International Journal of Nursing and Health Care Research

Dijkhuis T, et al. Int J Nurs Health Care Res 8: 1613
www.doi.org/10.29011/2688-9501.101613
www.gavinpublishers.com

Research Article

# Exploring Whether Ventilated ICU Patients Were in Optimal Nutritional Status Regarding Energy and Protein Requirements

**Talko B. Dijkhuis[1*], Hildegard S. Franke[2], Wolter Paans[2,3], Willem Dieperink[2,3], Rix Groenboom[4]**

[1]Research Group Personalised Health, Hanze University of Applied Sciences, Groningen, The Netherlands

[2]Department of Critical Care, University Medical Center Groningen, University of Groningen, Groningen, The Netherlands

[3]Research Group Nursing Diagnostics, Hanze University of Applied Sciences, Groningen, The Netherlands

[4]Research Group Digital Transformation, Hanze University of Applied Sciences, The Netherlands

[*]**Corresponding author:** Talko B. Dijkhuis, t.b.dijkhuis@pl.hanze.nl, Research Group Personalised Health, Hanze University of Applied Sciences, Groningen, The Netherlands

**Citation:** Dijkhuis TB, Franke HS, Paans W, Dieperink W, Groenboom R (2025) Exploring Whether Ventilated ICU Patients Were in Optimal Nutritional Status Regarding Energy and Protein Requirements. Int J Nurs Health Care Res 8:1613. DOI: https://doi.org/10.29011/2688-9501.101613

**Received Date**: 18 January 2025; **Accepted Date:** 25 January, 2025; **Published Date**: 29 January, 2025

**Abstract**

**Purpose:** Under- and overfeeding in Intensive Care Units (ICUs) are linked to prolonged hospitalisation, increased morbidity, and elevated mortality. This study investigates whether ICU patients were optimally nourished according to the European Society for Clinical Nutrition and Metabolism (ESPEN) guidelines. **Methods:** A cohort of 158 COVID-19 patients requiring intensive care for severe respiratory failure, necessitating a nuanced approach to nutritional support, was analysed. Nutritional status was determined regarding kilocalories and protein using the Energy Expenditure derived from ventilator-measured VCO2 and the adjusted Weir equation, and data on intake through enteral feeding was used. The study included ventilated patients hospitalised for over five days without Extra Corporeal Life Support (ECLS) and receiving enteral nutrition. Associations between mortality and (i) calorie intake and (ii) protein intake were examined using Chi-Square statistics. **Results:** Conforming to the ESPEN guidelines, 45% of patients were malnourished, and 21% were over-nourished in kilocalories. Additionally, 61% were malnourished, and 16% were over-nourished in protein. The distribution between the groups of survivors and deceased relative to each of the groups well nourished, malnourished, and over-nourished was not statistically different ($p = 0.21$). The protein distribution among survivors and deceased groups was not statistically different ($p = 0.67$) regarding correct, insufficient, or excessive protein intake. **Conclusions:** Based on ESPEN guidelines, most ICU patients were inadequately nourished in kilocalories and protein. However, no significant survival differences were observed across groups with varying nutritional adequacy. Further research is recommended to explore the implications of nutritional interventions in critically ill patients.

**Citation:** Dijkhuis TB, Franke HS, Paans W, Dieperink W, Groenboom R (2025) Exploring Whether Ventilated ICU Patients Were in Optimal Nutritional Status Regarding Energy and Protein Requirements. Int J Nurs Health Care Res 8:1613. DOI: https://doi.org/10.29011/2688-9501.101613

**Keywords**: Nutrition; Energy expenditure; Protein intake; Patient outcomes

## Introduction

Nutrition of patients in ICU settings has been an ongoing matter of controversy for a long time. Under- and overfeeding are common and are strongly associated with prolonged hospital admission, increased morbidity, and mortality [1-4]. It is recommended by the European Society for Clinical Nutrition and Metabolism (ESPEN) guidelines to give hypocaloric nutrition in the early phase and isocaloric nutrition after 3 days of acute illness [5]. It is known that there is still progression to be made in feeding critically ill patients. Also, a combination of long hospital stays and hypermetabolism makes it challenging to estimate the right nutritional therapy. COVID-19 patients are an interesting group to study in nutrition. Patients with COVID-19 often have severe respiratory failure, among other things, and are often admitted to a long hospital-stay Intensive Care Unit (ICU). Additionally, it is known that nutritional requirements are not met in COVID-19 patients because of feeding intolerance due to COVID-19 and also often caused by the necessary prone position due to respiratory problems [6-8].

