses that increase nutritional requirements. This retrospective cohort study aimed to evaluate the association between the adequacy of energy, protein, and zinc intake and the Sequential Organ Failure Assessment (SOFA) score and length of hospital stay in patients with major burns. Medical record data were obtained from patients treated at the Burn Unit of the Ngoerah General Hospital, Denpasar, between February 2025 and February 2026. Eligible patients were aged ≥ 17 years, had burns involving $\geq 20\%$ of the total body surface area, received enteral nutrition, and were hospitalized for at least three days. Multivariable analyses were performed using negative binomial regression for SOFA scores and a generalized linear model with a gamma distribution and log link for the length of hospital stay. A total of 150 patients were included in the analysis. Energy, protein, and zinc adequacy were achieved by 31.3%, 41.3%, and 90.0% of the patients, respectively. None of the nutritional adequacy measures were independently associated with the length of hospital stay. Protein adequacy (adjusted IRR, 0.196; 95% CI, 0.038–0.999; $P = 0.049$) and zinc adequacy (adjusted IRR, 0.043; 95% CI, 0.017–0.109; $P < .001$) were independently associated with lower SOFA scores. In conclusion, adequate protein and zinc intakes were associated with lower SOFA scores; however, causality cannot be inferred from this retrospective study design. Prospective studies with temporally defined nutritional exposure are needed.

Keywords: SOFA score, burns, energy intake, organ dysfunction, protein intake, zinc

Abstrak

Luka bakar mayor memicu respons hipermetabolik dan hiperkatabolik yang meningkatkan kebutuhan nutrisi. Penelitian kohort retrospektif ini mengevaluasi hubungan kecukupan asupan energi, protein, dan seng dengan skor Sequential Organ Failure Assessment (SOFA) dan lama rawat inap pada pasien luka bakar mayor. Data rekam medis diperoleh dari pasien yang dirawat di Unit Luka Bakar RS Ngoerah, Denpasar, pada Februari 2025 hingga Februari 2026. Kriteria inklusi meliputi usia ≥ 17 tahun, luas luka bakar $\geq 20\%$ total body surface area, pemberian nutrisi enteral, dan lama rawat minimal 3 hari. Analisis multivariat dilakukan menggunakan regresi binomial negatif untuk skor SOFA dan generalized linear model (GLM) dengan distribusi gamma serta fungsi hubungan (link function) log untuk lama rawat inap. Sebanyak 150 pasien dianalisis. Kecukupan energi, protein, dan seng tercapai masing-

masing pada 31,3%, 41,3%, dan 90,0% pasien. Tidak ada indikator kecukupan nutrisi yang berhubungan secara independen dengan lama rawat inap. Kecukupan protein (adjusted IRR = 0,196; 95% CI 0,038–0,999; $p = 0,049$) dan seng (adjusted IRR = 0,043; 95% CI 0,017–0,109; $p < 0,001$) berhubungan secara independen dengan skor SOFA yang lebih rendah. Kesimpulan, kecukupan asupan protein dan seng berhubungan dengan skor SOFA yang lebih rendah; namun, hubungan kausal tidak dapat disimpulkan dari penelitian retrospektif ini. Penelitian prospektif dengan paparan nutrisi yang ditetapkan secara temporal diperlukan.

Kata Kunci: Skor SOFA, seng, luka bakar, asupan energi, asupan protein, disfungsi organ, zink

Introduction

Burn injuries may cause metabolic instability and immune dysfunction (Burgess et al., 2022; Farahat et al., 2026; Knuth et al., 2021). Major burns are characterized by a large total body surface area (TBSA) involvement and are accompanied by systemic inflammatory, endocrine, and metabolic responses (Żwieręto et al., 2023). Following severe thermal injury, the release of catecholamines, cortisol, glucagon, and proinflammatory cytokines accelerates the resting energy expenditure, protein catabolism, insulin resistance, and lean body mass loss (Li et al., 2024; Mulder et al., 2024; Nunez & Clark, 2023). These changes make nutritional management a central component of burn care because inadequate nutritional intake may impair immune defense, delay wound healing, increase infection risk, and worsen clinical outcomes (Jeschke et al., 2020; Shields & Nakakura, 2023).

