Energy intake and nutritional status in older adults hospitalised in general hospitals for long-term rehabilitation owing to cardiovascular, cerebrovascular, respiratory, or musculoskeletal diseases: A multicentre prospective observational study

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Running title: Energy intake in older adults in rehabilitation

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ABSTRACT

Background and Objectives: In this multicentre prospective observational study, we aimed to investigate changes in energy intake and nutritional indices, including cardiovascular, cerebrovascular, respiratory, and musculoskeletal conditions, among older adults hospitalised in general hospitals who required long-term rehabilitation. **Methods and Study Design:** This study included patients aged ≥65 years who were admitted to 41 National Hospital Organization hospitals between September 2019 and March 2020 with cardiovascular, cerebrovascular, respiratory, or musculoskeletal diseases. Physical measurements, blood test values, energy intake, and activities of daily living were evaluated at admission and discharge. **Results:** The analysis included 222 patients (125 men, 97 women; mean age, 78.9 years). On admission, 75.7% of patients were malnourished or at risk of malnutrition based on the Mini Nutritional Assessment-Short Form score, with the highest prevalence (84.1%) observed in patients with respiratory disease. Although energy intake significantly increased during hospitalisation in all disease groups, only 31.1% of patients met the estimated energy requirements at discharge, and their body mass index and nutritional indices decreased. Logistic regression analysis showed that older age, female sex, higher energy intake at admission, and lower inflammation were associated with sufficient energy intake at discharge. Energy intake at admission was consistently associated with sufficient energy intake at discharge regardless of disease category, whereas other associated factors differed by disease. **Conclusions:** Nutritional management in general hospitals may be inadequate for older adults requiring long-term rehabilitation. These findings suggest the need for early individualised nutritional management in hospitalised older adults undergoing long-term rehabilitation.

Key Words: malnutrition, energy intake, protein intake, rehabilitation nutrition, nutrition management

INTRODUCTION

In Japan, patients with conditions requiring prolonged recovery of physical function are initially treated for acute illnesses in general hospitals and subsequently continue their rehabilitation in recovery-phase rehabilitation wards, community comprehensive care wards, outpatient clinics, or at home.

Nutritional management plays a crucial role in maintaining skeletal muscle, preserving physical function, and promoting muscle gain during extended rehabilitation periods.[1] However, previous studies have reported that 66% of hospitalised older adults are malnourished or at risk of malnutrition,[2] and 50% of patients admitted to rehabilitation wards are malnourished.[3] One contributing factor may be inadequate nutritional management during hospitalisation.[4–6]

Malnutrition rates are notably high among patients undergoing rehabilitation for cerebrovascular,[7,8] cardiovascular,[9–11] respiratory,[12,13] and musculoskeletal diseases.[14,15] The nutritional status among these patients has been reported to deteriorate further during hospitalisation.[8] This deterioration may result from the primary disease itself and reduced energy and nutrient intake.[16]

Consequently, patients requiring long-term rehabilitation require close monitoring of their energy and nutrient intake from the time of hospital admission, and nutritional management should be implemented to maintain or improve their nutritional status. However, limited information exists on how energy and nutrient intake change during hospitalisation in older adults admitted to general hospitals, how these changes influence nutritional indices, and how these changes are reflected in their nutritional indicators.

Therefore, in this multicentre observational study, we aimed to investigate the changes in energy intake and nutritional indices during hospitalisation in older adults admitted to general hospitals with conditions requiring long-term rehabilitation, such as cerebrovascular, cardiovascular, chronic respiratory, and musculoskeletal diseases. In addition, we examined factors influencing energy intake at discharge.

