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Original article

The impact of an individually tailored, stepwise nutrition protocol on energy and protein adequacy in post-ICU patients: The PROSPECT-II observational cohort study

Michelle C. Paulus [a,b], Imre W.K. Kouw [a,b], Nienke van Beek-Westeneng [b], Ilze de Leeuw [a], Evita C. van Lingen [b], Mirjam Holverda [a], Bert Strookappe [a], Arthur R.H. van Zanten [a,b,*]

[a] Department of Intensive Care Medicine & Research, Gelderse Vallei Hospital, Willy Brandtlaan 10, 6716 RP Ede, the Netherlands
[b] Division of Human Nutrition and Health, Nutritional Biology, Wageningen University & Research, HELIX (Building 124), Stippeneng 4, 6708 WE, Wageningen, the Netherlands

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SUMMARY

Background & aims: Adequate nutritional intake is suggested to be essential to support rehabilitation and clinical outcomes in intensive care unit (ICU) survivors. However, nutritional intake during the post-ICU rehabilitation period has often been reported to decrease drastically following ICU discharge, with the most significant deficit observed when transitioning to oral food intake. This study evaluates the effect of an individually tailored, stepwise nutrition protocol, aimed at closely matching daily oral and enteral tube feeding intake from ICU discharge to hospital discharge, on daily energy and protein intake levels in post-ICU patients.

Methods: A prospective, observational, single-centre cohort study was conducted at Gelderse Vallei Hospital, the Netherlands, among 70 adult post-ICU patients with an ICU stay of 72 h or longer who received enteral tube feeding at ICU discharge. An individually tailored, stepwise feeding protocol included the gradual reduction of enteral tube feeding, based on the contribution of actual oral food intake (on the previous day) to total prescribed targets, aiming to achieve ≥95 % of the daily prescribed energy and protein goals. Oral and enteral tube feeding intake was quantified daily using digital photography and food record charts. The primary outcomes, energy and protein intake levels (% adequacy to the prescribed goal), were assessed daily throughout hospitalisation. Secondary outcomes included physical performance (Medical Research Council (MRC) sum score, Chelsea Critical Care Physical Assessment (CPAx), and hand grip strength (HGS)) at ICU and hospital discharge, hospital duration, hospital discharge destination, and mortality rates at hospital discharge and 3 months and 6 months post-ICU discharge. Data are mean ± SD, median (interquartile range [IQR]) or number [percentage]).

Results: A total of 70 patients were included (median age: 69 [61–74] years; 36 men (51 %)). The overall mean energy and protein adequacy during the first 14 days after ICU discharge averaged 100.2 ± 28.8 % and 97.1 ± 29.0 %, respectively. The median post-ICU hospital stay was 10 days [7–16], during which 50 patients (71 %) weaned from enteral tube feeding to exclusive oral nutrition on the post-ICU hospital ward. At ICU discharge, median MRC sum score was 42 [36–47], CPAx score 25 [18–30], and handgrip strength 14 [9–21] kg; and at hospital discharge, the MRC sum score increased to 48 [44–51], CPAx score to 40 [34–44], and handgrip strength to 20 [14–28] kg (all $p < 0.001$). In-hospital mortality was 10 % ($n = 7$), 3-month mortality was 16 % ($n = 11$), and 6-month mortality was 19 % ($n = 13$).

Abbreviations: ABW, Actual Body Weight; APACHE, Acute Physiology And Chronic Health Evaluation; ASPEN, American Society for Parenteral and Enteral Nutrition; BIA, Bioelectrical Impedance Analysis; BMI, Body Mass Index; CPAx, Chelsea Critical Care Physical Assessment tool; CVVH, Continuous Veno-Venous Hemofiltration; ECW, Extracellular Water; EMR, Electronic Medical Records; EN, Enteral Nutrition; ESPEN, European Society for Clinical Nutrition and Metabolism; FFM, Fat-free mass; FM, Fat mass; GRV, Gastric residual volume; HGS, Handgrip strength; ICU, Intensive Care Unit; IDDSI, International Dysphagia Diet Standardisation Initiative; MRC, Medical Research Council; NICE, Nationale Intensive Care Evaluation; mNUTRIC, Modified Nutrition Risk in Critically Ill; ONS, Oral Nutritional Supplement; PDMS, Patient Data Monitoring System; SOFA, Sequential Organ Failure Assessment; TBW, Total Body Water; UCR, Urea-to-Creatinine ratio.

* Corresponding author. Chair Department of Intensive Care Medicine & Research, Gelderse Vallei Hospital, Willy Brandtlaan 10, 6716 RP Ede, the Netherlands.

E-mail addresses: mpaulus@zgv.nl (M.C. Paulus), imre.kouw@wur.nl (I.W.K. Kouw), nienke.westeneng@wur.nl (N. van Beek-Westeneng), ilzedeleeuw.idl@gmail.com (I. de Leeuw), evita.vanlingen@wur.nl (E.C. van Lingen), HolverdaM@zgv.nl (M. Holverda), StrookappeB@zgv.nl (B. Strookappe), zantena@zgv.nl, arthur.vanzanten@wur.nl (A.R.H. van Zanten).

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Conclusion: Daily energy and protein adequacy during the first 14 days after ICU discharge was high, reaching >100 % of prescribed energy and >95 % of protein targets, following a personalised, stepwise nutrition protocol in ICU survivors. The effect on clinical and functional outcomes remains to be further investigated.

1. Introduction

Adequate nutritional intake, such as energy and protein, is suggested to be essential for rehabilitation and clinical outcomes in survivors of intensive care units (ICUs) [1]. The majority of ICU survivors transition from enteral tube feeding to oral intake as part of the rehabilitation process as soon as possible after ICU discharge or prior to discharge home. However, this transition poses a risk of inadequate nutrition, potentially compromising post-ICU recovery. This phase of recovery is critical, as muscle wasting occurs rapidly during critical illness and can persist for weeks to months in long-stay patients with ongoing catabolism [2–4]. In the early stages, the body primarily breaks down muscle tissue; however, as recovery progresses and anabolism increases, nutrition (specifically energy and protein) becomes essential for muscle regeneration [5–7]. An inadequate nutritional intake in ICU survivors has been highlighted in several previous observations [1,8,9], and a recent review by *Rosseel* et al. reported that energy and protein adequacy among ICU survivors in hospital wards ranges from 51 to 102 % and 63–83 %, respectively, with the most pronounced deficits observed in patients relying on exclusive oral nutrition [10]. Importantly, patients relying on oral intake only have been shown to be most prone to inadequate food intake, reaching 55–75 % of their energy targets and 27–74 % of their protein targets during the post-ICU phase [1]. In contrast, patients in the post-ICU period who continued to receive enteral tube feeding, with or without oral food intake, showed better energy and protein adequacy, reaching 62–104 % and 59–100 % of the prescribed targets, respectively [1].

During the transition from enteral tube feeding to oral nutrition, nutritional intake can be highly variable and influenced by several personal-, clinical,- system-, and/or clinician-related factors that impact nutrition [11–13]. For example, early removal of the enteral feeding tube may result in insufficient total nutritional intake, as oral intake alone might not yet be adequate [10]. In our previous observational PROSPECT-I study, we demonstrated that discontinuation of enteral tube feeding resulted in a substantial reduction in oral food intake, with energy and protein intake dropping by 44 % and 51 %, respectively [8]. The pronounced deficit in patients relying on oral intake may be attributed to several factors reported in ICU survivors, including reduced appetite, changes in taste and smell, increased fullness, and post-extubation dysphagia [11,14–17].