The burden of burn injuries is substantial worldwide. Recent global estimates indicate that major burns continue to contribute significantly to morbidity, mortality, disability, and healthcare utilization, particularly in low- and middle-income countries (Lee et al., 2025). Mortality and complications are strongly influenced by the burn extent, age, inhalation injury, infection, and quality of early supportive care (Foppiani et al., 2024). Among these complications, sepsis is one of the most important causes of deterioration in patients with burns (Boehm & Menke, 2021). Loss of the skin barrier, immune dysregulation, invasive procedures, prolonged hospitalization, and repeated wound manipulation increase susceptibility to infection and sepsis (Țânțu et al., 2026). Recent reviews and cohort studies have emphasized that sepsis in burn care is associated with organ dysfunction, longer

hospital stays, and increased mortality (Dvorak et al., 2021; Tedesco et al., 2025). Therefore, early identification of modifiable factors that may reduce organ dysfunction and improve recovery is clinically important.

Nutritional adequacy is a modifiable aspect of burn management (Clark et al., 2017). Energy intake is required to meet increased metabolic demand and prevent excessive catabolism (Shields & Nakakura, 2023). Protein intake is essential for collagen synthesis, immune cell function, acute-phase protein production, preservation of muscle mass, and wound repair (Qinyuan et al., 2026; Wang et al., 2022). However, achieving energy and protein targets in patients with burns is often difficult because enteral feeding may be interrupted by surgery, procedures, gastrointestinal intolerance, hemodynamic instability, or clinical deterioration. Chourdakis et al. (2020) showed that optimal delivery of nutritional therapy remains challenging even in specialized burn centers. Similarly, recent implementation studies suggest that structured enteral nutrition protocols may improve nutritional delivery in critically ill burn patients; however, real-world barriers remain (Chourdakis et al., 2020; Jutba et al., 2024).

In addition to macronutrients, zinc is an important micronutrient for burn recovery. Zinc contributes to epithelial regeneration, DNA and RNA synthesis, antioxidant defense, immune regulation and wound healing. In major burns, zinc loss may increase through wound exudate, urine, and systemic inflammatory redistribution, making zinc adequacy clinically relevant in this context. A recent systematic review and meta-analysis reported the potential benefits of zinc on wound healing outcomes, although burn-specific clinical evidence remains heterogeneous (Arribas Lopez et al., 2025). This suggests that zinc should be considered as part of a

comprehensive nutritional assessment rather than as an isolated intervention.

In Indonesia, evidence regarding nutritional intake adequacy among patients with major burns remains limited. Although international guidelines recommend meeting energy, protein, and micronutrient requirements to support recovery, little is known about the extent to which these nutritional targets are achieved in Indonesian burn centers or whether nutritional adequacy is associated with clinically relevant outcomes in this population. Funding Acknowledgments In particular, no previous Indonesian study has comprehensively evaluated the association between energy, protein, and zinc intake adequacy and organ dysfunction and length of hospital stay in patients with major burns.

Sequential Organ Failure Assessment (SOFA) score and hospital length of stay were selected as the primary clinical outcomes because they reflect early organ dysfunction and healthcare resource utilization, respectively, and are commonly used indicators of disease severity and recovery in critically ill burn patients.

Therefore, this study aimed to explore the association between the adequacy of energy, protein, and zinc intake with the SOFA score and length of hospital stay among patients with major burns treated at the Burn Unit of Ngoerah Hospital, Denpasar. The primary outcome was organ dysfunction assessed using the Sequential Organ Failure Assessment (SOFA) score, and the secondary outcome was the length of hospital stay. We hypothesized that greater nutritional adequacy is associated with lower SOFA scores. Because nutritional adequacy may change throughout hospitalization and length of stay is influenced by multiple clinical factors, the analysis of length of stay was considered exploratory rather than hypothesis driven.