The caloric content of nutrition is determined based on the calculation of the patient's Energy Expenditure (EE), which is estimated by measurement of macronutrient or oxygen consumption and heat production or carbon dioxide production [9]. Due to the changing conditions of critically ill patients, caused, among others, by their pathophysiological response, the EE varies frequently over time, and so do the nutritional needs of the patients [10]. Determining the EE using indirect calorimetry is the golden standard for measuring caloric needs in critically ill patients at the bedside.

Indirect calorimetry uses the Weir equation to estimate EE using measured oxygen consumption (VO2) and carbon dioxide production (VCO2) [11]. Additionally, it calculates the patient's Respiratory Quotient (RQ). The RQ is a ratio of VCO2 and VO2 resulting from the oxidation of energy substrates. It can indicate the adequacy of measurements: careful interpretation is required when the RQ falls outside the range of 0.67 and 1.3 [12].

If indirect calorimetry is unavailable, the VCO2 derived from the mechanical ventilator is recommended to determine the EE [12]. This method measures only exhaled gas volume and CO2 concentrations and does not measure O2 consumption. Therefore, a fixed RQ value of 0.86 is often assumed [14], and the calculation is then based on an adjusted version of the Weir equation [11].

The research question was: Were adult ICU patients at UMCG in optimal nutritional status regarding protein and energy requirements?

## Materials and Methods

The data consisted of measurements on 158 patients from the ICU wards. Some of the IC-EE measurements were inaccurate or absent, resulting in a final population of 124 patients, 92 males. A total of 1502 measurements were obtained, as multiple measurements were done on the same patients over multiple days.

The patient's baseline characteristics, energy expenditure data, and related clinical data for this study were extracted from the Patient Data Management System (PDMS) of ventilated patients in the ICU of the University Medical Center Groningen, the Netherlands, from January 6, 2020, to November 6, 2021.

The nutritional status in kilocalories and protein was determined using the Energy Expenditure (EE); only the VCO2 of the ventilator was available; therefore, the adjusted version of the Weir equation [11] was used to determine the EE using data of the intake through enteral nutrition. Ventilated patients who had been hospitalised for over five days without Extra Corporeal Life Support (ECLS) and had been fed by enteral nutrition were included in the study. Kruskal-Wallis and Dunn's post-hoc tests were used to test whether there was a difference in enteral nutrition given in the ICU.

For calculations of the nutritional needs, actual body weight (ABW) was used for non-obese (BMI < 30), and both actual and adjusted body weight (AdjBW) [5] were utilised for obese subjects (BMI >=30). To determine how optimally the patients were fed, the number of kilocalories and proteins consumed by the patients was calculated. Subsequently, the calorie intake in kilocalories was compared with the EE. The protein intake was compared to the protein requirement. The extent to which a patient is optimally fed is expressed in percentages.

The association between mortality and the factors (i) calorie and (ii) protein intake was examined using Chi-Square statistics. The data were statistically analysed using Python 3.8.8; the packages statsmodels 0.13.5, and lifelines 0.27.4.

## Results

Table 1 presents the patient characteristics per dataset of this study. Figures 1 and Figure 2 visualise calorie and protein intake.