Given the multifactorial causes and dynamic setting during recovery after critical illness, the use of more individualised nutrition protocols that closely monitor food intake and adjust for appropriate timing in tapering enteral tube feeding provides opportunities to optimise nutritional support in post-ICU patients [18,19]. While the EFFORT and INTENT trials have shown that tailored nutrition interventions can help achieve higher energy targets, the focus has been primarily on energy adequacy, while protein adequacy is also crucial for recovery [18,19]. Given the observed deficits in energy and protein intake following premature discontinuation of enteral tube feeding [8,10], and the limitations of standard protocols that do not account for the multifactorial and dynamic barriers to adequate nutritional intake during recovery, we developed an individually tailored nutrition protocol. This protocol incorporates stepwise adjustments to enteral tube feeding prescriptions based on actual oral intake, thereby aiming to reach daily adequacy of 90–110 % of prescribed targets. The present study investigated daily protein and energy adequacy following the implementation of this individually tailored, stepwise nutrition protocol, aiming to closely match daily oral and enteral tube feeding intakes in ICU survivors during the first 14 days from ICU discharge to hospital discharge. Secondly, we described energy and protein adequacy in patients who successfully weaned of enteral tube feeding during the recovery from critical illness, when an individually tailored, stepwise nutrition protocol is followed.

2. Methods

2.1. Study design and participants

A revised nutrition protocol was implemented for all post-ICU patients at Gelderse Vallei Hospital, Ede, the Netherlands, starting in June 2023. As part of this implementation, a prospective, observational, single-centre study was conducted in our mixed medical-surgical ICU and on all hospital wards where patients are transferred after ICU discharge, from September 11, 2023, to November 30, 2024. Follow-up continued for an additional six months after the end of the inclusion period. All critically ill patients in the ICU were screened for eligibility prior to ICU discharge. Inclusion criteria were: age ≥18 years, ICU stay ≥72 h, and receiving enteral tube feeding at the time of ICU discharge were eligible for inclusion. Exclusion criteria included: receiving exclusive parenteral or oral nutrition at ICU discharge, not being discharged to a hospital ward (e.g. transfer to a nursing home, another ICU, or another hospital), life expectancy ≤48 h, participation in another study aimed at improving nutritional intake after ICU, and/or expected incomplete nutrition after ICU stay (e.g. refeeding syndrome or protein-restricted diet). Enrolment was only on weekdays, and for patients discharged on a Sunday, informed consent was obtained the following day, after which they were eligible for study participation. A maximum of four patients could be monitored during the post-ICU phase simultaneously due to the limited number of tablets (used for photography of daily food intake) available.

The research protocol was approved by the local ethical committee of Gelderse Vallei Hospital, Ede, the Netherlands (study protocol number 2305-026). The study was conducted in accordance with the ethical standards outlined in the Declaration of Helsinki of the World Medical Association. Participants' data were collected in accordance with the Personal Data Protection Act and used in a pseudo-anonymised form. All eligible participants were informed about the study and provided written informed consent prior to participating in the study. If a legal representative gave initial consent, patients were approached later to confirm their consent when they were able to make an informed decision.

2.2. Stepwise nutrition protocol

An individually tailored, stepwise nutrition protocol was designed to adjust the patient's daily enteral tube feeding rates based on the amount of oral intake consumed the previous day. The protocol was designed by a multidisciplinary team of dietitians and clinicians with the aim of optimising daily protein intake during the post-ICU recovery phase. Central to the protocol is the daily evaluation of both enteral tube feeding and oral food intake, as nutritional intake in post-ICU survivors is extensively shown to decline on the hospital ward as a result of multiple personal, clinical, system-, and clinician-related factors that fluctuate heavily throughout the post-ICU period [11–13]. Experience from our previous PROSPECT-I study [8] and findings from other hospitals, also highlighted practical challenges in post-ICU nutrition management, reporting the high prevalence of nutritional barriers such as early removal of enteral feeding tubes, reduced appetite, changes in taste and smell, increased satiety, and post-extubation dysphagia to impact food intake [10,11,14–17]. Recognising these multifaceted and dynamic challenges, the feeding protocol incorporates a stepwise, individualised approach that enables close monitoring of actual intake and timely adjustments of enteral tube feeding. By applying gradual adjustments in enteral tube feeding prescriptions to the quantification of actual oral food intake, the protocol is designed to ensure that nutritional support is responsive to each patient's changing requirements and to help achieve adequate protein and energy intake throughout recovery. The feeding protocol was targeted to reach a daily protein adequacy of 90–110 %. Daily enteral tube feeding rates and oral intake were quantified, and enteral feeding rates were adjusted accordingly in a stepwise manner (Fig. 1). If the total daily protein intake exceeded 110 % of the prescribed target, the enteral feeding rate was reduced by 20 % of the target on the following day. If protein adequacy was greater than 130 %, the enteral feeding rate was reduced by 40 % of the target to avoid overfeeding. Conversely, if protein adequacy was below 90 %, the enteral feeding rate was increased by 20 % of the target, and if adequacy was below 70 %, it was increased by 40 % of the target. Oral nutrition supplements (ONS; Nutridrink Compact Protein (Nutricia, Zoetermeer)) were prescribed when enteral tube feeding reached only 20 % of the target. Once a patient was able to taper off enteral tube feeding, the prescribed amount of ONS was increased to two servings per day. The enteral feeding tube was left in place for an additional 24 h to ensure adequate oral intake (e.g. if more than 90 % of protein intake was consumed orally). If the patient maintained adequate oral intake during this period, the feeding tube was removed. After the feeding tube was removed, the amount of ONS was gradually reduced to ensure nutritional adequacy through a regular oral diet without the use of ONS.

2.3. Patient demographics and clinical outcomes during ICU stay

The study began for each patient on the day of ICU discharge (day 0), with a study day defined as a calendar day. At study enrolment, ICU admission data were collected using the electronic patient data management system (PDMS, MetaVision; iMDsoft, Tel Aviv, Israel) and the hospital electronic medical records (EMR, NEXUS Nederland, Vianen, the Netherlands). Outcomes included patient demographics (sex, age, body weight, and body mass index (BMI)), admission type (medical or surgical), duration of ICU stay, and use and duration of invasive mechanical ventilation, continuous veno-venous hemofiltration (CVVH), vasopressors, inotropes, and neuromuscular blocking agents. Clinical outcomes including Barthel score [0–20], Clinical Frailty Score [1–9], Sequential Organ Failure Assessment (SOFA) [0–24], Acute Physiology and Chronic Health Evaluation (APACHE) II score [0–71], APACHE IV score [0–286] and Modified Nutrition Risk in Critically Ill (m-NUTRIC) score [0–9] were also recorded. Additionally, the urea-to-creatinine ratio (UCR) was recorded at ICU admission,

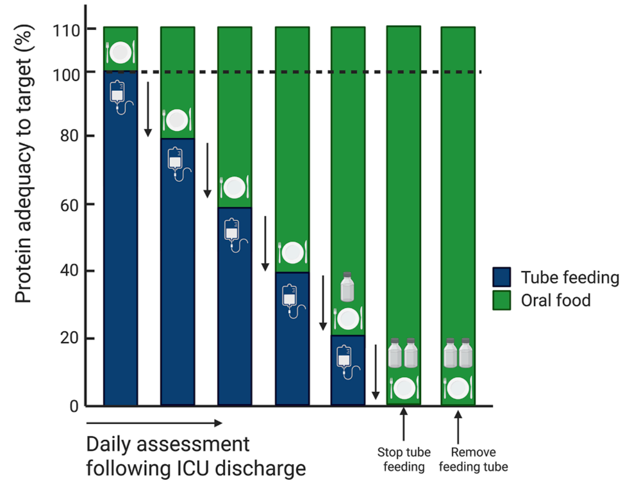

Fig. 1. Individually tailored, stepwise protocol for tapering enteral tube feeding in ICU patients following ICU discharge. When total daily protein intake exceeded 110 % of the prescribed target, the enteral feeding rate was progressively reduced by 20 % on the following day. Oral nutritional supplements were introduced when 20 % of enteral tube feeding remained and increased to two servings per day upon complete discontinuation of tube feeding. The feeding tube was kept in place for an additional 24 h to confirm sufficient oral intake. If oral intake remained adequate during this monitoring period, the feeding tube was subsequently removed. Additional procedural details are available in Supplementary Fig. 1. *Created with* Biorender.com.

throughout the ICU stay, and at ICU discharge, given that elevated UCR levels during critical illness may reflect muscle protein catabolism and indicate the development of persistent critical illness [20].