Methods

Design

This was a retrospective cohort study using secondary data obtained from electronic medical records. This study included patients with major burns who were treated at the Burn Unit of Ngoerah Hospital, Denpasar, Indonesia, between February 2025 and February 2026. Following ethics approval, medical records were accessed and data were extracted retrospectively from June to July 2026 for analysis

Population and Sample

The study population comprised all patients with major burns treated at the Burn Unit of Ngoerah Hospital.

Sampling was performed using a total sampling technique, in which all eligible patients during the study period were included in the study. In this study, 150 patients met the eligibility criteria and were analyzed in this study. Of the 150 patients, 18 had SOFA scores greater than zero. Patients were included if they were aged ≥ 17 years, had major burns defined as total body surface area involvement of at least 20%, received enteral nutrition, and were hospitalized for at least three days. Patients were excluded if their medical record data were incomplete; if they had unstable comorbid diseases that substantially affected nutritional metabolism, such as advanced malignancy or end-stage kidney disease; or if they had severe gastrointestinal disorders affecting enteral nutrition tolerance, such as bowel obstruction or short bowel syndrome. The participant selection process is shown in Figure 1.

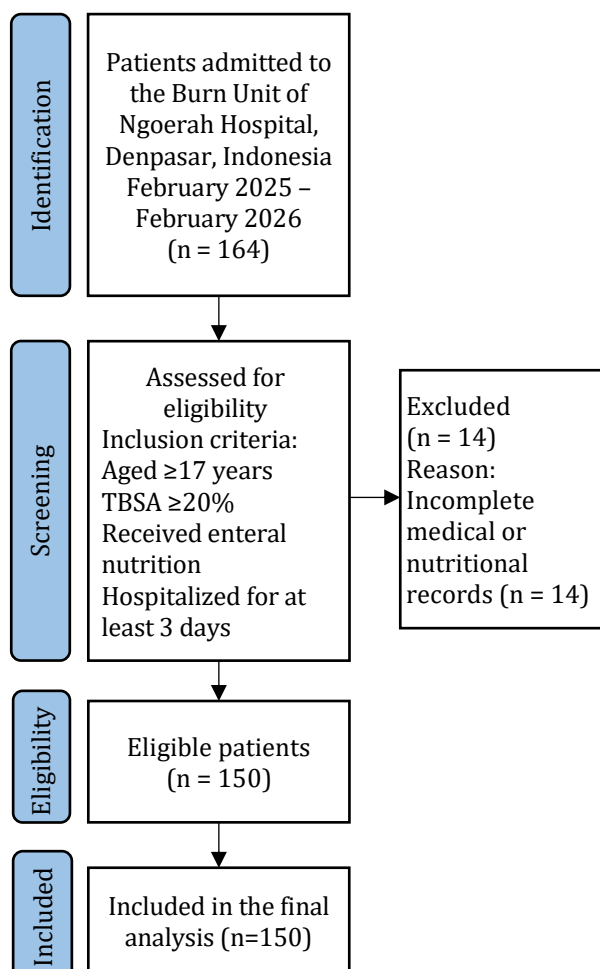


Figure 1. Flow diagram of participant selection

Variables and Measurements

The independent variables were the adequacy of energy, protein, and Zn intake. The dependent variables were the Sequential Organ Failure Assessment (SOFA) score and length of hospital stay. Potential confounding variables included age, comorbidities, inhalation injury, and total body surface area burned (TBSA).