MATERIALS AND METHODS

Participants and study design

Participants

A flowchart of the participant selection process is shown in Figure 1. This study included hospitalised patients diagnosed with cardiovascular disease (myocardial infarction, angina pectoris, post-cardiovascular surgery, or chronic heart failure), respiratory disease (chronic obstructive pulmonary disease [COPD], pulmonary fibrosis, or interstitial pneumonia), cerebrovascular disease (cerebral infarction, cerebral haemorrhage, subarachnoid haemorrhage, or brain trauma), or musculoskeletal disease (proximal femur fracture, spinal compression fracture, or knee osteoarthritis). Patients with cardiovascular or respiratory diseases often require outpatient or at-home rehabilitation, whereas those with cerebrovascular or musculoskeletal diseases frequently require transfer to a rehabilitation hospital. To ensure sufficient observation of nutritional changes during hospitalisation, patients who were expected to stay in the hospital for at least three weeks were included.

Study design and setting

This prospective observational study included patients aged ≥65 years who were hospitalised for one of the four specified diseases between September 2019 and March 2020. A total of 410 patients provided informed consent, of whom 222 were included in the final analysis (Figure 1). In total, 188 patients were excluded: 74 because of missing admission data or predefined exclusion criteria and 114 because of missing discharge data. Among the 74 patients excluded at admission, 46 had missing baseline data, whereas 28 met predefined exclusion criteria or had substantial missing data. Patients were excluded if they met any of the following criteria: 1) hospitalisation for <1 week; 2) terminal-stage condition without the need for active nutritional management; 3) sudden changes in physical or mental condition, rendering them unsuitable for the study as determined by a physician; or 4) death prior to discharge.

Sample size

This exploratory prospective observational study employed a feasibility-based consecutive enrolment approach without a priori sample size calculations. The adequacy of the final analysed sample (n = 222) was retrospectively evaluated by assessing the precision of the primary proportion index (energy sufficiency rate). The 95% confidence interval (CI) had a half-width of 6.1%, indicating sufficient precision for an observational study.

Data collection

Patient characteristics, nutritional status, and activities of daily living

Data on patient age, sex, primary disease, and nutritional management instructions (type of food and route of nutritional administration) were collected at admission and discharge. Some baseline and discharge data were unavailable because of pragmatic clinical circumstances in routine practice. For patients requiring emergency admission or urgent surgery, nutritional screening (Mini Nutritional Assessment-Short Form [MNA-SF]), anthropometric measurements (e.g., calf circumference [CC], triceps skinfold thickness [TSF], and body weight), or Barthel Index (BI) assessment could not be consistently performed at admission. Discharge data were unavailable in some cases where patients were discharged before scheduled assessments (e.g., weekends or holidays) or when blood tests were not performed in clinically stable patients. Patients with missing data on variables required for the analysis were excluded from the final analysis. Nutritional status at admission was determined using the MNA-SF.[17] Functional assessment of activities of daily living (ADL) was performed using the BI,[18] measured at both admission and discharge. Rehabilitation duration was recorded according to the physician's instructions and rehabilitation implementation reports.

Anthropometric measurements

Height was measured within three days before and after admission. Weight, arm circumference (AC), TSF, and CC were measured on admission and within three days of discharge. Body mass index (BMI) and arm muscle circumference (AMC) were also calculated. AC, TSF, CC, and AMC were adjusted using the Japanese anthropometric reference data (JARD, 2001)19 based on the median percentage for sex and age.

Blood biochemical tests

Haemoglobin (Hb), total serum protein (TP), serum albumin (Alb), total lymphocyte count (TLC), and C-reactive protein (CRP) levels were measured at admission and within 3 days before and after discharge.

Assessment of energy and nutrient intake

Physicians and registered dietitians determined the energy and nutrient contents of hospital-provided meals in accordance with disease-specific guidelines. Meal consumption was evaluated on an 11-point scale (from 0 to 10) recorded in the electronic medical records for each staple and subsidiary meal.[20,21] This 11-point intake recording method is routinely used within the National Hospital Organization, and nurses are trained in this assessment as part of the standard education programme, ensuring a common approach across the participating hospitals. Energy intake per body weight was calculated as the primary exposure, whereas nutrient intake was assessed descriptively to complement the interpretation of energy intake.[4]

Nurses recorded any additional food and drinks consumed outside of hospital meals that were included in the total intake calculations. For patients receiving infusions and tube feeding, the nutrient content was calculated based on the dosage recorded in electronic medical records, and total energy intake was calculated as the sum of energy from all nutritional routes (oral, enteral nutrition [EN], and parenteral nutrition [PN]).

