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ORIGINAL RESEARCH

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# Protein and energy intake in intensive care unit survivors during the first year of recovery: A descriptive cohort study

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## Abstract

**Background:** Many intensive care unit (ICU) survivors suffer long-term health issues that affect their quality of life. Nutrition inadequacy can limit their rehabilitation potential. This study investigates nutrition intake and support during ICU admission and recovery.

**Methods:** In this prospective cohort study, 81 adult ICU patients with stays ≥48 h were included. Data on dietary intake, feeding strategies, baseline and ICU characteristics, and 1-year outcomes (physical health and readmission rates) were collected. The number of patients achieving 1.2 gram per kilogram per day of protein and 25 kilocalories per kilogram per day at 3 months, 6 months, and 12 months after ICU admission was recorded. The impact of dietary supplementation during the year was assessed. Baseline characteristics, intake barriers, and rehabilitation's influence on nutrition intake at 12 months were evaluated, along with the effect of inadequate intake on outcomes.

**Results:** After 12 months, only 10% of 60 patients achieved 1.2 g/kg/day protein intake, whereas 28% reached the advised 25 kcal/kg/day energy target. Supplementary feeding significantly increased protein intake at 3, 6, and 12 months ($P = 0.003$, $P = 0.012$, and $P = 0.033$, respectively) and energy intake at 3 months ($P = 0.003$). A positive relation was found between female sex and energy intake at 12 months after ICU admission ($\beta = 4.145$; $P = 0.043$) and taste issues were independently associated with higher protein intake ($\beta = 0.363$; $P = 0.036$). However, achieving upper-quartile protein or energy intake did not translate into improved physical health outcomes.

**Conclusion:** Continuous and improved nutrition care is urgently needed to support patients in reaching nutrition adequacy.

KEYWORDS
critical illness, dietary intake, nutrition care, PICS, protein

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## CLINICAL RELEVANCY STATEMENT

Intensive care unit survivors often experience suboptimal protein and energy intake during the first year of recovery, impacting their potential for rehabilitation. Although dietary supplementation can enhance intake, the majority of patients do not reach nutrition targets throughout the year. This highlights the need for multidimensional aftercare to support patients in attaining nutrition adequacy to facilitate recovery.

## INTRODUCTION

Advances in intensive care medicine in the past decades have resulted in increased survival rates.[1] Still, many survivors of critical illness suffer from long-term health deficits and a reduced quality of life.[2–4] These health problems are described as the post–intensive care syndrome and can have various consequences, including increased healthcare utilization and reduced societal participation.[5–7]

Recovery after critical illness can be tedious or even fail to occur. The consequences of critical illness include, but are not limited to, severe catabolism, loss of muscle mass and function, overall weakness, and multiple organ dysfunction.[8,9] To illustrate, a recent 5-year follow-up of 433 intensive care unit (ICU) survivors observed that more than a third of patients experienced abnormal aerobic exercise capacity and reduced physical functioning, compared with that of a healthy sedentary control population.[10]

A key element that may limit the recovery potential of ICU patients during and after ICU admission is nutrition status. Previous research has indicated that a significant proportion of ICU patients is malnourished (38%–78%) or physically frail (30%).[11,12] Patients with impaired nutrition status at ICU admission, as for instance approximated by a low bioimpedance analysis (BIA) –derived phase angle, have a higher risk of 1-year mortality.[13] However, muscle loss associated with ICU admission may be reduced by providing adequate nutrition support during an ICU stay when combined with early mobilization.[14,15] To achieve this, protein adequacy during and after an ICU stay in particular may be essential in reducing catabolism in critical illness survivors.[16]

There are several opinion papers and reviews focused on nutrition strategies after an ICU stay, with protein targets for the recovery phase ranging from 1.2 to 2.5 g/kg/day, but data regarding dietary intake after ICU stay are lacking.[17,18] Therefore, we performed a prospective observational 12-month follow-up study in ICU patients with a length of stay (LOS) of at least 48 h from the Medical Center Leeuwarden in Fryslân, the Netherlands. The aim of this study was, first, to assess energy and protein intake during the ICU stay and the first year of recovery. Second, the impact of baseline characteristics, intake barriers, and rehabilitation on dietary intake was evaluated. Third, the relation between dietary intake and long-term outcomes was explored.