Sepsis was defined according to the Sepsis-3 criteria as a suspected or documented infection accompanied by an acute increase in the Sequential Organ Failure Assessment (SOFA) score of ≥ 2 points (Singer et al., 2016). SOFA scores were calculated from routinely collected clinical and laboratory data documented in the electronic medical records, including the respiratory, coagulation, liver, cardiovascular, neurological, and renal components using the standard SOFA scoring system. The SOFA score was assessed by an anesthesiologist. Patients with insufficient data were excluded. The highest SOFA score recorded during the first seven days of hospitalization was used for the analysis. Energy requirements were estimated using the Xie formula according to the institutional burn nutrition protocol: total energy requirement (kcal/day) = $(1,000 \times \text{body surface area [m}^2]) + (25 \times \text{percentage of total body surface area burned [\%TBSA]})$. Body surface area was calculated as $\sqrt{[(\sqrt{\text{height (cm)}} \times \text{body weight (kg)})/3,600]}$ (Xie et al., 1993). Actual body weight was used to estimate the body surface area and daily nutrition requirements. Protein and zinc requirements were determined according to the Clinical Practice Guideline for Burn Patients by Ngoerah General Hospital, with protein requirements set at 1.5–2.0 g/kg/day and zinc requirements at 40 mg/day (Ngoerah Hospital, 2023). The lower target (1.5 g/kg/day) was applied to clinically stable patients, whereas the higher target (2.0 g/kg/day) was used for patients with extensive burns or greater metabolic stress, according to the treating physician's clinical judgment.

Nutritional intake was calculated as the average daily intake during the first seven days of hospitalization. For patients hospitalized for fewer than seven days, the average daily intake was calculated based on the available hospitalization period. Daily energy, protein, and zinc intakes were obtained from nutrition records, summed over the observation period, and divided by the number of days observed.

The average daily intake was then compared with the estimated individual requirement and expressed as a percentage of the requirement. Nutritional intake was classified as adequate when the average intake achieved $\geq 80\%$ of the estimated requirement and inadequate when it was $< 80\%$ (Suryaningsih et al., 2025).

The length of hospital stay was calculated from the date of hospital admission to the date of discharge or in-hospital death. In the primary analysis, patients who died during hospitalization were retained, and the date of death was considered the end of hospitalization. Because in-hospital death may truncate the observed length of hospital stay and potentially bias its association with nutritional adequacy, a sensitivity analysis restricted to patients who were discharged alive was performed using the same model specification.

Data Collection and Processing

All patients admitted to the Burn Unit of Ngoerah General Hospital between February 2025 and February 2026 were screened for eligibility using electronic medical records. During the study period, 164 patients met the initial screening criteria for inclusion. Fourteen patients were excluded because of incomplete medical or nutritional records, resulting in a final analytical sample of 150. The participant selection process is presented in a study flow diagram (Figure 1).

Data were collected retrospectively from admission until hospital discharge or in-hospital death for each patient. Demographic characteristics, burn severity, comorbidities, inhalation injury, nutritional intake, sepsis status, SOFA score, length of hospital stay, and mortality were obtained from electronic medical records and nutrition records.

The data completeness was assessed before the analysis. Patients with incomplete data for the primary exposure or outcome variables were excluded using complete case analysis. No imputations were performed for missing data.

Energy, protein, and zinc intakes were obtained from daily nutrition records and calculated based on the type, volume, and composition of all nutritional products administered during hospitalization. Energy and protein intakes included contributions from enteral formulas and any documented oral or parenteral nutrition. Zinc intake included zinc

contained in enteral formulas, oral diets or oral nutritional supplements, parenteral nutrition or multitrace-element preparations, and separately prescribed zinc supplements. For each zinc-containing product, the formulation, manufacturer-reported zinc content, administered dose, route, frequency, and duration were noted. All zinc values were converted to milligrams of elemental zinc per day prior to analysis. For zinc salts, the amount of elemental zinc was calculated from the product composition rather than from the total salt weight; for example, 220 mg of zinc sulfate provides approximately 50 mg of elemental zinc.