Energy and nutrient intake at admission were calculated as the average of four consecutive days, starting from the second day of hospitalisation.[22] The intake at discharge was calculated as the average from three days before discharge to the day before discharge.[23] Data from patients who fasted during the survey period for surgery or other reasons and received peripheral PN were included to accurately reflect nutritional management during hospitalisation.

Estimated energy requirements (EER) were calculated using the basal energy expenditure obtained from the National Institutes of Biomedical Innovation, Health, and Nutrition formula for Japanese individuals,[24] multiplied by the activity coefficient (1.0–1.4) and the stress coefficient (1.0–1.5). As part of routine clinical practice at each participating hospital, these coefficients were assigned by the attending physicians and registered dietitians based on a predefined common framework, considering each patient's activities of daily living, rehabilitation intensity, and degree of surgical or inflammatory stress.[25]

The EER was primarily calculated using each patient's measured body weight, including those who were underweight or overweight outside the normal weight range for Japanese individuals (18.5 ≤BMI ≤24.9 kg/m²).[4, 5, 26]

Patients with a value of 100% or higher were classified as the 'sufficient intake group', and those with a value below 100% were classified as the 'insufficient intake group'.

Personnel responsible for data collection

Nutritional screening was conducted jointly by a doctor, a nurse, and a registered dietitian. Physical measurements were performed by a nurse or registered dietitian, and ADL assessments were conducted by a nurse or physical therapist. Food intake was assessed by a nurse, and nutritional values were calculated by a registered dietitian.

Statistical analysis

All values are expressed as means ± standard deviation, median (interquartile range), or percentage. All analyses were performed using IBM SPSS Statistics software (version 31.0; IBM Corp., Armonk, NY, USA).

Chi-squared test or Fisher's exact test was used to compare qualitative variables between the two groups. Within-group temporal changes were evaluated by using paired t-tests for continuous variables. For categorical variables, McNemar's test was applied to binary variables, and the McNemar–Bowker test was used for multinomial variables (e.g. dietary type). For comparisons of normally distributed data between two independent groups, Student's t-test was applied, whereas the Mann–Whitney U test was used for non-normally distributed data.

The effect sizes for group comparisons shown in Table 3 were calculated as Hedges' g (95% confidence interval [CI]). According to Cohen's convention, values of 0.2, 0.5, and 0.8 were interpreted as small, medium, and large effects, respectively.[27]

In addition, to assess sample size adequacy, a post-hoc power analysis was performed using G*Power (version 3.1.9.7) under the conditions of $\alpha = 0.05$ and power = 0.80. The minimum detectable effect size was estimated as Cohen's d = 0.41, which is close to a medium effect.

Multivariate analysis was performed using logistic regression with odds ratios (ORs), 95% CIs, and p-values, with adjustment for age, sex, and other relevant covariates identified in the univariate analyses. Continuous variables were rescaled for interpretability: age per 10-year increase, energy intake per 5 kcal/kg/day increase, and CC and TSF per 10% increase (expressed as ratios relative to the JARD2001 reference). CRP was log-transformed because of its right-skewed distribution to improve model stability and satisfy the linearity assumption in the logit.

The linearity assumption for age, baseline energy intake, and CRP was checked using alternative specifications (categorised variables). Model discrimination for the fully adjusted model was assessed using the area under the receiver operating characteristic (ROC) curve. Model stability was assessed using the events-per-variable (EPV) ratio; across Models 1–3, the EPV ranged from 9.9 to 13.8 (69 events with 5–7 parameters), which was close to or exceeded the conventional threshold of 10. Because EERs reflect physical activity level, the BI at admission (an ADL indicator) was included as an additional covariate. For the binary outcome (energy intake sufficiency at discharge, defined as ≥100% of estimated energy requirement), inverse probability weighting (IPW)–weighted multivariable logistic regression models were used to account for potential selection bias due to missing discharge data; the probability of having complete discharge data was estimated using logistic regression based on baseline characteristics. Of the 410 consented patients, 382 were included in the multiple imputation analysis, whereas 28 were excluded because missingness in both admission and discharge variables precluded reliable imputation. In addition to the binary outcome analysis, multivariable linear regression analyses were conducted for the continuous outcome 'energy intake sufficiency ratio at discharge'. All statistical tests were two-tailed, and a p-value <0.05 was considered statistically significant.