## METHODS

### Standard nutrition care practice

In this mixed ICU, a standard care protocol based on the international European Society for Clinical Nutrition and Metabolism (ESPEN) and American Society for Parenteral and Enteral Nutrition (ASPEN) guidelines is used to provide adequate nutrition support during and after ICU admission.[19,20] According to this protocol, patients at risk for malnutrition (expected LOS ≥48 h and/or enteral nutrition [EN] or exclusive parenteral nutrition [PN] at ICU admission) receive nutrition support led by nurses and a dedicated intensivist, which consists of the following steps: (1) assessing nutrition status by Simplified Nutritional Appetite Questionnaire score[21] or bioimpedance-derived phase angle[22]; (2) defining energy and protein requirements (1.2–1.5 g/kg/day protein intake; 25 kcal/kg/day energy intake); (3) defining the feeding route; (4) defining the necessary dietary supplementation (eg, thiamin [vitamin B complex] in case of suspected malnutrition); and (5) starting, stepwise increasing, and ending of nutrition support. As part of this standard protocol, in-hospital nutrition support is continued by a clinical dietitian after ICU discharge. This dedicated dietitian provides information regarding specific nutrition needs when a patient is discharged to home or a care facility. After 3 months, patients and their informal caretakers are invited to visit the specialized outpatient clinic where they are seen by a physical therapist, a dedicated ICU nurse, and an intensivist.

Throughout the hospital admission, dietary support is supervised by clinical dietitians and a hospital-wide team of nutrition experts. For specific cases (eg, the patient is discharged home with PN), follow-up by a registered dietitian is part of standard care. Otherwise, a request for dietary follow-up is included in the discharge communication to the general practitioner.

### Study design and population

This prospective, observational study was performed in the ICU ward of the main tertiary teaching hospital in the Frisian region in the northern part of the Netherlands, between May and November 2019. Adult patients admitted to the ICU with an ICU LOS of ≥48 h were asked to participate. The use of this cutoff value was based on our previously published research and aimed to exclude patients who were less severely ill, such as patients admitted for 1 or 2 days after elective surgery, per protocol, without serious complications, because this group may be at lower risk for long-term health problems.[2]

With approval of the local research ethics committee of the Medical Center Leeuwarden (Medisch Ethische Toetsingscommissie) - number: RTPO 1055), this study was conducted with a deferred consent procedure. If a patient was unable to provide consent during the baseline measurements because of, for example, sedation or delirium, they were asked when clinical evaluation indicated them fit to give an informed response.[23] Patients who died before written

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informed consent could be obtained, who had severe cognitive impairments after awakening (eg, postanoxic coma) or those for whom ICU mortality was inevitable were therefore not included.

### Data collection

Our primary outcomes were protein intake and energy intake at 12 months after ICU admission, determined by averaging the intake of two 24-h recalls of a normal weekday.[24] Our secondary outcomes were dietary intake at 3 and 6 months after ICU admission, swallowing or taste issues, use of dietary supplementation, visits to a registered dietitian or speech and language therapist (SLT), and participation in any form of rehabilitation during the year, determined by telephonic or in person interview. Nutrition-related outcomes (ie, ultrasound rectus femoris muscle layer thickness,[25] handgrip strength,[26] Morton Mobility Index score,[27] 6-min walking distance,[28] and BIA-derived phase angle[22]) were measured during a clinic or home visit at 12 months after ICU admission. Other outcomes, including baseline and ICU characteristics, dietary intake and feeding routes for the first 7 days of ICU admission, ICU and hospital readmissions, and 1-year mortality, were obtained retrospectively from hospital records.

A food processing application of the Dutch Nutritional Society (de Eetmeter, Voedingscentrum) was used to estimate energy and protein intake of the dietary recall data at 3, 6, and 12 months.[29] Dietary intake during ICU admission was obtained from patients' electronic data records (food registration lists and dietary consultation records). For food consumed out of the patient's own accord, hereafter referred to as oral diet (OD), standard digital food registration lists were used. The registration of EN, PN, or OD was recorded by a specialized ICU nurse or dietitian.

#### Missing data

Because the follow-up period of this study coincided with the start of the coronavirus disease 2019 (COVID-19) pandemic, which resulted in periods of lockdown and a reduced ability to perform research visits in the hospital, some data could not be collected. If possible, a researcher performed a home visit to secure the data collection when a research visit was not feasible. An overview of the amount of missing data can be found in Table S1. After data collection, all data were processed in accordance with the General Data Protection Regulation on a dedicated research drive within the hospital's digital storage system. All nondigital material (eg, interview reports) were stored in a secured research archive.