Additionally, energy and protein intake data were collected from the day before (day −1) and the day of ICU discharge (day 0), along with information on whether the patient was receiving exclusive enteral tube feeding or a combination of enteral tube feeding with oral intake at the time of ICU discharge. Refeeding syndrome during the ICU stay was documented if phosphate levels decreased from >0.70 mmol/L on admission to <0.65 mmol/L (delta >0.16 mmol/L) within 72 h of feeding. Body composition was assessed by multifrequency bioelectrical impedance analysis (BIA) using the InBody S10® device (InBody Co., Ltd., Seoul, Korea) at both ICU admission and ICU discharge, with the following parameters collected: body fat mass (BFM) (kg), fat-free mass (FFM) (kg), extracellular water (ECW) (kg), total body water (TBW) (kg), and the ECW/TBW ratio. To account for fluid overload, dry FFM (kg) was calculated when the ECW/TBW ratio was ≥0.380, using a formula previously employed in ICU research: FFM = (ECW - (0.38 × ICW))/0.62 [21,22]. All these parameters were routinely collected during standard clinical care.

At study inclusion, swallowing function was assessed by a speech therapist or ICU nurse and scored as good, good/moderate, moderate, or bad, based on clinical judgment and recommendations towards the texture and thickness of the diet was provided accordingly based upon the International Dysphagia Diet Standardisation Initiative (IDDSI) framework. For patients with swallowing disorders or other contraindications to oral intake, the dietitian determined an appropriate diet for each patient, involving the speech therapist when necessary. This approach allowed patients to gradually transition from tube feeding, when possible, while those with a nil per os order were closely monitored and regularly reassessed by the speech therapist to determine when it was safe to resume oral intake. A specialised ICU physiotherapist assessed physical performance at ICU discharge with the Medical Research Council (MRC) score [0–60] [23], Chelsea Critical Care Physical Assessment tool (CPAx) score [0–50] [24], and Hand Grip Strength (HGS) with Jamar dynamometer (Fabrication Enterprises Inc., Irvington, NY, USA), in kg and calculated as a percentage of the expected value, adjusted for age and sex [25].

2.4. Nutritional assessment post-ICU

A registered dietitian calculated energy and protein targets for the post-ICU period. Energy targets were set at ICU discharge and calculated using the World Health Organisation equation for patients with a BMI $\leq$30 kg/m^2 [26] and the Harris-Benedict (1918) equation for patients with a BMI >30 kg/m^2 [27,28]. Protein targets were also set at ICU discharge based on 1.5–1.9 g/kg/day of dry FFM as measured by BIA, with protein and energy goals carefully aligned. If BIA data were not available on ICU admission, protein targets were calculated based on actual body weight for patients with a BMI of 20–25, or on ideal body weight for those with a BMI over 25, with a recommended intake of 1.2–1.5 g/kg/day based on the European Society for Clinical Nutrition and Metabolism (ESPEN) and the American Society for Parenteral and Enteral Nutrition (ASPEN) guidelines for ICU patients [29,30]. Nutrition targets were calculated on the day of ICU discharge during weekdays, and for patients discharged on Sunday, targets were calculated on Monday morning. Using these targets, the dietitian determined the type of enteral tube feeding formula (Nutrison Protein Plus Multi Fibre® (Nutricia Zoetermeer) or Nutrison Protein Advance® (Nutricia, Zoetermeer)), and the initial feeding rate was set and recorded in the EMR.

Upon admission to the general ward, the patient was provided with a tablet and instructions for taking photographs of all meals before and after consumption. A poster was placed in the patient's room with instructions for photography of all their meals, e.g. taking photos from ~40 to 50 cm at a 45° angle, ensuring that the entire tray was visible, lids and foils were removed, and empty cups or containers to be placed upside down on the tray. In case a patient was unable to take a photograph, the bedside nurse and nutrition assistants were informed and assisted during pre- and post-meal photography. The patient could order all meals free by choice, which were delivered to their bedside within 45 min after ordering. The hospital meal service system was programmed to automatically log all patients' ordered meals, including the energy and protein content of each product. If a patient brought food items or meals from outside the hospital, they were instructed to document this on a separate form provided at their bedside. The tablet automatically uploaded all photographs to a local server accessible only to the research staff. Using the hospital's food service system, the research team was able to view all meals ordered for each patient, including detailed information on the content and portion sizes of individual food items. By comparing these records with the uploaded photographs, a quantitative assessment of oral food intake was conducted for each food item, scoring the amount consumed for each food item based on what was ordered. The following scoring system was employed to rate the consumption of each item: 0 (no consumption), 0.125, 0.25, 0.5, 0.75, or 1 (complete consumption). This scoring method has been validated as an accurate method of quantifying food consumption [31].

All data collected by the hospital food service system regarding the ordered meals was available on a local server. In cases of technical issues, insufficient photo quality, a missing pre- or post-meal photo, or no photos being available, data from the food record charts were used if available to assess food consumption. Bedside nurses use these charts to record daily food consumption (of each food item/meal), using the same scoring system as photography scoring (0 = no consumption, 0.125, 0.25, 0.5, 0.75, or 1 = complete consumption). If food record charts were unavailable, food consumption data were extracted from the hospital's EMR if available. Otherwise, the patient or bedside nurse was asked to recall the estimated amount of food consumed for each item. This procedure was done as soon as possible (preferably on the same day) to minimise recall bias. For each meal, the method used to assess food intake (digital photography, food record cards, medical records, or recall) was documented.

The quantitative assessment of intake for each food item was assessed, converted into energy (kcal) and protein (g), actually consumed, and subsequently summed to determine the total daily intake. Data on the type of enteral feeding formula, start and end times and feeding rates of the administered (par)enteral nutrition were extracted from the EMR. Enteral tube feeding was typically administered at a constant rate or as a bolus (every 3 h) between 6:00 am to 10:00 pm. Each weekday before 10:00 am, the research team calculated a patient's total daily energy and protein intake by combining oral and enteral tube feeding intake and then calculated the daily percentage of energy and protein adequacy. The stepwise nutrition protocol (Fig. 1, Supplementary Fig. 1) was followed to adjust the enteral feeding rate gradually. The changes in nutrition prescriptions were communicated daily through the hospital's EMR system and via direct communication with the ward nurse. Over the weekend, the enteral feeding rate was not adjusted. On Monday morning, the average nutritional intake from both weekend days was used to determine the tube feeding rate for Monday.

If protein adequacy by oral intake was sufficient (e.g. 90–110 % of goal) for feeding tube removal, this was then communicated to the medical team (responsible nurse and physician). If the feeding tube was removed earlier, the reason for removal was documented. All patients were monitored daily until hospital discharge, death, or withdrawal.

2.5. Clinical outcomes at hospital discharge

In addition to nutritional data, we included functional outcomes relevant to patient recovery, including swallowing function, MRC score, CPAx score, and HGS were collected at hospital discharge. The length of hospital stay, discharge destination (rehabilitation centre, home, or hospice), and in-hospital 3-month, and 6-month mortality rates were recorded. For patients discharged from the hospital with enteral tube feeding, the rehabilitation centers where they stayed were contacted monthly until discharge from the rehabilitation facility to inquire about the termination date of tube feeding. As the impact of achieving nutritional targets during the post-ICU phase on clinical outcomes relevant to ICU recovery has not been formally established, we included these outcomes to explore the potential influence of nutrition on patient recovery.

2.6. Statistical analysis

Continuous data were reported as mean and standard deviation (SD): mean (SD). Skewed data were reported as median and interquartile range (IQR): median [IQR]. The normality of the data was visually tested using histograms, and the Shapiro–Wilk test was used to determine if the data were normally distributed, with a p-value greater than 0.05 indicating normality. Discrete data were displayed as proportions, such as frequencies (n) and percentages (%). All instances of missing data were documented at the time of data collection and are reported in the corresponding tables.