Ethics statement

A registered dietitian explained the study to the patients, both orally and in writing, and informed consent was obtained prior to participation. The study was conducted in accordance with the principles of the Declaration of Helsinki. This study was approved by the ethics committee of the National Hospital Organisation Fukuoka Hospital (approval number F31-07), followed by approval by the ethics review committees of each participating hospital. This was a prospective, multicentre, observational study with no intervention or treatment allocation. Because this was an exploratory observational study and involved no interventional components, it was not included in the clinical trial registry.

RESULTS

Nutritional indicators for hospitalised patients: Disease-specific analysis

To ensure that data exclusion did not introduce selection bias, the baseline characteristics of the patients included in the final analysis were compared with those of patients excluded because of missing discharge data (Supplementary Table 1). Except for CRP and AC, which were higher among the excluded patients, possibly reflecting greater disease severity, no significant differences were observed in anthropometric, biochemical, or functional parameters at admission. The exclusion criteria included terminal-stage cases and patients who died prior to discharge. Patients receiving EN or PN were included in the analyses. The proportion of patients receiving EN/PN at admission was 4.1% in the analysed cohort and was comparable among those included in the final analysis and those excluded owing to missing discharge data ($p = 0.350$).

The final analysis included 222 patients (125 men and 97 women; mean age 78.9 ± 7.6 years) out of 410 initially enrolled, after excluding those with missing data. According to the MNA-SF assessment at admission, 75.7% of patients were classified as malnourished or at risk of malnutrition, with the highest proportion observed in patients with respiratory disease (84.1%).

Regarding physical measurements, the mean BMI and adjusted values for other anthropometric indices (AC, TSF, AMC, and CC)[19] were lower in patients with respiratory diseases than in those with other conditions. In addition, the average energy intake (kcal/kg/day) was low in all disease groups.

Although the type of food provided on admission varied according to the disease, the proportion of patients receiving regular and therapeutic diets with energy, fat, or salt restrictions was approximately equal (Table 1).

Next, we compared dietary type, energy and nutrient intake, blood test indices, and anthropometric measurements between admission and discharge. Energy intake increased during hospitalisation across all disease groups, although this increase was not statistically significant in all disease groups; however, the proportion of patients who achieved their estimated energy requirements at discharge remained low: 32.4% for heart disease, 43.8% for cerebrovascular disease, 21.6% for respiratory disease, and 34.7% for musculoskeletal disease (Table 2). In addition, the median percentages of energy intake at discharge relative to the EERs were 83.0%, 85.0%, 84.0%, and 84.0% for heart, cerebrovascular, respiratory, and musculoskeletal disease, respectively (Supplementary Table 2).

Despite increased energy intake during hospitalisation, most anthropometric and blood biochemical parameters significantly decreased or tended to decrease across all disease groups (Table 2).

Conversely, the proportion of patients who underwent rehabilitation with therapists and the time spent on rehabilitation remained constant throughout the hospitalisation period (Supplementary Table 3). BI scores at discharge were significantly higher than those at admission. When analysed by disease, the median BI score at discharge for patients with heart and respiratory diseases was 100, indicating independence, whereas those with cerebrovascular disease scored above the benchmark of 85, indicating independence (Table 2).

Finally, to complement the energy intake findings, nutrient intake was compared by meal type; energy and protein intake were significantly lower in patients on a therapeutic diet than in those on a regular diet at both admission and discharge (Supplementary Table 4).