### Statistical analysis

All data were assessed for normality and visually inspected for quality assurance. Because most data were non-normally distributed, outcomes are displayed as median (interquartile range [IQR]) or *n* (%), depending on the variable type. Baseline and clinical characteristics are presented for the total study population. Between-group differences were tested with a Mann-Whitney *U* test or chi-square test, when appropriate. Two separate multiple linear regression analyses were conducted to explore the impact of clinically relevant predictor variables (age, biological sex, frailty score, severity of illness, participation in rehabilitation, altered taste, and swallowing difficulties) on distinct dependent variables, protein intake (grams per kilogram per day), and energy intake (kilocalories per day) after 12 months. In a post hoc analysis, differences in nutrition-related outcomes at 12-months after ICU stay were explored with a group comparison using Mann-Whitney *U* tests between patients who reached the upper quartile of protein and/or energy intake and patients who did not reach the upper quartile. Data were visualized using GraphPad Prism, version 9, for Windows (GraphPad Software). All statistical analyses were conducted using SPSS Statistics for Windows, version 27 (IBM).

## RESULTS

### Baseline and clinical characteristics

In total, 107 patients were found to be eligible to participate after the initial screening. Of these patients, 16 were excluded because of mortality before written informed consent could be obtained, and six patients with an expected LOS of >48 h were discharged within the first 2 days. Four patients declined participation during the informed consent procedure. Eighty-one patients participated in the follow-up period and were subsequently included in this study. The majority of patients were male (68%), with a median age of 69 (60–76) years. According to the Clinical Frailty Scale, 28% were prefrail at ICU admission, and all patients were severely ill (Acute Physiology And Chronic Health Evaluation III: 76 [IQR: 57–99]) (Table 1). Out of 81 patients, five (6%) did not survive until the end of the study period.

### Protein and energy intake during and after ICU

During and after ICU admission, the majority of patients did not reach the minimum protein (1.2 g/kg/day) or advised average energy (25 kcal/kg/day) targets (Figure 1; Table S2 for absolute values and valid percentages). At day 7 in the ICU, 32 patients (out of 36 still admitted) did not reach 1.2 g/kg protein intake, and 30 of them received <25 kcal/kg. In the post-ICU recovery period, median protein intake remained below the minimal intake target of 1.2 g/kg/day at all time points. After 12 months of recovery, six out of 60 patients managed to achieve protein adequacy, and 17 patients reached the advised energy target. Overall, 34%, 23%, and 38% of the population had a protein intake of <0.8 g/kg/day at 3, 6, and 12 months of follow-up, respectively. Considering those with an extremely low protein intake (<0.6 g/kg/day), these percentages were 14%, 9%, and 10%, respectively.

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**TABLE 1** Baseline characteristics.

| Baseline characteristics | Total (*N* = 81) |
|---|---|
| Age, median (IQR), years | 69 (60–76) |
| Sex, female, *n* (%) | 26 (32) |
| BMI, median (IQR), kg/m$^2$ | 27 (24–31) |
| Phase angle, median (IQR), degrees | 5.4 (4.3–6.4) |
| Admission type, *n* (%) | |
| Medical | 45 (56) |
| Acute surgical | 18 (22) |
| Elective surgical | 18 (22) |
| APACHE III score, median (IQR) | 76 (57–99) |
| CFS, median (IQR), 1–9 | 3 (2–4) |
| Nonfrail at admission, *n* (%) | 50 (62) |
| Prefrail at admission, *n* (%) | 23 (28) |
| Length of stay, median (IQR), days | |
| ICU | 5 (4–11) |
| Hospital | 15 (9–25) |
| Mechanical ventilation, median (IQR), days | 3 (1–6) |
| Renal replacement therapy in ICU, *n* (%) | 13 (16) |

Abbreviations: APACHE, Acute Physiology And Chronic Health Evaluation; BMI, body mass index; CFS, Clinical Frailty Scale; ICU, intensive care unit; IQR, interquartile range.