The primary outcome, daily energy and protein adequacy (% of actual intake from prescribed target) was calculated for a maximum of 14 days after ICU discharge, as most patients are discharged within this timeframe, providing a representative period for the entire study cohort. Daily mean and overall mean intake were calculated over the first 14-days after ICU discharge and expressed as % of target (adequacy). A subsequent analysis for dietary intake was calculated for patients who discontinued according to the stepwise nutrition protocol and those who did not, including the reasons for early discontinuation. Differences in the primary outcomes, energy and protein adequacy, were also examined between patients on different wards, categorised by speciality (internal medicine, pulmonary/cardiology, or surgery/orthopaedics), using a one-way ANOVA when the data were normally distributed, and a Kruskal–Wallis test was applied when the assumption of normality was not met.

The secondary outcomes included hospital duration (in days) and discharge destination, as well as in-hospital, 3-month, and 6-month mortality rates. These outcomes were described for the entire cohort, with no comparisons made between groups. The difference in physical scores (MRC sum, CPAx, HGS in kg, and as a percentage of the expected value) between ICU and hospital discharge was tested using a paired t-test for normally distributed data and a Wilcoxon signed-rank test for non-normally distributed data. Exploratory comparisons of physical function scores (MRC sum and CPAx) were made between a similar patient cohort that was evaluated in the period prior to implementation of the nutrition protocol (PROSPECT-I; ICU patients receiving enteral nutrition at ICU discharge ($n = 24$), comparable to the current study population) and the current patient cohort. An independent samples t-test was used for normally distributed data, and a Mann–Whitney U test was used for non-normally distributed data.

A sample size calculation was conducted based on previous observational data of nutritional intake after ICU discharge in our hospital [8], which reported an average daily protein intake of 79 ± 22g and 83.1 ± 19.8 % adequacy to protein targets. In the present study, we expected to achieve an average protein adequacy of 95 % over 14 days after ICU discharge using the tailored nutrition protocol. Based on expert consensus and in line with international guidelines (ESPEN: 1.3 g/kg/day; ASPEN: 1.2–2.0 g/kg/day), we defined ≥95 % as a clinically relevant protein intake level, corresponding to a minimal clinically important difference (MCID) of approximately 12 % compared to our previous PROSPECT-I observations, where mean protein adequacy was 83.1 ± 19.8 % [8]. This MCID of 12 % was established in consultation with clinical dietitians treating post-ICU patients on the wards, representing an improvement that is both clinically meaningful and realistically achievable. Although the overall SD for protein adequacy in the PROSPECT-I cohort was 19.8 %, there was considerable variation between subgroups, and we similarly expected substantial variability between patients in the present study; therefore, we conservatively assumed a higher SD of 24 %, resulting in a standardized effect size of $d = 0.5$. With this effect size, a power of 0.90 and $\alpha < 0.05$, a total sample size of $n = 70$ was calculated to detect an expected protein adequacy above 95 % after implementation of the nutrition protocol. A p-value <0.05 was considered significant. Statistical analysis was performed using SPSS Statistics (version 29, IBM Corp., Armonk, USA).

3. Results

As presented in the study flowchart in Fig. 2, a total of 848 patients were discharged from the ICU during the study period from September 11, 2023, to November 30, 2024, with 76 patients being eligible, of which 70 were enrolled in the study. Patients' characteristics are presented in Table 1. Study patients had a median age of 69 years [61–74], with an almost equal distribution of men and women (51.4 % men). The median BMI was 27.1 kg/m^2 [23.5–30.1]. The median length of stay in the ICU was 9 days [6–16]. At the time of discharge from the ICU, 23 patients (33 %) received exclusive enteral tube feeding, while 47 patients (67 %) received a combination of enteral tube feeding and oral nutrition.

3.1. Primary outcome: nutritional intake during ICU recovery

The overall mean energy and protein adequacy during the first 14 days after ICU discharge averaged 100.2 ± 28.8 % and 97.1 ± 29.0 %, respectively (Fig. 3). The mean energy target averaged 25.3 ± 4.0 kcal/kg actual body weight (ABW)/day, and the protein target averaged 1.9 ± 0.3 g/kg FFM/day, equivalent to 1.3 ± 0.2 g/kg ABW/day. Dietary intake was assessed over a total of 836 study days, with a mean of approximately 12 days per patient. Dietary intake was available from pre- and post-meal photographs in 35 % ($n = 570$), from hospital dietary records in 52 % ($n = 843$), a combination of both in 4 % ($n = 60$), from medical records in 8 % ($n = 123$), and from patient and/or nurse recall in 1 % ($n = 23$).

In total, 50 patients (71 %) transitioned from enteral tube feeding to exclusive oral intake, with a median duration of enteral tube feeding of 5 days [3–7]. In these patients, mean energy adequacy decreased from 107.8 ± 32.1 % to 80.2 ± 31.3 % ($p < 0.001$) from the day before enteral tube feeding was discontinued to the first day of exclusive oral intake and from 104.4 ± 31.3 % to 78.2 ± 33.1 % ($p < 0.001$) for protein adequacy. In the seven days following the discontinuation of enteral tube feeding, the mean energy and protein adequacy averaged 82.4 ± 32.2 % and 79.8 ± 33.4 %, respectively (Fig. 4). However, the mean energy and protein ordered - rather than consumed - as a percentage of the target were 100.1 ± 28.3 % and 98.0 ± 29.5 %, respectively, highlighting a discrepancy between what was ordered and what was consumed (Supplementary Fig. 2).

Of the 50 patients completely weaned off enteral tube feeding, 11 (22 %) had their feeding tube removed according to the stepwise nutrition protocol. In contrast, 39 (78 %) had their tube removed before complete weaning of enteral tube feeding according to the nutrition protocol. In the first seven days following tube feeding cessation, those who followed the nutrition protocol had a mean energy and protein adequacy of 96.4 ± 22.1 % and 101.9 ± 21.8 %, respectively, compared to 79.9 ± 33.6 % and 75.9 ± 33.7 % in those who did not comply with the nutrition protocol (Supplementary Fig. 3). Reasons for stopping enteral tube feeding before complete weaning off enteral tube feeding according to the nutrition protocol included patient discomfort (24 %) or refusal (14 %), clinician decisions (18 %), moribund status (14 %), impending hospital discharge with low dose enteral tube feeding (20–40 % of target) (6 %), or initiation of parenteral nutrition (PN) (2 %).

3.2. Clinical outcomes and physical functioning

Patients spent a median of 10 [8–16] days in the hospital ward (Table 2). Of the 70 patients, $n = 43$ (61 %) were discharged to a rehabilitation centre where they stayed for a median of 35 [15–64] days. In-hospital mortality occurred in 7 (10 %) patients, 3-month mortality in 11 (16 %), and 6-month mortality in 14 (20 %). No correlation was found between energy and protein intake across wards of different specialisms ($p = 0.682$ and $p = 0.266$, respectively).