Factors determining energy intake at discharge

Patients were categorised into two groups based on whether their energy intake at discharge was sufficient or insufficient relative to their estimated energy requirements. Univariate analysis revealed significant differences in sex, energy intake, MNA-SF classification, CRP levels, BMI, and TSF scores at admission, although no statistically significant differences were observed by disease category (Table 3).

Subsequently, logistic regression analysis was performed to identify the factors associated with sufficient or insufficient energy intake at discharge because differences observed in univariate analyses may change after covariate adjustment; therefore, variables that showed significant associations in the univariate analysis (sex, CRP, and energy intake at admission), as well as clinically relevant variables (age), were included as covariates (Table 4). BMI was not included in the primary model because it was considered a potential confounding factor in estimating energy requirements and overlapped with other anthropometric measures. Instead, CC (as a proxy for BMI) was used as the anthropometric covariate in Model 1. To examine the effects of nutritional status at admission and energy reserves, Model 2 was specified as an alternative model incorporating the MNA-SF and TSF scores. In addition, to evaluate the influence of disease category, Model 3 included disease category as a substitute covariate (Table 4). In sensitivity analyses after additional adjustment for the BI at admission, the BI itself was not independently associated with energy intake sufficiency at discharge, whereas the associations of sex, CRP, and energy intake at admission remained statistically significant (data not shown). Sensitivity analyses using generalised estimating equations with hospital-level clustering yielded directionally and quantitatively consistent results with those of the multivariable logistic regression analyses, supporting the robustness of the primary findings (data not shown).

The multivariate analysis identified several significant factors associated with achieving the EERs at discharge. Older age, female sex, and higher energy intake at admission were independently associated with energy intake sufficiency at discharge, whereas higher CRP levels at admission were inversely associated with energy intake sufficiency. CC was not a significant independent predictor after covariate adjustment. In the alternative model (Model 2), the associations among age, sex, CRP level, and energy intake at admission remained consistent, and the TSF and MNA-SF scores were not significant predictors. These associations were maintained in Model 3, which incorporated disease category, and disease category itself was identified as a significant factor (Table 4). The discriminative ability of the fully adjusted model was reflected by an area under the ROC curve of 0.914 (95% CI, 0.878–0.951). To assess the potential impact of selection bias due to missing discharge data, we conducted sensitivity analyses using IPW. The IPW-weighted logistic regression analysis and the corresponding multivariable linear regression analysis produced results broadly consistent with those obtained using the multivariable logistic regression models presented in Table 4. The direction of associations remained similar, and sex, CRP level, and energy intake at admission remained significantly associated with energy intake sufficiency at discharge (Supplementary Table 5). The results of the multiple imputation analysis were also consistent with those of the primary complete-case analysis (Supplementary Table 6).

Furthermore, to investigate disease-specific patterns in greater detail, we compared baseline characteristics between patients with adequate and inadequate energy intake at discharge and conducted supplementary analyses within each disease category

(Supplementary Table 7). Across all disease groups, higher energy intake at admission was consistently associated with energy sufficiency at discharge. However, other associated factors differed by disease category, suggesting disease-specific patterns.

DISCUSSION

In this multicentre observational study, we examined changes in energy intake and related nutritional status among older adults requiring long-term rehabilitation in general hospitals, and identified several implications for nutritional management.

The first was that 75.7% of patients were classified as malnourished or at risk of malnutrition, which was notably higher than that reported for hospitalised patients in other studies.[2] Notably, patients with respiratory diseases had a higher prevalence of malnutrition or related risk factors (84.1%). Chronic respiratory failure, particularly in conditions such as COPD, has been shown to increase the risk of undernutrition as the disease progresses, with cachexia observed in 30–60% of hospitalised patients in Western countries.[11] Although differences in nutritional assessment and cachexia evaluation methods make direct comparisons challenging, there is a consensus that patients with chronic respiratory failure are at an elevated risk of malnutrition. Therefore, it is crucial to not only assess nutritional status at admission but also consider the presence of underweight status, which is associated with poor prognosis.[11] Previous studies have suggested that the prognostic performance of the MNA or MNA-SF is only low to moderate, and concerns have been raised regarding its potential to overestimate malnutrition risk.[28] Accordingly, our findings are discussed mainly in relation to nutrient intake and anthropometric measurements rather than MNA-SF risk alone.