| **(a) Baseline characteristics (n =124)** | | | | | |
|---|---|---|---|---|---|
| Age (mean, range) | 63.4 (37-82) | | | | |
| Male sex (n, %) | 92 (74.2) | | | | |
| Weight (mean, range) | 95,4 (58-159) | | | | |
| BMI (mean, range) | 30.8 (18.7-48.5) | | | | |
| BMI > 30 (%) | 52 | | | | |
| Ventilator days (21-day study period only) (mean, range) | 8.9 (3-21) | | | | |
| Mortality (21-day study period only) (n, %) | 42, 39.6 | | | | |
| Mortality (hospital mortality) (n, %) | 48, 38.7 | | | | |
| **(b) Energy expenditure/data** | **D0-2** | **D3–7** | **D8–14** | **D15-21** | **p-value** |
| Measured EE in absolute kCal/ day (all patients) (median, IQR) | 1289 (719-1708) | 2035 (1769-2328) | 2240 (1955-2604) | 2309 (2054-2604) | <0.05 |
| Measured EE kCal/kg actual BW (non-obese, BMI < 30) (median, IQR) | 22.35 (19.58-26.16) | 25.55 (22.44-28.82) | 25.31 (22.42-30.71) | 25.80 (22.64-29.59) | <0.05 |
| Measured EE kCal/kg actual BW (obese, BMI >= 30) (median, IQR) | 18.08 (15.87-21.6) | 21.26 (18.63-24.34) | 22.85 (19.52-25.87) | 22.72 (20.72-24.24) | <0.05 |
| Measured EE kCal/kg adjusted BW [5] (obese, BMI >= 30) (median, IQR) | 22.45 (19.73-26.28) | 25.92 (23.19-29.59) | 28.02 (24.43-31.09) | 27.79 (25.89-32.20) | <0.05 |
| Measured EE kCal/kg actual BW (all patients) (median, IQR) | 20.54 (17.11-24.09) | 23.28 (20.07-26.66) | 24.09 (21.26-27.91) | 24.00 (21.85-28.76) | <0.05 |
| Protein (median, IQR) | 62.64 (35.39-83.52) | 91.97 (67.71-96.46) | 95.09 (71.69-105.65) | 94.93 (75.61-108.86) | <0.05 |
| Calories (median, IQR) | 1289.34 (719.66-1708.98) | 1914.88 (1384.7-1979.15) | 1929.98 (1460.23-2144.11) | 1935.36 (1662.75-2205.82) | <0.05 |
| **(c) Clinical data** | D0-2 | D3–7 | D8–14 | D15-21 | p-value |
| Use of prone positioning (%) (mean, sd) | | 20.3 (4.0) | 20.5 (4.0) | 14.8 (3.51) | 0.79 |
| (a) patient characteristics; (b) nutrition data for the first three weeks post-intubation; (c) clinical care; BMI: Body Mass Index, BW: Body Weight in kilogram, EE kCal/kg: Energy Expenditure kilocalories per kilogram; obese BMI>=30, non-obese BMI<30; sd: standard deviation. p values are for the Kruskal-Wallis test. | | | | | |

**Table 1:** Baseline characteristics.

**Citation:** Dijkhuis TB, Franke HS, Paans W, Dieperink W, Groenboom R (2025) Exploring Whether Ventilated ICU Patients Were in Optimal Nutritional Status Regarding Energy and Protein Requirements. Int J Nurs Health Care Res 8:1613. DOI: https://doi.org/10.29011/2688-9501.101613