Physical performance improved from ICU discharge to hospital discharge, with a median MRC-sum score increasing from 42 [36–47] to 48 [44–51] ($p < 0.001$), the CPAx score increasing from 25 [18–30] to 40 [34–44] ($p < 0.001$), and the HGS increasing from 14 [9–21] to 20 [14–28] kg ($p < 0.001$) (Table 3). In addition, HGS as

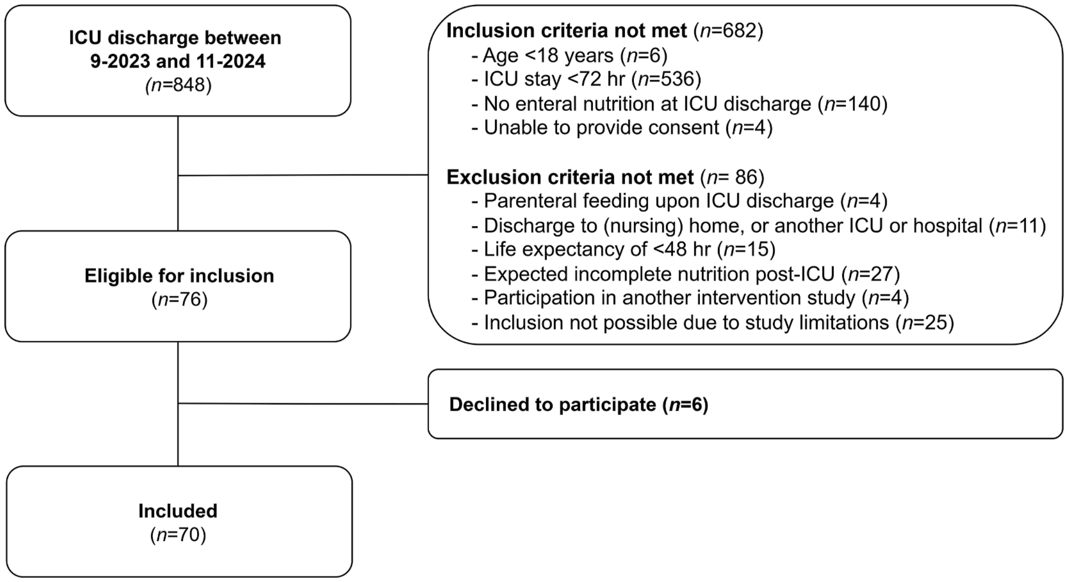

Fig. 2. Study flowchart. The flow chart reflects the actual screening process, with eligibility criteria assessed sequentially. Study limitations refer to practical constraints, such as Saturday discharges and a limited capacity to enroll a maximum of four patients at a time, due to the availability of study tablets. ICU: Intensive Care Unit.

a % of the expected value, adjusted for age and sex, showed an increase from a median of 50 % [30–70] to 70 % [50–83] ($p < 0.001$) from ICU discharge to hospital discharge. After implementation of the nutrition protocol, patients had a median MRC score increase of 6 [2–10] compared with 4 [1–7] in patients before implementation (PROSPECT-I) (p = 0.164), and a median CPAx score increase of 12 [8–18] compared with 9 [5–13] (p = 0.117) (Supplementary Table 1). The number of patients with ICU-acquired weakness (defined as an MRC sum score <48) decreased from $n = 53$ at ICU discharge to $n = 23$ at hospital discharge, while the number of patients with severe ICU-acquired weakness (MRC sum score <36) decreased from $n = 17$ to $n = 3$.

4. Discussion

In this single-centre, observational, prospective cohort study, the implementation of an individualised, stepwise nutrition protocol during post-ICU recovery resulted in mean energy and protein delivery of 100.2 % and 97.1 % of targets during the first 14 days after ICU discharge. In total, 71 % of patients ($n = 50$) transitioned to exclusive oral intake, although only 22 % of these patients followed the complete nutrition protocol. In the week following the cessation of tube feeding, those who adhered to the nutrition protocol exhibited higher levels of nutritional adequacy (energy: 96.4 % and protein: 101.9 %) compared to those who did not comply with the study procedures for enteral feeding tube removal (energy: 79.9 % and protein: 75.9 %). These findings show that adherence to an individualised, stepwise nutrition protocol is associated with the attainment of >95 % of daily energy and protein targets in patients throughout the first 14 days of recovery from critical illness.

Despite the well-established importance of optimal nutrition in ICU survivors, energy and protein intake levels frequently prove to be very low [1,9,10]. It has been established that, as most survivors of critical illnesses transition from enteral tube feeding to exclusive oral intake during their rehabilitation prior to discharge, this shift presents a significant risk of energy and protein inadequacy, potentially hindering recovery after critical illness [32]. In the observational PROSPECT-I study, we demonstrated that removal of the enteral feeding tube during recovery from critical illness on the general ward resulted in a 44 % reduction in energy adequacy and a 51 % reduction in protein adequacy [8]. Consequently, the critical transition from enteral tube feeding to exclusive oral nutrition, a period during which patients are particularly vulnerable to undernutrition and nutrition-related symptoms associated with the ICU stay are highly present, is often not adequately supported. Therefore, in this study, we implemented an individualised, stepwise nutrition protocol in which enteral tube feeding was only reduced once overall intake, from actual consumed oral food intake and tube feeding, exceeded 90 % of the prescribed protein targets. We observed an overall mean energy and protein adequacy during the first 14 days after ICU discharge of 100.2 ± 28.8 % and 97.1 ± 29.0 %, respectively. Among all patients who transitioned from enteral tube feeding to exclusive oral nutrition, the mean energy and protein adequacy levels in the first seven days after removal of the feeding tube were 82.4 ± 32.2 % and 79.8 ± 33.4 %, respectively. In contrast, in the group that adhered to the nutrition protocol and had their enteral feeding tube removed after consuming >90 % of the prescribed protein target for more than 24 h, energy and protein intake levels averaged 96.4 ± 22.1 % and 101.9 ± 21.8 %, respectively, in the first seven days following feeding tube removal. These data exceed the energy and protein adequacy levels of 55–75 % and 27–74 %, respectively, reported in the literature for post-ICU patients in the general ward who rely on exclusive oral food intake [8].

Previously, the INTENT trial was the first randomised study to evaluate an intensively monitored and tailored nutrition intervention aimed at improving energy intake in ICU survivors [18]. The personalised intervention started in the late acute phase of the ICU stay and continued until hospital discharge, involving structured dietitian-led care with regular consultations, individualised meal adjustments, and prescription of daily oral and (par)enteral supplements. This structured approach yielded improved energy adequacy, with a notable increase from 64 % in the conventional care group to 80 % in the intervention group. However, it is essential to note that the majority of patients in the INTENT trial received parenteral nutrition, which is not a routine practice in

Table 1
Baseline characteristics of study population.

ICU admission			($n = 70$)
Age (y)	Median [IQR]		69 [61–74]
Sex (men)	n (%)		36 (51.4 %)
ABW (kg)	Mean (SD)		83.5 (21.1)
BMI (kg/m^2)	Median [IQR]		27.1 [23.5–30.1]
ICU NICE admission type	n (%)		
Medical			58 (82.9 %)
Elective surgery			5 (7.1 %)
Emergency surgery			7 (10.0 %)
Barthel score [a]	Median [IQR]	($n = 67$)	20 [18–20]
Clinical Frailty Score [b]	Median [IQR]	($n = 53$)	3 [2–6]
APACHE II score [c]	Mean (SD)		26 (9)
APACHE IV score [d]	Mean (SD)		91 (28)
SOFA score [e]	Mean (SD)		8 (4)
m-NUTRIC score [f]	Mean (SD)		5 (2)
UCR[g]	Median [IQR]		82 [62–119]
BIA		($n = 67$)	
Dry FFM (kg)[h]	Mean (SD)		61.5 (14.2)
FM (kg)	Median [IQR]		23.0 [15.6–30.5]
ECW/TBW ratio	Median [IQR]		0.402 [0.390–0.411]
ICU stay			($n = 70$)
Invasive mechanical ventilation	n (%)		50 (71.4 %)
Duration (days)	Median [IQR]		6.8 [2.0–13.6]
CVVH use (y/n)	n (%)		8 (11.4 %)
Duration (days)	Median [IQR]		2.8 [2.0–11.6]
Vasopressor use (y/n)	n (%)		62 (88.6 %)
Duration (days)	Median [IQR]		2.8 [1.4–5.5]
Neuroblocker use (y/n)	n (%)		12 (17.1 %)
Duration (days)	Median [IQR]		1.3 [0.6–3.9]
Inotropy use (y/n)	n (%)		25 (35.7 %)
Duration (days)	Median [IQR]		1.5 [0.5–3.5]
Refeeding syndrome (y/n)[i]	n (%)		20 (28.6 %)
Average UCR[g,j]	Mean (SD)		134 (48)
ICU discharge			($n = 70$)
Days in ICU	Median [IQR]		9 [6–16]
ABW (kg)	Mean (SD)		85 (21)
SOFA score[e]	Median [IQR]		1 [0–2]
UCR[g]	Median [IQR]		153 [117–188]
BIA		($n = 62$)	
Dry FFM (kg)[h]	Mean (SD)		56.7 (12.6)
BFM (kg)	Median [IQR]		23.0 [15.2–35.1]
ECW/TBW ratio	Mean (SD)		0.408 (0.017)
Swallowing function[k]	n (%)		
Good			31 (44.3 %)
Good/moderate			4 (5.7 %)
Moderate			24 (34.3 %)
Bad			11 (15.7 %)
Nutritional route	n (%)		
Exclusive EN			23 (32.9 %)
Combination EN + oral			47 (67.1 %)