Second, although energy intake increased overall during hospitalisation, this increase was not statistically significant in all disease groups, and the proportion of patients who met their EERs remained low. A previous study in Japan found that the prevalence of malnutrition in 205 older adults with stroke increased from 42% at admission to 72% at discharge, as assessed using the Geriatric Nutritional Risk Index.[8] Additionally, in acute cerebrovascular diseases, including stroke, malnutrition has been reported to increase during hospitalisation owing to feeding and swallowing disorders following stroke onset, resulting in insufficient intake of energy, proteins, and other nutrients.[7,8] In the present study, changes in several nutritional indicators during hospitalisation were observed, in patients with cerebrovascular disease and those with cardiovascular, respiratory, and musculoskeletal diseases, all of whom required rehabilitation. This decline may be attributed to factors such as disease-associated appetite loss.[29]

Therapeutic diet prescriptions are based on clinical needs and do not necessarily reflect inadequate intake. For example, overweight patients with cardiovascular disease may require reduced total energy but not reduced protein levels. Such diets, including sodium-restricted or fat-modified diets, are intentionally designed to restrict specific nutrients and total energy for disease management while aiming to maintain adequate levels of other nutrients.

In the present study, patients receiving therapeutic diets tended to have lower energy and protein intakes than those receiving regular diets. Nevertheless, this difference should be interpreted with caution, as therapeutic diet prescriptions reflect clinical indications and patient conditions, and patients receiving therapeutic diets may differ systematically in clinical characteristics, including swallowing function, comorbidity burden, and dietary restrictions. Given that 75.7% of our participants were classified as malnourished or at risk of malnutrition at admission, careful consideration is required regarding whether restrictive dietary therapies based on disease-specific guidelines are always optimal for older adults requiring rehabilitation. In particular, factors such as reduced palatability or disease-related conditions may be associated with decreased appetite and food intake.[30] Among frail older adults undergoing rehabilitation, such unintended reductions in intake could contribute to muscle loss and impaired functional recovery; therefore, the present findings should be interpreted as associations rather than causal interpretations regarding the effect of diet type itself. In some cases, the continued prescription of therapeutic diets may have been intended not for sodium reduction but for energy restriction (weight reduction). Given that weight reduction in older adults requires careful attention[31] and may not always be desirable during hospitalisation when rehabilitation is required, such dietary strategies may not always align with individual nutritional needs.

In the present study, the clinical intent underlying therapeutic diet prescriptions and the degree of dietary restriction were not evaluated; therefore, the appropriateness of therapeutic diets cannot be directly verified. The observed changes may suggest that nutritional management may not have been fully aligned with patients' changing clinical conditions. Accordingly, flexible nutritional management that comprehensively considers nutritional status, inflammation, physical function, and rehabilitation dose is required, and periodic reevaluation of therapeutic diets should also be considered.

In contrast, the rehabilitation time remained consistent, and the expansion of ADL was presumed to increase energy expenditure. Consequently, the anthropometric measurements and blood biochemical parameters declined during hospitalisation. These findings may suggest possible deterioration in nutritional status during hospitalisation, regardless of underlying disease. Some of the observed biomarkers, such as albumin and total lymphocyte count, may be influenced by inflammation, hydration status, and disease severity, and therefore do not necessarily reflect nutritional status independently. Therefore, the observed changes should be interpreted as suggestive of possible nutritional deterioration rather than definitive evidence. This decline may be associated with insufficient dietary intake relative to the increased energy expenditure associated with rehabilitation and ADL expansion.

Third, in the univariate analysis, significant differences were observed in sex, CRP level, BMI, TSF, and energy intake at admission between patients with sufficient and insufficient energy intake at discharge; therefore, a multivariable binary logistic regression analysis was performed to account for potential confounding factors. Age was included as a clinically relevant covariate. Because the components of BMI (height and body weight) were used in the calculation of estimated energy requirements, BMI was excluded to avoid collinearity, and CC was used as an alternative anthropometric variable.