Nutrient intake was analyzed using NutriSurvey 2007 and supplemented with product-label composition data when a commercial formula or supplement was unavailable in the software database. The mean daily intake was calculated over the nutritional observation period and divided by the corresponding calculated requirement as follows:

Nutritional adequacy (%)

$$= \frac{\text{mean daily intake}}{\text{daily nutritional requirement}} \times 100$$

Statistical analysis

Categorical variables are presented as frequencies and percentages. Numerical variables are presented as mean and standard deviation if normally distributed, or median and interquartile range (IQR) if not normally distributed. Data normality was assessed using the Kolmogorov–Smirnov test.

Bivariate analysis was performed using the independent-samples t-test for normally distributed numerical data or the Mann–Whitney U test for non-normally distributed data. For multivariate analysis, because the SOFA score showed an overdispersed count distribution, negative binomial regression with a log link function was used to evaluate the association between nutritional intake adequacy and SOFA score after adjustment for age, burn size, comorbidity, and inhalation injury. Length of hospital stay was analyzed using a generalized linear model with a gamma distribution and log link function, after adjusting for the same potential confounders. Because in-hospital death could truncate the observed length of hospital

stay, a sensitivity analysis restricted to patients discharged alive was performed using the same model specifications. Results from the negative binomial regression were reported as adjusted incidence rate ratios (IRRs), while results from the gamma regression were reported as adjusted ratios of expected length of hospital stay, both with 95% confidence intervals and P values. Model fit was evaluated using the Pearson chi-square/degrees of freedom ratio, deviance statistics, and Akaike Information Criterion (AIC). Multicollinearity was assessed using variance inflation factors (VIFs), and the model residuals were inspected to identify potential outliers or influential observations. All statistical tests were two-sided, and a P-value < .05 was considered statistically significant. All statistical analyses were performed using the Statistical Package for the Social Sciences (SPSS) version 26.

Ethical considerations

This study was approved by the Research Ethics Committee of the Faculty of Medicine, Universitas Udayana, Denpasar, Indonesia (approval number: 2503/UN14.2.2).VII.14/LT/2026. Because of the retrospective design and use of de-identified medical record data, the requirement for informed consent was waived by the Ethics Committee. Ethical approval was obtained prior to data extraction and analysis. Access to electronic medical records was limited to the research team, and all data were anonymized and stored in a password-protected database accessible only to the investigators.

Result and Discussion

A total of 150 patients with major burns were included in this study. The median age was 39 years (IQR, 25–55 years), and 57.3% of the patients were male. The mean TBSA was 28.78% ± 21.96%. Inhalation injury was found in 27.3% of the patients, and comorbidity was present in 25.3%.

Energy and protein adequacy remained suboptimal, with only 31.3% and 41.3% of patients achieving adequate intakes, respectively. In contrast, zinc adequacy was achieved in 90.0% of the patients. Sepsis was documented in 12.0% of patients, the median SOFA score was 0, and the median length of hospital stay was 6.5 days.

Table 1. Baseline characteristics of the study population (n= 150)

Variable	Value
Age, years, median (IQR)	39 (25–55)
Male sex	86 (57.3%)
BMI, kg/m ² , mean ± SD	23.81 ± 4.98
TBSA, %, mean ± SD	28.78 ± 21.96
Inhalation injury	41 (27.3%)
Comorbidity	38 (25.3%)
Energy intake, % requirement, median (IQR)	57 (32–84)
Adequate energy intake (≥80%)	47 (31.3%)
Protein intake, % requirement, median (IQR)	73 (40–101)
Adequate protein intake (≥80%)	62 (41.3%)
Zinc intake, % requirement, median (IQR)	168.4 (137.15–206.9)
Adequate zinc intake (≥80%)	135 (90.0%)
SOFA score, median (IQR)	0 (0–0)

Variable	Value
<2	132 (88.0%)
≥2	18 (12.0%)
Length of hospital stay, days, median (IQR)	6.5 (3–9)
<7 days	75 (50.0%)
≥7 days	75 (50.0%)
Mortality	38 (25.3%)

BMI, Body Mass Index; TBSA, Total Body Surface Area; SD, standard deviation; SOFA, Sequential Organ Failure Assessment.