Patient demographics of 70 post-ICU patients who completed an individually tailored stepwise nutrition protocol. At the time of inclusion (ICU discharge), data from the ICU admission and stay were retrospectively collected from standard care records. Data from ICU discharge onwards were collected prospectively after inclusion. Legend: ABW = Actual Body Weight; APACHE = Acute Physiology And Chronic Health Evaluation; FM = Fat Mass; BIA = Bioelectrical Impedance Analysis; BMI = Body Mass Index; CVVH = Continuous Veno-Venous Hemofiltration; ECW = Extracellular Water; EN = Enteral Nutrition; FFM = Fat-Free Mass; ICU = Intensive Care Unit; m-NUTRIC = modified Nutrition Risk in Critically Ill; NICE = National Intensive Care Evaluation; SOFA = Sequential Organ Failure Assessment; TBW = Total Body Water; UCR = Urea-to-Creatinine Ratio.

[a] Barthel score: assesses activities of daily living, with scores ranging from 0 (indicating dependence) to 20 (indicating independence).
[b] Clinical Frailty score: a seven-point scale employed to assess the level of fitness or frailty, with higher scores indicating a higher degree of frailty.
[c] APACHE II score: ranges from 0 to 71, with higher scores indicating greater disease severity and an increased risk of mortality.
[d] APACHE IV score: ranges from 0 to 286, with higher scores indicating greater disease severity and an increased risk of mortality.
[e] SOFA score: ranges from 0 to 20, with higher scores indicating more severe organ failure.
[f] M-NUTRIC score: ranges from 1 to 9, measures the risk of adverse events in critically ill patients that can be modified by aggressive nutritional therapy, with higher scores indicating a greater risk.
[g] Urea (μmol/L) and Creatinine (μmol/L) Ratio in blood.
[h] Dry FFM = FFM-(ECW-(0.38*ICW)/0.62).
[i] Refeeding syndrome is defined by blood phosphate level falling below 0.65 mmol/L within 72 h after ICU admission, with a reduction of at least 0.16 mmol/L/day.
[j] Average of all UCR values of ICU stay.
[k] Swallowing function assessed by a speech therapist or ICU nurse.

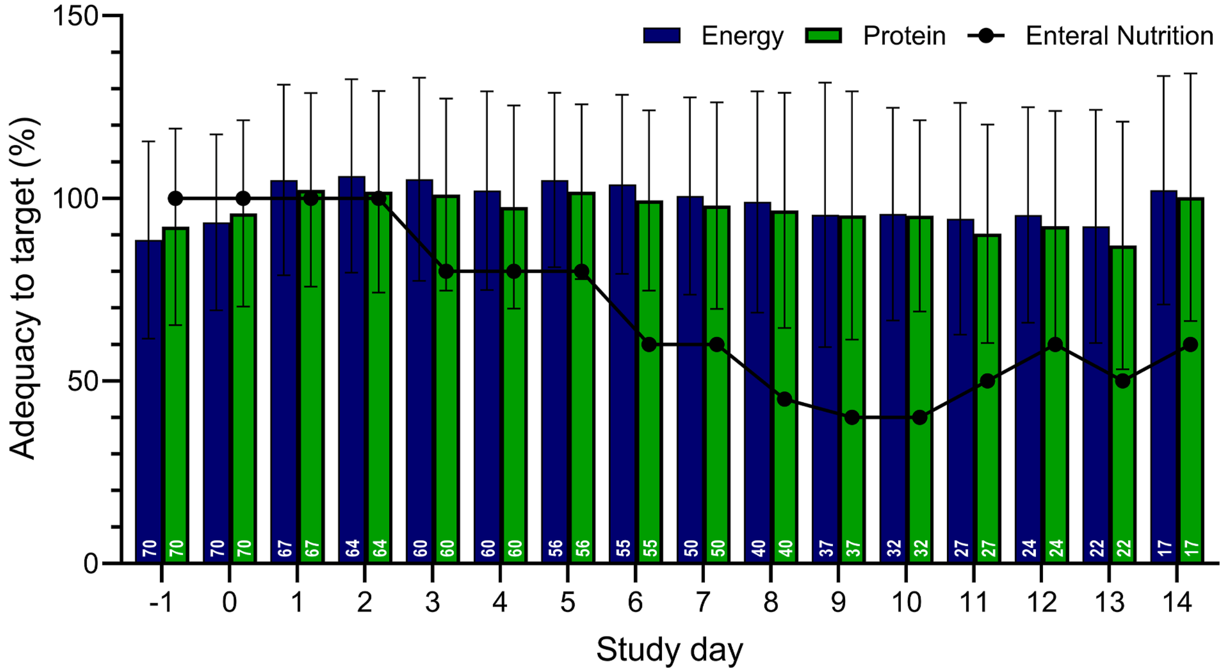

Fig. 3. Daily energy and protein adequacy. Mean (±SD) daily energy (grey bars) and protein (white bars) adequacy in 70 post-ICU patients who completed an individually tailored stepwise nutrition protocol, expressed as a % of intake relative to the prescribed target per calendar day. Study day −1 represents the last full day in the ICU, day 0 the day of ICU discharge, followed by the first 14 days in the general ward. The number of patients (n) contributing data on each day is indicated within each bar. The connected black line represents the median proportion of total intake provided by enteral tube feeding per study day, starting at 100 % adequacy on ICU discharge and tapering thereafter.

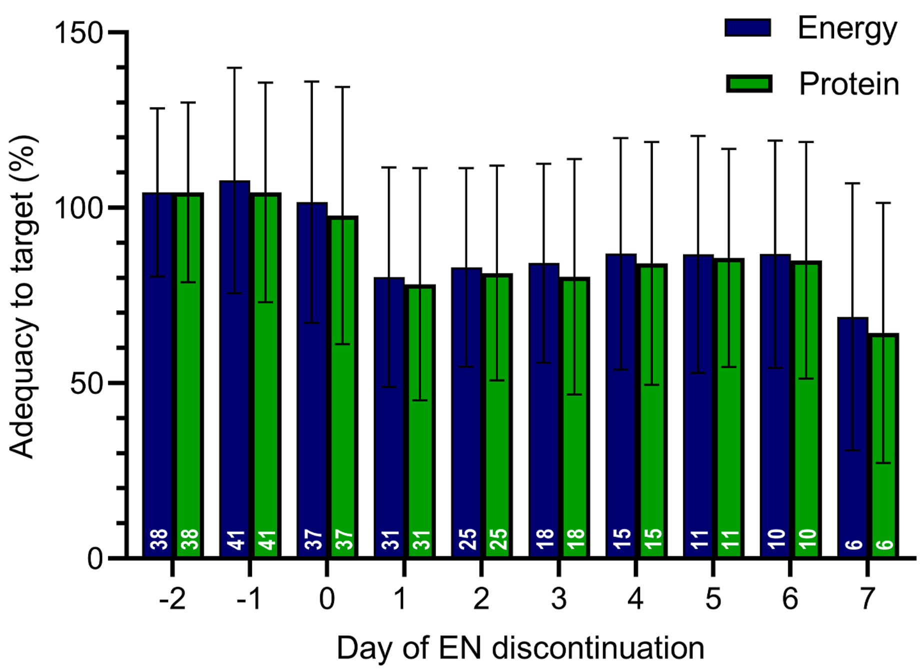

Fig. 4. Daily energy and protein adequacy after enteral tube feeding discontinuation. Mean (±SD) daily energy (grey bars) and protein (white bars) adequacy in post-ICU patients who completed an individually tailored stepwise nutrition protocol, expressed as a % of intake relative to the prescribed target, on the calendar days preceding and following enteral tube feeding discontinuation. Day 0 represents the day of EN discontinuation, with days −2 and −1 being the two preceding days and days 1–7 representing the first seven days following discontinuation. The number of patients (n) contributing data on each day is indicated within each bar. This analysis includes data from the 50 patients (71 %) in whom enteral tube feeding was discontinued during the study.

many ICUs or post-ICU care settings and, therefore, represents a distinct cohort of ICU survivors. The ESPEN guidelines support a more conservative approach, often delaying or even avoiding parenteral nutrition in the early ICU phase [29]. While the INTENT trial prioritises energy targets, protein targets are equally crucial for recovery, making it worthwhile to quantify daily protein intake alongside physical outcomes relevant to physical recovery.