After adjusting for these variables, multivariate logistic regression analyses showed that energy intake at admission, age, sex, and CRP level, were associated with achieving the EERs at discharge in the models.

Although EERs tend to be lower in older adults, the effect of age is not straightforward, as it is also influenced by comorbidities, functional status, and appetite. Since evidence regarding age- and sex-related differences in dietary intake during hospitalisation remains limited, this interpretation should be made with caution. Because energy sufficiency is defined relative to estimated energy requirements, which are partly determined by age, sex, and body size, the observed associations may partly reflect lower requirements rather than higher actual intake.

Although CRP levels reflect disease severity and inflammatory burden, recent studies have shown that acute inflammation can directly influence appetite and food intake via inflammatory mediators. Therefore, CRP may not only act as a confounding factor but also represent a potential determinant, serving as a physiological indicator linking inflammation to reduced nutritional intake.[32,33]

In contrast, the MNA-SF score at admission was not independently associated with energy sufficiency at discharge after covariate adjustment. The MNA-SF is a screening tool designed to rapidly identify the risk of malnutrition; however, it is known to be susceptible to the effects of acute illness and inflammatory burden, which may lead to an overestimation of malnutrition risk.[28] Because the MNA-SF includes items related to dietary intake and disease-related stress, the score may be influenced by inflammatory status at admission, as reflected by CRP, as well as by actual energy intake in the early phase of hospitalisation. Accordingly, the informational overlap between MNA-SF, inflammation, and energy intake may partly explain the lack of an independent association in the multivariate models.

Disease category showed a significant association with energy sufficiency after covariate adjustment in the logistic regression analysis, although no significant difference was observed in the univariate analysis; therefore, this finding should be interpreted with caution. This is because the EER used in this study was calculated using a uniform method for research purposes and did not necessarily correspond to the dietary management actually implemented at each participating institution. Accordingly, the observed association may have been influenced by differences in case mix, the method used to assign EERs, and residual confounding inherent in the observational study design.

Energy intake at admission was associated with energy sufficiency at discharge across disease groups. In contrast, after additional adjustment for disease category, the associations with sex, CRP, and energy intake at admission remained, whereas age was not a significantly associated factor. This pattern suggests that the observed associations may reflect patient background or clinical status rather than differences attributable to the underlying diseases. Because energy sufficiency is defined relative to estimated energy requirements, these associations may partly reflect differences in estimated requirements rather than actual intake.

Although length of stay has often been considered a potential confounder in nutritional outcomes, our analysis did not find a significant association between length of stay and energy sufficiency at discharge.[34] This may be explained by the study design, as only patients expected to stay for at least 3 weeks were included, thereby reducing variability in length of stay and attenuating its association with nutritional outcomes.

Proactive nutritional interventions at an early stage are essential for addressing this issue. In addition to initiating early interventions, careful monitoring of food intake and adjustments to dietary content, including meal-type modifications, are necessary to prevent unintended nutritional deterioration during hospitalisation. These findings suggest that nutritional management in general hospitals may be insufficient for patients requiring rehabilitation, particularly those with inflammatory conditions or poor intake at admission, indicating the need for earlier and more individualised nutritional management.

This study had several limitations. The first limitation relates to the method used to calculate EER. In this study, the EER was calculated using the actual body weight of all participants, including underweight and overweight patients, based on methods commonly used in previous studies[35,36] and routine clinical practice, with activity and stress coefficients assigned according to a standardised clinical framework.[25] Although these coefficients were determined using established clinical criteria, their individual-level appropriateness could not be formally evaluated in this study, partly owing to incomplete recording. This approach may underestimate the energy requirements of underweight patients, particularly those with a BMI <18.5 kg/m², from the perspective of rehabilitation nutrition aimed at restoring body weight and skeletal muscle mass. Consequently, the proportion of underweight patients who achieved energy sufficiency at discharge might have been overestimated. Because this was a non-interventional multicentre observational study, and energy prescriptions during hospitalisation were determined by each institution, we prioritised consistency with real-world clinical practice using actual body weight for analysis. Importantly, this potential underestimation does not weaken our conclusion that energy intake during hospitalisation was insufficient; rather, it suggests that the degree of energy inadequacy may have been greater than that observed. Similar results were obtained when the target body weight was applied to underweight patients. Because intake at discharge was calculated as the average over the last three days, it might have been influenced by discharge-related procedures or fasting. In our cohort, five patients experienced fasting during this period, and the possible effect of this cannot be ruled out.