The length of hospital stay differed significantly according to protein adequacy in the bivariable analysis ($p = 0.013$), whereas differences according to energy and zinc adequacy were not statistically significant. The SOFA score differed significantly according to energy, protein, and zinc adequacy (Table 2).

Table 2. Length of hospital stay and SOFA score according to nutritional adequacy

Nutritional variable	Category	Length of hospital stay (n=150)	p-value	SOFA score (n=150)	p-value
Energy	Adequate	7 (5–9)	0.206	0 (0–0)	0.002
	Inadequate	5 (3–10)		0 (0–0)	
Protein	Adequate	7 (4.75–10)	0.013	0 (0–0)	0.001
	Inadequate	4.5 (3–8)		0 (0–0)	
Zinc	Adequate	7 (3–10)	0.318	0 (0–0)	<0.001
	Inadequate	4 (3–8)		0 (10–12)	

*P values were obtained using the Mann–Whitney U test, Data are presented as median (IQR). Length of stay was expressed in days.

In the primary multivariable analysis, protein inadequacy was associated with a longer expected length of hospital stay (adjusted ratio 1.405; 95% CI 1.010–1.954; $p = 0.044$), whereas energy inadequacy, zinc inadequacy, age, burn size, comorbidity, and inhalation injury were not significantly associated with length of stay. For SOFA score, protein adequacy, zinc adequacy, age, TBSA, and inhalation injury were independently associated with SOFA score,

whereas comorbidity was not. The effect of energy adequacy could not be estimated because of the sparse outcome distribution (Table 3). In the sensitivity analysis restricted to patients discharged alive, the association between protein inadequacy and length of stay was attenuated and no longer statistically significant, whereas burn size remained significantly associated with a longer length of stay (Table 4).

Table 3. Multivariable analysis of factors associated with length of hospital stay and SOFA score

Variable	Adjusted Effect Estimate	95% CI	p-value
Length of hospital stay, adjusted ratio			
Energy inadequacy	0.841	0.593–1.194	0.332
Protein inadequacy	1.405	1.010–1.954	0.044
Zinc inadequacy	1.226	0.871–1.726	0.242
Age	1.006	1.000–1.012	0.054
Burn size	1.005	0.999–1.010	0.100
Comorbidity	1.029	0.809–1.309	0.816
Inhalation injury	0.900	0.715–1.133	0.371

SOFA score, adjusted IRR			
Energy adequacy	NE	NE	NE
Protein adequacy	0.196	0.038–0.999	0.049
Zinc adequacy	0.043	0.017–0.109	<0.001
Age	1.041	1.014–1.069	0.003
Burn size	1.057	1.024–1.090	<0.001
Comorbidity	2.331	0.873–6.222	0.091
Inhalation injury	8.828	1.835–41.973	0.007

*Length of hospital stay was analyzed using a generalized linear model (gamma, log link; $n = 150$), and the SOFA score was analyzed using negative binomial regression (log link; $n = 150$). Both models were adjusted for age, burn size, comorbidities, and inhalation injury. Reference categories were adequate nutritional intake, no comorbidity, and no inhalation injury. Model fit: GLM gamma, Pearson $\chi^2/df = 0.411$, Deviance/ $df = 0.337$; negative binomial, Pearson $\chi^2/df = 3.187$. CI, confidence interval; IRR, incidence rate ratio; NE, not estimable. The effect estimate for energy adequacy could not be obtained because of sparse outcome distribution and lack of variability in SOFA scores among patients with adequate energy intake.