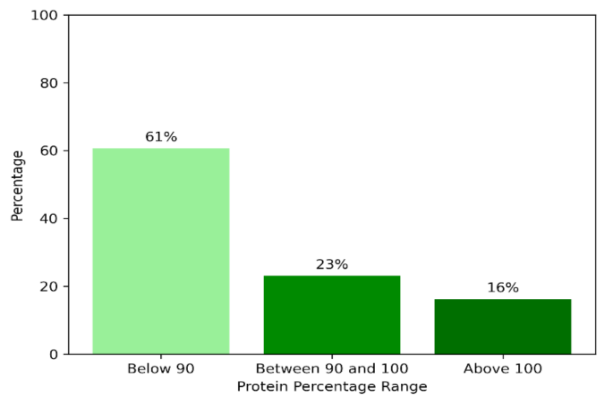


**Figure 1:** Protein per day.

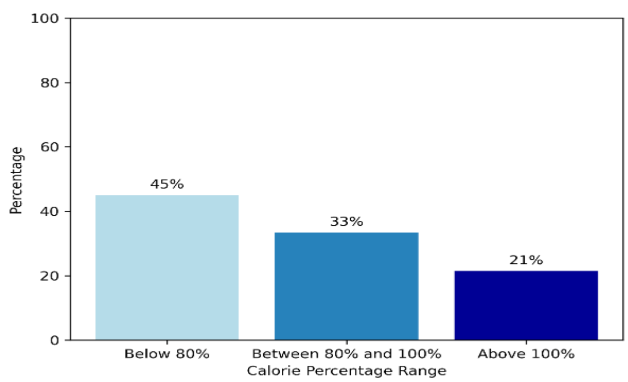


**Figure 2:** Calories per day.

According to Recommendation 8, to avoid overfeeding, early full Enteral Nutrition (EN) and Parenteral Nutrition (PN) shall not be used in critically ill patients; they shall be prescribed within three to seven days (5). Using Kruskal-Wallis and Dunn's post-hoc tests, we found that the mean of the calories and protein given to a patient during the first two days differed from the remaining days in the ICU ($p<0.01$).

The nutritional needs of ventilated patients in the ICU appear to be an average of 2224 (sd 477) kilocalories/24h; the patients received an average of 1788 (sd 508) kilocalories per 24h. The need for proteins was 110 (sd 14.49) grams/24h; the patients received an average of 89 (sd 26.73) grams per 24h.

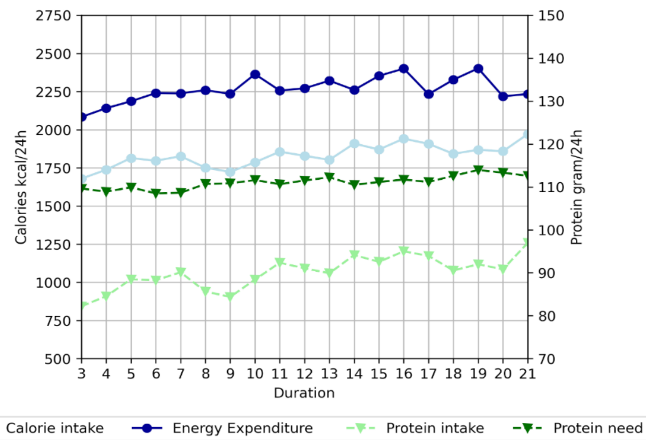


**Figure 3:** Nutrition in ICU.

The number of kilocalories and proteins consumed by the patients was calculated (Table 1, baseline characteristics). Subsequently, the calorie intake in kilocalories was compared with the EE and the protein intake was compared to the protein requirement (Figure 3).

The extent to which a patient is optimally fed can be expressed in percentages. The EE was measured per patient/24h, and the ingested kcal/24h was calculated. How many kcal/24 hours a patient takes in compared to the requirement of that day is expressed in percentages, Figure 4. This shows that 45% are malnourished and 21% are over-nourished in kilocalories, conforming to recommendation 18 (5). This means that 66%% of ESPEN margins were not fed in kilocalories. The percentage in which the ventilated patients received protein is shown in Figure 5. This shows that 61% are malnourished and 16% are overfed with protein (conforming to recommendation 22 [5]), which means that 77% have not received the prescribed protein and are therefore not optimally fed.

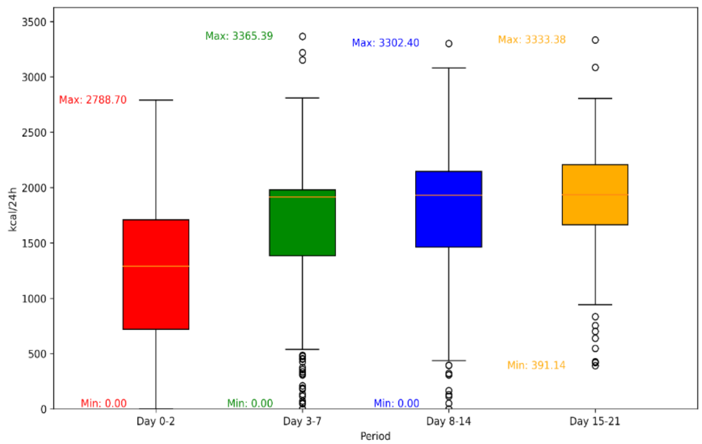


**Figure 4:** ESPEN-related distribution of the calories.

### Statistics on Mortality and Calorie Intake

We applied the Chi-Square test to determine whether calorie intake influenced survival. The distribution between the groups of survivors and deceased relative to each of the three Calorie groups is not statistically different ($p = 0.21$) Table 2.