Daily monitoring is important because post-ICU intake can be impacted by multiple factors, including decreased appetite, alterations in taste and smell, post-extubation dysphagia, and

Table 2
Clinical outcomes of the study population.

Nutritional data			($n = 70$)
Energy target (kcal)	Mean (SD)		2075 (332)
Kcal/kg ABW/day	Mean (SD)		25 (4)
Protein target (g)	Median [IQR]		100 [93–120]
g/kg dry FFM/day	Mean (SD)	($n = 62$)	1.9 (0.3)
g/kg ABW/day	Mean (SD)		1.3 (0.2)
Duration (supplemental) EN on ward (days)	Median [IQR]	($n = 50$)	5 [3–7]
Reason discontinuation EN	n (%)	($n = 50$)	
Stepwise nutrition protocol			11 (22 %)
Discomfort			12 (24 %)
Medical			9 (18 %)
Refusal			7 (14 %)
Moribund			7 (14 %)
Discharge			3 (6 %)
Start PN			1 (2 %)
Responsible care provider for EN discontinuation	n (%)	($n = 50$)	
Research team			11 (22 %)
Medical team			15 (30 %)
Patient			3 (6 %)
Medical team + patient			14 (28 %)
Death/moribund			7 (14 %)
Hospital discharge			($n = 70$)
Days in hospital after ICU discharge	Median [IQR]		10 [8–16]
Total days hospital[a]	Median [IQR]		22 [16–31]
ABW (kg)	Mean (SD)	($n = 55$)	79 (20)
Swallowing function[b]	n (%)		
Good			41 (59 %)
Good/moderate			8 (12 %)
Moderate			15 (22 %)
Bad			5 (7 %)
Feeding route	n (%)		
Combination EN + oral			20 (29 %)
Days EN post-hospital discharge	Median [IQR]	($n = 20$)	14 [8–27]
Total days EN	Mean (SD)	($n = 20$)	38 (34)
Exclusive oral			50 (71 %)
Discharge information			($n = 70$)
Discharge location	n (%)		
Rehabilitation centre			43 (61 %)
Home			19 (28 %)
In-hospital death			7 (10 %)
Hospice			1 (1 %)
Days in rehabilitation centre	Median [IQR]	($n = 43$)	35 [15–64]
Energy target (kcal)	Mean (SD)	($n = 44$)	2118 (348)
Kcal/kg body weight/day	Median [IQR]	($n = 40$)	26.8 [24.9–29.1]
Protein target (gram)	Mean (SD)	($n = 44$)	107 (24)
G/kg body weight/day	Median [IQR]	($n = 40$)	1.4 [1.3–1.5]
ONS target (portions)	Mean (SD)	($n = 23$)	2 (1)
Mortality			($n = 70$)
In-hospital death	n (%)		7 (10 %)
3-months	n (%)		11 (16 %)
6-months	n (%)		14 (20 %)

Clinical outcomes were assessed in 70 post-ICU patients who completed an individually tailored stepwise nutrition protocol. Patients were included at the time of ICU discharge and followed during their hospital stay. During the subsequent rehabilitation period, the length of stay and the number of days on enteral tube feeding post-hospital discharge were recorded. Mortality was recorded up to 6 months after ICU admission. Legend: ABW = Actual Body Weight; EN = Enteral Nutrition; ICU = Intensive Care Unit; ONS = Oral Nutritional Supplement; PN = Parenteral Nutrition.

[a] Total days from hospital admission until hospital discharge.

[b] Swallowing function assessed by a speech therapist or ICU nurse.

increased satiety, all of which have been previously reported in ICU survivors [1,11,14–17,33–35]. Interestingly, we observed differences within our study cohort between patients who complied with the nutrition protocol and patients who had the enteral feeding tube removed before oral intake was adequate, which was in contrast to our study instructions. More specifically, the group with early removal of the enteral feeding tube showed lower energy and protein adequacy in the first seven days following cessation of tube feeding, with mean energy and protein adequacy of 79.9 ± 33.6 % and 75.9 ± 33.7 %, respectively, compared to 96.4 ± 22.1 % and 101.9 ± 21.8 % in patients who complied with the nutrition protocol. Reasons for premature cessation of enteral tube feeding included patient discomfort or refusal, medical complications, moribund status, impending hospital discharge, and initiation of parenteral nutrition. These findings align with previous studies [8,36] and suggest that, in addition to the well-known risk factors for intake impairment in post-ICU patients, those whose feeding tubes are removed before achieving adequate intake are particularly vulnerable to failing to meet daily nutritional requirements and therefore require close monitoring. Despite some patients having intakes below 90 % after premature removal of enteral feeding tubes, reinsertion was uncommon, suggesting a high clinical threshold and reluctance among patients and clinicians to reinitiate tube feeding to achieve nutritional

Table 3
Physical functioning.

Physical functioning		ICU discharge		Hospital discharge		P value
MRC sum [a]	*Median [IQR]*	(*n* = 69)	42 [36–47]	(*n* = 62)	48 [44–51]	<0.001
CPAx [b]	*Median [IQR]*	(*n* = 69)	25 [18–30]	(*n* = 61)	40 [34–44]	<0.001
HGS (%) [c]	*Median [IQR]*	(*n* = 62)	50 [30–70]	(*n* = 54)	70 [50–83]	<0.001
HGS (kg) [c]	*Median [IQR]*	(*n* = 62)	14 [9–21]	(*n* = 54)	20 [14–28]	<0.001

Physical functioning was assessed in 70 post-ICU patients who completed an individually tailored stepwise nutrition protocol, with evaluations conducted at ICU discharge and hospital discharge. Legend: CPAx = Chelsea Critical Care Physical Assessment; HGS = Hand Grip Strength; ICU = Intensive Care Unit; MRC = Medical Research Council.

[a] MRC sum score: assesses global muscle strength by evaluating manual strength in six muscle groups (shoulder abduction, elbow flexion, wrist extension, hip flexion, knee extension, and ankle dorsiflexion) using the MRC scale, ranging from 0 (indicating complete paralysis) to 60 (indicating normal strength), with lower scores indicating weaker muscle strength.

[b] CPAx score: rates physical morbidity in critical care patients using a numeric and pictorial composite score of 10 physical function components graded on a 6-point Guttman Scale, ranging from 0 (complete dependence) to 5 (independence), with lower scores indicating greater dependence.

[c] HGS: Conducted with the Jamar dynamometer, the resulting scores are expressed in kg and as a percentage of a reference population based on sex, age, and weight. Lower scores indicate reduced handgrip strength.

targets. A scoping review by Vinci et al. demonstrated that tube feeding removal is often based on the clinical judgment of nurses and physicians on the ward rather than on an assessment of the actual oral intake of energy and protein [32]. Additionally, in our study, we found that while the ordered amount after feeding tube removal was approximately 100 % of the target, the actual intake was around 20 % lower. This highlights the importance of monitoring actual intake rather than relying solely on ordered amounts. No differences were observed in changes in physical function from ICU discharge to hospital discharge between the pre-implementation (PROSPECT-I) and post-implementation (PROSPECT-II) cohorts for MRC-sum and CPAx scores. However, these outcomes were only included as exploratory outcomes comparison to provide insight into the potential effect of a tailored nutrition protocol on functional outcomes.