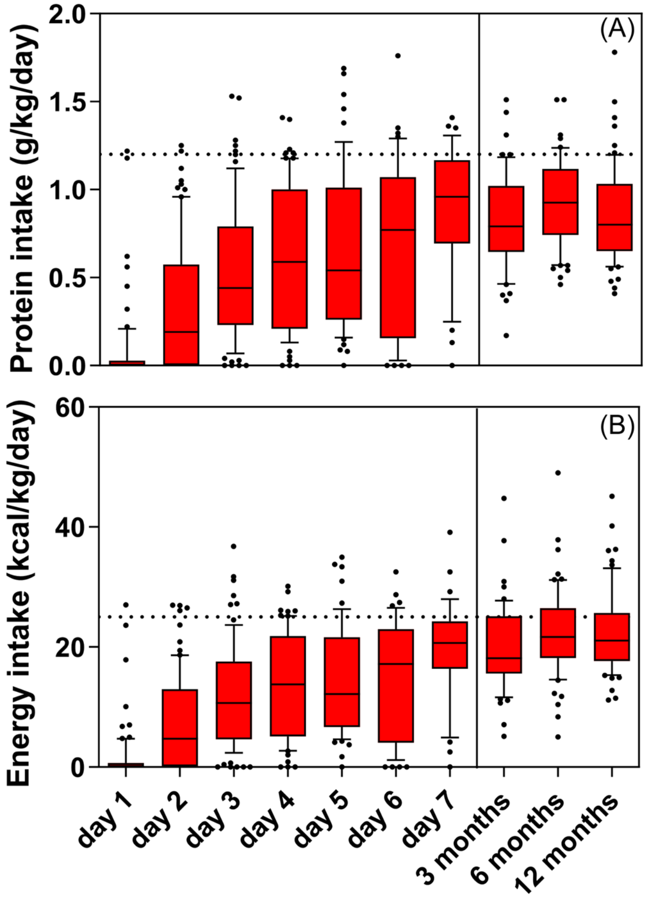


**FIGURE 1** Protein and energy intake during the first 7 days of intensive care unit (ICU) admission and at 3 months, 6 months, and 12 months after ICU admission, with the median and 10th to 90th percentile shown. The dotted horizontal lines indicate the (A) minimum protein goal of 1.2 g/kg/day and (B) average energy goal of 25 kcal/kg/day.[16]

## Feeding routes and dietary supplementation

During the first 7 days of ICU admission, EN/PN was the most commonly adopted feeding strategy. Out of 81 patients, 30% received any form of feeding on the first day of ICU admission, which increased to 75% from day 2 onwards. PN was administered to 11 patients during their ICU stays.

During recovery, the proportion of patients using supplementation to increase energy and/or protein intake was 15% at 3 months, 12% at 6 months, and 10% at 12 months. On average, supplementation provided them with 24–36 g of protein (29%–47% of total protein intake) and 450–775 kcal (24%–35% of total energy intake). One patient received PN throughout the year. Overall, patients using dietary supplements had a higher protein intake ($P = 0.003$, $P = 0.012$, and $P = 0.033$ at 3, 6, and 12 months, respectively) and higher energy intake after ICU admission ($P = 0.003$ at 3 months; Figure 2).

## Factors related to daily protein and energy intake

Fifty-eight patients participated in any form of rehabilitation activities, which varied from performing physical exercises at home to participating in a cardiac rehabilitation program. Taste and swallowing difficulties were reported by some patients throughout the year (taste: 28%, 16%, and 12% at 3, 6, and 12 months, respectively; swallowing: 16%, 7%, and 9% at 3, 6, and 12 months, respectively).

Multiple linear regression analyses yielded no statistically significant results for the overall regression model (protein intake: $F = 1.100$ [$P = 0.379$]; energy intake: $F = 0.880$ [$P = 0.530$]), and the $R^2$ values were 0.143 and 0.118, respectively. However, in the protein model, altered taste demonstrated significance, whereas biological sex was found to affect energy intake (Table 2). These findings indicated that patients with taste issues have a higher protein intake and female patients tend to have a higher energy intake at 12 months after ICU admission.