| | Survivors % | Deceased % |
|---|---|---|
| Calorie < 80% | 41.35 | 47.44 |
| Calorie >=80% and <=100% | 30.83 | 35.14 |
| Calorie> 100% | 27.82 | 17.41 |
| Total | 100 | 100 |

**Table 2:** Mortality versus calorie intake.

| | Survivors % | Deceased % |
|---|---|---|
| Protein < 90% | 60.15 | 61.02 |
| Protein >=90% and <=100% | 25.81 | 21.41 |
| Protein > 100% | 14.04 | 17.57 |
| Total | 100 | 100 |

**Table 3:** Mortality versus protein intake.

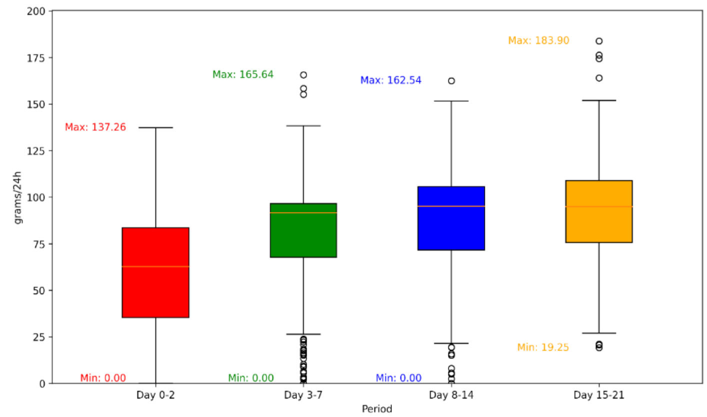


**Figure 5:** ESPEN-related distribution of the protein.

### Statistics on mortality and protein intake

We applied the Chi-Square test to determine whether protein intake influenced mortality. The distribution between the groups of survivors and deceased relative to each of the three protein groups is not statistically different ($p = 0.67$) Table 3.

## Discussion

The results show that nutrient requirements in ventilated COVID-19 patients are lowest in the first week, then increase in the second and third week.

This pattern can be explained from the literature by the metabolic phases of a critically ill patient. The first part of this is the acute phase. This means that only the processes in the body that are essential at that moment require energy. A lower energy requirement characterises this phase. This is followed by the post-acute phase, during which an increase in the need can be seen. This phase is called the recovery phase. The ongoing picture of hypermetabolism is reflected in the results [14]. However, little reliable literature has described the metabolism of COVID-19.

The results also show that the nutritional intake does not equal the nutritional requirement in our patient group. However, the protein intake shows an upward trend in weeks 1, 2 and 3. Gastric retention in ml/24h was subtracted from the total nutritional intake consumed regardless of the concentration of gastric retention.

An optimal nutritional status of both kilocalories and protein is important for a good recovery during and after a stay in the ICU [15]. Nutritional status can be related to how well patients are fed, expressed in percentages. The ventilated patients in the ICU are 33% well-fed with kcal/24h and 21% well-fed with protein. This large difference is mainly due to the ESPEN guidelines that consider a patient to be well-fed if he/she is fed between 80 and 100%. Only if the result falls outside this range is the patient considered malnourished. This works differently for protein; the patient is not considered well-fed until the patient is fed between 90% and 100% [5]. However, the ESPEN guideline is the gold standard for ICU power supply. The corresponding formulas are, therefore, also applied in this study.

A limitation of this study is a negative intake on some days due to gastric retention in ventilated patients with a gastric tube. The measured gastric retention was so high that it contained more kcal/24h than the intake. Gastric retention in these patients cannot consist of tube feeding alone. However, the concentration of the tube feeding cannot be traced back to gastric retention. This can affect the results to an extent that cannot be traced.