4.1. Strengths and limitations

The present study reports dietary intake data from 14 days of post-ICU hospitalisation in 70 patients recovering from critical illness, totaling 850 study days. Using the hospital food ordering system, digital photography, and food record charts, we accurately quantified comprehensive longitudinal dietary data, including ordered and consumed energy and protein intake from all food items, including snacks, beverages, ONS, and enteral tube feeding administration rates and discontinuations. This approach enhances the reliability and completeness of our dietary intake data, enabling comprehensive daily monitoring of intake, including weekends. Dietary targets were set upon ICU discharge, and an individualised, stepwise nutrition protocol allowed for daily adjustments to enteral tube feeding rates based on actual oral food intake. Moreover, weaning from enteral tube feeding was more precisely monitored, with enteral tube feeding being prolonged for at least 24 h after daily protein targets were met. Unlike previous research, which has shown that few ICU survivors receive specific nutrition plans upon transfer to general wards, often resulting in nutritional deficits due to poor handovers [33], our study's nutrition protocol ensured continuity and personalisation of care, addressing a critical gap in post-ICU nutrition management. In addition to dietary intake, we incorporated FFM-based protein targets derived from body composition measurements to enable more accurate protein dosing [37]. We also included functional outcome measures to monitor patients' recovery.

Our study has limitations, including its single-centre design, as Gelderse Vallei Hospital is a hospital with a specific focus on nutrition, with a meal service that allows patients to order meals whenever they have an appetite, an emphasis on healthy food choices, wide availability of energy- and protein-enriched products, and close monitoring of nutritional intake, as well as on functional patient rehabilitation. During the study, participant bias may have occurred, as patients were aware that their intake was calculated daily. The use of digital photography to assess dietary intake is a relatively new method and can be more time-consuming than using the hospital's food ordering system. However, in this study we found that patients can assist in photographing their meals, and digital photography enables a similar estimation of food consumption compared to weighed food records [38]. In this study, technical issues, including charging problems, poor photo quality, tablet usability issues, staff shortages, and unclear instructions, resulted in missing photographs. As a result, the dietary assessment was based on hospital dietary records (52 %), pre-and post-meal photographs (35 %), a combination of both (4 %), medical reports in the hospital (8 %), and patient and/or nurse recall (1 %) for a total of 1404 ordered meals. In clinical practice, particularly in hospitals less experienced in assessing food intake, using intensive methodology to assess food consumption and provide daily nutritional counselling, can be time-consuming and may not be feasible in all hospitals due to resource limitations [18]. Additionally, misinterpretation of dietary intake in daily practice can occur due to inconsistencies in food intake recording methods. Moreover, liquid products such as drinks, soups, and ONS were complex to assess based on a picture due to opaque packaging [8,38]. Additionally, weekend dietary intake data were collected on Mondays, which may have introduced recall bias on these days. Since we presented averages over a 14-day period, we expect this to have no impact on our results, and previous research has shown that weekend days do not affect the accuracy of measuring oral food intake in hospitalized patients [39]. A limitation of this study is that the number of patients with available nutritional data decreased over the 14-day follow-up period due to discharge or death; although this was expected and anticipated by daily reporting of available patient data, it may still have influenced group averages and the observed variability between patients. This observational study was powered to assess whether patients achieved ≥95 % of prescribed energy and protein intake, a threshold established with clinical dietitians as meaningful and achievable, although evidence supporting 95 % adequacy as clinically relevant is limited. In our data, the observed standard deviation (~29 %) exceeded the anticipated 24 %, reflecting greater variability in protein intake levels between patients. Additionally, the primary outcome, achieving ≥95 % of prescribed daily energy and protein goals, relies on targets for which no official guidelines exist for ICU survivors, and the existing recommendations for ICU patients are based on expert consensus [29,30]. Predictive equations were used to set energy targets, as energy expenditure measurements were not available for all patients. While there is only limited data available on resting energy expenditure changes in post-ICU patients and the feasibility of indirect calorimetry during recovery on the ward is challenging [21], we acknowledge that measured energy expenditure is preferable to predictive formulas to determine energy intake recommendations [29]. Although patients achieved >95 % of daily energy and protein adequacy in parallel with improvements in functional outcomes at hospital discharge compared to ICU discharge values, these observed changes were similar to those observed before implementation of the study nutrition protocol (PROSPECT-I), likely reflecting typical functional recovery [8,22].

4.2. Future directions and recommendations

The present study demonstrates that an individually tailored, stepwise nutritional protocol in ICU survivors can achieve high energy and protein adequacy (>95 %). Further studies should focus on the implementation and efficacy of individually tailored nutrition protocols in post-ICU patients, with a focus on clinical outcomes. These studies should include daily quantification of both enteral tube feeding rates and oral food intake, as well as close monitoring of enteral feeding tube removal. Additionally, the applicability and success of such protocols may vary between hospitals due to differences in resources, staff expertise, and organisational practices, warranting investigation into context-specific barriers and facilitators to optimise implementation. Accurate food monitoring remains a challenge in clinical practice [40], and we observed that digital photography before and after meals is time-consuming and only shows limited compliance (35 %). More work is needed to assess ready-to-use methods for accurately assessing nutritional intake in hospitalised patients, including the use of food record charts where patients and family members may also contribute, as well as the potential future application of artificial intelligence for monitoring food consumption [31,41]. Furthermore, future research should explore how the presence of a gastric feeding tube influences swallowing rehabilitation (particularly in post-ICU dysphagia) and oral food intake. In our standard practice, a large-bore nasogastric tube (allowing gastric residual volume (GRV) measurement) is exchanged by a smaller-bore tube before ICU discharge which can ease the transition to oral food intake. However, future work is needed to further assess the potential impact of prolonged feeding tube presence and tube size on swallowing function recovery. It is important to highlight that there are currently no evidence-based guidelines on the amount, transition of feeding route, and timing of post-ICU nutrition, and limited data exist regarding the energy and protein requirements for ICU survivors. However, this remains a significant focus in the field, providing insight into the relationship between adequate nutritional intake, the role of nutritional support, and functional and clinical outcomes during recovery in post-ICU patients.

5. Conclusion

This single-center observational cohort study demonstrated that the implementation of an individually tailored, stepwise nutrition protocol within the first 14 days after ICU discharge achieved high energy and protein adequacy (100 % and 97 %, respectively) in post-ICU patients. Close monitoring of oral intake in parallel with gradual, patient-specific weaning from enteral tube feeding supported achieving >95 % of energy and protein targets throughout the post-ICU period. Our findings suggest that an individualised post-ICU nutrition protocol may provide practical guidance to support nutritional adequacy while tailoring the timing of tube removal to the patient's recovery. The effects on clinical and functional outcomes, as well as feasibility in other hospitals, remain to be investigated.

Author contributions

Michelle Paulus: Conceptualization, investigation, formal analysis, data curation, writing – Original Draft, writing – Review & Editing. Imre Kouw: Conceptualisation, writing – Review & Editing. Nienke Westeneng: Investigation, formal analysis, data curation. Ilze de Leeuw: Investigation. Evita van Lingen: Investigation. Mirjam Holverda: Conceptualisation, investigation. Bert Strookappe: Investigation. Arthur van Zanten: Conceptualisation, funding acquisition, writing – Review & Editing.

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Conflict of interest

Prof. Dr. Van Zanten reported receiving honoraria for advisory board meetings, lectures, research, and travel expenses from AOP Pharma, Abbott, Baxter, Cardinal Health, Danone Research and Innovation, DIM3, Dutch Medical Food, Fresenius Kabi, GE Healthcare, InBody, Mermaid, Rousselot, and Lyric. The other authors have no declarations to make.

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Appendix A. Supplementary data

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