Table 4. Sensitivity Analysis of factors associated with length of stay ($n=112$)

Variable	Adjusted Effect Estimate	95% CI	p-value
Length of stay, adjusted ratio			
Energy adequacy	0.858	0.610–1.208	0.380
Protein adequacy	1.349	0.969–1.878	0.076
Zinc adequacy	1.962	0.654–5.895	0.229
Age	1.007	0.999–1.015	0.079
Burn size	1.013	1.006–1.020	<0.001
Comorbidity	1.119	0.845–1.480	0.435
Inhalation injury	0.978	0.755–1.267	0.866

* Generalized linear model (gamma distribution, log link), adjusted for age, burn size, comorbidities, and inhalation injury. The analysis was restricted to patients who were discharged alive ($n = 112$). Reference categories were adequate nutritional intake, no comorbidity, and no inhalation injury. Model fit: Pearson $\chi^2/df = 0.418$; Deviance/ $df = 0.340$. CI: confidence interval.

This study found that achieving energy and protein targets was difficult in patients with major burns. This finding is consistent with the pathophysiology of major burn injuries, in which hypermetabolism and hypercatabolism substantially increase nutritional requirements. Previous evidence also indicates that achieving optimal nutritional targets in critically ill burn patients remains challenging, even in specialized burn centers (Chourdakis et al., 2020). In this study, inadequate energy and protein intakes may have been influenced by interruptions in enteral feeding, procedures, gastrointestinal intolerance, and clinical instability during hospitalization.

Protein adequacy was associated with the SOFA score after adjustment for potential confounders. This finding is biologically plausible because protein is required for collagen synthesis, immune function, acute-phase protein production, muscle preservation and wound healing. A systematic review by Hampton et al. (2021) emphasized that a higher protein intake is commonly recommended in burn care to counteract catabolism, although

clinical evidence regarding its effect on outcomes remains heterogeneous (Hampton et al., 2021). However, the association observed in the present study should be interpreted cautiously because the effect estimate was imprecise, with a wide 95% confidence interval (CI) and borderline statistical significance. Therefore, this finding should be considered exploratory and hypothesis-generating, rather than evidence that adequate protein intake independently improves organ dysfunction.

Zinc adequacy was also independently associated with a lower SOFA score. The markedly higher zinc adequacy than energy or protein adequacy may reflect protocolized zinc supplementation that can be administered independently of enteral feeding volume and may, therefore, be less affected by feeding interruptions or gastrointestinal intolerance. This interpretation requires confirmation from the hospital supplementation protocol and source records. Zinc plays an important role in epithelial regeneration, DNA synthesis, antioxidant defense, immune regulation, and tissue repair. In patients with burns, zinc loss

may increase through wound exudates, urine, and systemic inflammatory responses. This finding is consistent with a systematic review and meta-analysis (Arribas Lopez et al., 2025), which reported that zinc may improve wound healing outcomes. However, Olson et al. found that normalization of serum zinc levels was not consistently associated with better clinical outcomes in patients with severe burns (Olson et al., 2020). Therefore, the present findings should be interpreted as an association between zinc intake adequacy and lower organ dysfunction, not as definitive evidence that zinc supplementation alone improves outcomes.

In the present study, energy intake was not significantly associated with length of hospital stay, in contrast to the findings of Sinaga et al. (2022), who reported a significant inverse correlation between energy intake and length of stay at the Burn Unit of Cipto Mangunkusumo Hospital ($r = -0.25$, $p = 0.03$). This discrepancy is likely attributable to differences in the analytical approach, study populations, definitions of nutritional adequacy, timing and duration of nutritional exposure assessment, burn severity, and adjustments for potential confounding factors. Sinaga et al. used correlation analysis, whereas the present study employed group comparisons followed by multivariable regression analysis adjusted for confounding factors (Sinaga et al., 2022).

Similar considerations apply to protein intake. Patients with adequate protein intake had a longer median length of hospital stay than those with inadequate protein intake. This finding should not be interpreted as evidence that achieving nutritional adequacy prolongs the hospitalization period. Instead, this is more likely explained by reverse causality and survivor bias. As nutritional targets in patients with major burns are often reached progressively over the course of treatment, patients who survive longer and remain hospitalized have more opportunities to achieve adequate intake. Conversely, those with more severe illness may deteriorate rapidly or die before nutritional goals are attained.