## Differences in nutrition-related outcomes at 12 months

Eighteen patients visited a registered dietitian during the 12 months after ICU admission, and three patients consulted an SLT at least once during the year. Patients in the upper quartile of at least one of

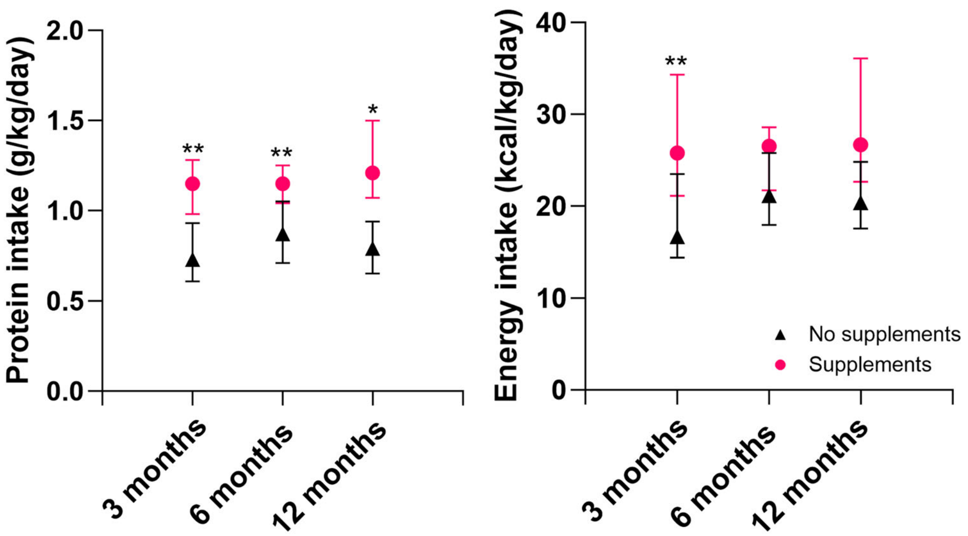


**FIGURE 2** Protein and energy intake at 3 months, 6 months, and 12 months after intensive care unit (ICU) admission for patients using supplements (red dot) or not using supplements (black triangle), shown in median and interquatile range. *$P < 0.05$; **$P < 0.01$.

**TABLE 2** Regression coefficients for predicting protein and energy intake per kilograms per day at 12 months after ICU admission.

| | Dependent 1: Protein intake | | | Dependent 2: Energy intake | | |
|---|---|---|---|---|---|---|
| Explanatory variables | Beta | 95% CI | *P* value | Beta | 95% CI | *P* value |
| Age at admission | −0.004 | −0.010 to 0.002 | 0.221 | −0.010 | −0.163 to 0.142 | 0.891 |
| Sex, female | 0.087 | −0.083 to 0.256 | 0.308 | 4.145 | 0.134–8.157 | 0.043 |
| CFS | −0.002 | −0.056 to 0.052 | 0.942 | 0.217 | −1.052 to 1.485 | 0.733 |
| APACHE III | 0.002 | −0.001 to 0.005 | 0.153 | 0.015 | −0.054 to 0.084 | 0.664 |
| Rehabilitation, yes | −0.034 | −0.237 to 0.169 | 0.740 | −2.665 | −7.470 to 2.140 | 0.270 |
| Taste issues, yes | 0.363 | 0.024–0.702 | 0.036 | 0.946 | −7.079 to 8.971 | 0.813 |
| Swallowing difficulties, yes | −0.237 | −0.596 to 0.121 | 0.189 | −1.847 | −10.328 to 6.635 | 0.663 |

Abbreviations: APACHE, Acute Physiology and Chronic Health Evaluation; CFS, Clinical Frailty Scale; 95% CI, confidence interval for beta.

the macronutrients visited an SLT more often. Thirty-five patients (43%) were readmitted to the medical center during follow-up. In addition, seven patients (8%) were readmitted to the ICU during the year. A total of 21 patients (24%) reached the upper quartile of energy and/or protein intake after 12 months, with the quartile starting at 1.0 g/kg/day protein and 26 kcal/kg/day. Besides a higher proportion of patients visiting an SLT during the year in the upper-quartile group, no differences were found in patient-centered outcomes (Table S3).

## DISCUSSION

This is the first study reporting on protein and energy intake during ICU recovery up to a year after ICU admission. In this prospective, descriptive cohort study, we show that the majority of ICU patients do not meet the lower limit of protein intake (1.2 g/kg/day) or the advised average daily energy intake (25 kcal/kg/day), as indicated by local protocol throughout the first year of recovery. Although dietary supplementation in the post-ICU period resulted in a higher protein intake at 3, 6, and 12 months and higher energy intake at 3 months after admission, only a small proportion visited a registered dietitian or SLT in the recovery period or used dietary supplements.