On the day of discharge, the study nurses did not register intake for most patients. These data for the kcal/24h intake and protein/24h are missing. Therefore, the study does not include the discharge day of ventilated patients. Excluding the discharge day does not influence the reliability of the results, but it does affect the number of hospital days for these patients.

## Conclusion

This study shows that the majority of COVID-19 patients are not very well-nourished in kilocalories and are poor in protein, according to the ESPEN guideline.

However, there is no significant difference in survival whether patients were betterfed calories or protein. Based on this conclusion, further research is recommended.

## Ethical Guidelines

The study was approved by the institutional review board of the University Medical Center Groningen (UMCG, METc M23.321896) and conducted in accordance with the principles of the Declaration of Helsinki (version 64, October 2013) and the European Union General Data Protection Regulation (EU GDPR), the Dutch code of conduct for science practice, and hospital regulations and acts.

## References

1. Casaer MP, Mesotten D, Hermans G, Wouters PJ, Schetz M, et al. (2011) Early versus late parenteral nutrition in critically ill adults. N Engl J Med 365: 506-517.
2. Rice TW, Mogan S, Hays MA, Bernard GR, Jensen GL, et al. (2011) Randomised trial of initial trophic versus full-energy enteral nutrition in mechanically ventilated patients with acute respiratory failure. Crit Care Med 39: 967-974.
3. Singer P, Anbar R, Cohen J, Shapiro H, Shalita-Chesner M, et al. (2011) The tight calorie control study (TICACOS): a prospective, randomised, controlled pilot study of nutritional support in critically ill patients. Intensive Care Med 37: 601-609.
4. Stapleton RD, Jones N, Heyland DK (2007) Feeding critically ill patients: What is the optimal amount of energy? Critical Care Medicine. 35: S535-S540.
5. Singer P, Blaser AR, Berger MM, Alhazzani W, Calder PC, et al. (2019) ESPEN guideline on clinical nutrition in the intensive care unit. ESPEN guidelines.
6. Wierdsma NJ, Kruizenga HM, Konings LA, Krebbers D, Jorissen JR, et al. (2021) Poor nutritional status, risk of sarcopenia and nutrition-related complaints are prevalent in COVID-19 patients during and after hospital admission. Clin Nutr ESPEN 43: 369-376.
7. Hills AP, Mokhtar N, Byrne NM (2014) Assessment of physical activity and energy expenditure: an overview of objective measures. Frontiers in nutrition.1:5.
8. Whittle J, Molinger J, MacLeod D, Haines K, Wischmeyer PE (2020) Persistent hypermetabolism and longitudinal energy expenditure in critically ill patients with COVID-19. Critical Care. 24:581.
9. Osuna-Padilla IA, Rodríguez-Moguel NC, López-Orduña LA, Gómez-Rodríguez AL, García-Grimaldo A, et al. (2023) Feeding intolerance during prolonged prone position in overweight and obese patients with severe COVID-19. Nutr Hosp 40: 250-256.
10. McClave S, Martindale R, Kiraly L (2013) The use of indirect calorimetry in the intensive care unit. Current Opinion in Clinical Nutrition and Metabolic Care. 16: 202-208.
11. Weir J (1949) New methods for calculating metabolic rate with special reference to protein metabolism. The Journal of Physiology. 109:1-9.
12. Stapel SN, de Grooth HJ, Alimohamad H, Elbers PW, Girbes AR, et al. (2015) Ventilator-derived carbon dioxide production to assess energy expenditure in critically ill patients: proof of concept. Crit Care 19: 370.
13. McClave S, Lowen C, Kleber M, McConnell J, Jung L, et al. (2003) Clinical use of the respiratory quotient obtained from indirect calorimetry. Journal of Parenteral and Enteral Nutrition. 27: 21-26.
14. Luke A, Dugas L, Kramer H (2007) Ethnicity, energy expenditure and obesity: Are the observed black/white differences meaningful? Curr Opin Endocrinol Diabetes Obes 14: 370-373.
15. van Zanten ARH, De Waele E, Wischmeyer PE (2019) Nutrition therapy and critical illness: practical guidance for the ICU, post-ICU, and long-term convalescence phases. Crit Care 23: 368.