Residual confounding by disease severity should be considered when interpreting these results. Although the multivariable analyses were adjusted for age, TBSA, inhalation injury, and comorbidities, other indicators of burn severity and clinical instability, including

baseline SOFA score, burn depth, baseline nutritional status, surgical interventions, mechanical ventilation, vasopressor use, infection status, and time to initiation of nutritional support, were not fully captured. Patients with more severe burns may experience prolonged shock, vasopressor use, mechanical ventilation, repeated surgical procedures, gastrointestinal intolerance, or interruptions to enteral feeding, all of which could reduce nutritional intake while independently increasing the risk of organ dysfunction. Consequently, the temporal relationship between nutritional adequacy and clinical outcomes cannot be determined. Therefore, protein and zinc adequacy may represent markers of greater hemodynamic stability, longer survival, fewer feeding interruptions, or overall higher quality of supportive care rather than independent protective exposures. Reverse causality is also possible, whereby patients with more severe illnesses were less likely to achieve nutritional targets because of their clinical condition. Furthermore, the large magnitude of the association observed for zinc adequacy should be interpreted cautiously because very few patients achieved adequate zinc intake, reducing the stability of the estimates and increasing their susceptibility to sparse-data bias and residual confounding. Age and TBSA were significantly associated with the SOFA score, supporting previous evidence that patient characteristics and injury severity remain major determinants of organ dysfunction in burn care. Tedesco et al. reported that sepsis and poor outcomes in patients with burns are strongly related to injury severity and clinical complications (Tedesco et al., 2025). Thus, nutritional adequacy should be viewed as an important supportive factor that interacts with but does not replace the dominant influence of burn severity.

This study has several limitations. First, the retrospective, single-center design limits the generalizability of the findings and precludes any causal inference. Second, only patients who received enteral nutrition and were hospitalized for at least three days were included, which may have introduced selection bias. Third, nutritional intake was obtained from medical records and may not fully represent the actual intake if feeding interruptions were not completely documented. The assessment of nutritional adequacy over the course of hospitalization

introduces the potential for reverse causality and survivor bias, as patients with longer survival and prolonged hospitalization have a greater opportunity to achieve nutritional targets. In addition, important confounders, including baseline SOFA score, burn depth, baseline nutritional status, surgical interventions, mechanical ventilation, vasopressor use, infection status, and time to initiation of nutritional support, were unavailable, leaving the possibility of substantial residual confounding factors. Averaging intake over as many as 7 days may also have obscured clinically important day-to-day variations, particularly during the early resuscitation phase, and overlapping exposure and outcome windows may have increased temporal ambiguity. In addition, missing data resulting from incomplete medical records led to the exclusion of some patients from the analysis, and selection bias cannot be excluded. The large proportion of zero SOFA scores and the very small number of patients with inadequate zinc intake may have reduced the stability of the regression estimates. Finally, zinc status was assessed based on intake adequacy rather than serum zinc levels, and the nutritional adequacy threshold of 80% was based on institutional practice and may not be universally applicable.

Overall, this study highlights the association between nutritional adequacy and organ dysfunction in patients with major burn injuries. Future prospective studies should evaluate nutritional exposures that clearly precede clinical outcomes, including serial nutritional intake, biochemical micronutrient status, inflammatory markers, wound healing, sepsis, and mortality.

Conclusion

Adequate protein and zinc intakes were associated with lower SOFA scores, whereas the association between energy adequacy and SOFA score could not be estimated. None of the nutritional adequacy measures were independently associated with the length of hospital stay. These findings are exploratory and should not be interpreted as evidence that nutritional adequacy reduces organ dysfunction independently. Prospective studies with temporally defined nutritional exposures and

interventional designs are needed to confirm these associations.

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