Overall, the evidence on dietary intake in the post-ICU recovery period is largely lacking. In a recent cohort study, energy and protein deficits during the hospitalization period were reported in ICU patients admitted with a traumatic brain injury.[30] Two other cohort studies showed patients did not meet estimated or measured energy and protein requirements in the general ward after ICU discharge, whereas patients receiving an OD were the most at risk.[31,32] Our study adds to the sparse body of post-ICU data, demonstrating that, in a significant proportion of ICU patients, nutrition intake is inadequate for up to 12 months after admission. Nevertheless, the impact of deficits during the post-ICU period remains unclear

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because of the complex relation between physiological adaptations to critical illness, frailty, and nutrition-related outcomes.

Although there are no clear guidelines on post-ICU protein intake, nutrition experts speculate intakes up to 2.5 g/kg/day may be necessary to support muscle regeneration and general recovery.[17] Furthermore, the traditional recommendation for protein intake for healthy elderly people is 1.0 g/kg/day, which increases depending on the level of physical activity.[33] Because this study portrays a relatively old ICU population, with a median age of 69 years, reaching nutrition targets may be even more relevant because sarcopenia and physical frailty are prevalent in this age category and management of these conditions can improve health outcomes and quality of life.[34] However, the impact of low nutrition intake on long-term, nutrition-related outcomes remains unclear. The evidence of protein interventions on physical health and performance is limited, possibly in part because of metabolic changes affecting nutrient intake and utilization.[35,36] For example, Chapple et al[37] showed a reduced capacity to use ingested protein despite normal digestion of protein and absorption of amino-acids. Further, because most patients in this study had a very low intake throughout the year, this may not have been sufficient to induce anabolism and recovery. Therefore, tailored nutrition plans considering factors like age, physical activity level, and physical frailty may be an essential part of rehabilitation after critical illness.

To illustrate, a large proportion of patients in our study participated in rehabilitation activities, but only a small group consulted a dietitian or SLT or used dietary supplements. However, taste and swallowing issues, fasting because of surgery, and feeding-tube consistency are recognized barriers.[38] In this study, taste issues and swallowing difficulties were reported by 12% and 9%, respectively, at 12 months, although underreporting because of the lack of a systematic screening may affect this.[39] Contrarily, the use of dietary supplementation significantly increased protein and energy intake during follow-up, and SLT consultations were higher in patients with more adequate intake. Improving nutrition support and addressing nutrition barriers in the post-ICU recovery period may therefore improve nutrition adequacy and ICU recovery.

This study is the first study investigating protein and energy intake in the ICU and during recovery. The personalized approach applied in this study enabled to minimize loss to follow-up, despite several restricting measures because of the ongoing COVID-19 pandemic (Table S1). This proportion is lower than what was reported in our previously conducted retrospective study, which used data collected at the standard care outpatient clinic.[2] There are some limitations to this study. Firstly, because of its small-scaled setup, generalization of the results should be done with caution. Also, we did not collect data on feeding intolerances, nutrition formulas used and intake barriers during the ICU stay, or dietary intake during the post-ICU hospitalization period. Information on dietary intake before ICU admission was lacking, because we were unable to collect these in the acute care setting. Finally, it is generally known that qualitative assessment methods of nutrition intake, like the 24-h dietary recall method, are prone to underreporting and overreporting,[40] which may have affected the post-ICU intake results.

# CONCLUSION

This study shows that protein and energy intake is below that of recommendations in the majority of ICU survivors in the ICU and during the first year of recovery. Long-term and improved nutrition care is urgently needed to support ICU patients in reaching nutrition adequacy during recovery.

## AUTHOR CONTRIBUTIONS

Lise F. E. Beumeler analyzed the results; Edith Visser, Hanneke Buter, Tim van Zutphen, Gerjan J. Navis, and E. Christiaan Boerma assisted in analyzing the results; Lise F. E. Beumeler, Edith Visser, Hanneke Buter, Tim van Zutphen, and E. Christiaan Boerma assisted in gathering data and helped draft the manuscript; Lise F. E. Beumeler, Edith Visser, Hanneke Buter, Tim van Zutphen, Gerjan J. Navis, and E. Christiaan Boerma wrote and corrected the manuscript; and all contributing authors read and approved the final manuscript.

## CONFLICT OF INTEREST STATEMENT

The authors declare no conflicts of interest.

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## SUPPORTING INFORMATION

Additional supporting information can be found online in the Supporting Information section at the end of this article.

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