Second, although several anthropometric and biochemical markers declined during hospitalisation, some indicators, such as albumin and total lymphocyte count, are influenced by inflammation, hydration status, and disease severity and therefore do not independently establish nutritional deterioration. In addition, because nutritional status was not formally assessed at discharge using MNA-SF or other diagnostic criteria, the extent of change in nutritional status during hospitalisation cannot be conclusively determined. Future studies should assess nutritional status at both admission and discharge using validated diagnostic criteria, including the GLIM criteria.[37]

Third, although the sample size was relatively small for certain disease groups, this nationwide multicentre study involving 41 hospitals provided data from 222 patients, allowing estimation of the primary outcome with a 95% CI half-width of 6.3%, indicating a reasonable level of precision for an observational study. However, inter-hospital variability was not accounted for in the primary statistical analysis, which may have influenced the results. In sensitivity analyses accounting for hospital-level clustering using generalized estimating equations, the results were directionally and quantitatively consistent with those of the main multivariable model, suggesting that the findings were not materially affected by hospital-level clustering.

Fourth, anthropometric measurements such as AC, TSF, AMC, and CC were conducted by registered dietitians at each hospital, which may have introduced inter- and intra-observer variability.[38] However, because all assessors were experienced registered dietitians familiar with anthropometric assessments and followed the JARD measurement manual,19 measurement errors were considered minimal.

Fifth, the potential sources of bias should be acknowledged. Although data collection was conducted by registered dietitians following a standardised manual, some degree of variability in dietary intake assessment across facilities, including inter-rater differences, may have occurred. Nevertheless, the study was conducted across 41 National Hospital Organization facilities nationwide to minimise potential regional bias. From the initial cohort, 188 patients were excluded owing to missing admission data, predefined exclusion criteria, or missing discharge data. Comparisons based on admission data showed no significant differences between patients with and without available discharge data for most variables; however, CRP levels were significantly higher in those without discharge data, suggesting that missingness might have been related to greater clinical severity or unstable clinical courses. A small proportion of patients received EN or PN, and the distribution did not differ between patients with and without discharge data. Sensitivity analyses using IPW showed that the main associations were generally consistent (Supplementary Table 5). Multiple imputation analyses yielded similar results; however, residual selection bias cannot be completely excluded. The lack of differences in EN/PN distribution and the overall consistency of the results suggest that any potential bias introduced by alternative feeding routes was limited, indicating that the principal conclusions were unlikely to have been substantially influenced by missing discharge data. Consequently, the degree of nutritional deterioration and energy intake insufficiency observed during hospitalisation may have been underestimated compared with that in the overall target population. To address these potential sources of bias, the analyses were adjusted for major confounding factors, including CRP. Although this approach cannot completely eliminate survival bias, it was intended to improve the transparency of the analysis. All participants were recruited from National Hospital Organization hospitals, and the generalisability of the findings to other healthcare settings may therefore be limited.

However, the use of data collected nationwide using a uniform protocol is a strength of this study. In addition, this study provides valuable insights into the nutritional management of older adults requiring rehabilitation who were hospitalised in general hospitals across Japan, a population for which few studies have been conducted.

Conclusions

Older adults hospitalised in general hospitals with cardiovascular, cerebrovascular, respiratory, or musculoskeletal diseases requiring rehabilitation had increased energy intake during hospitalisation. However, despite this increase, energy intake remained insufficient, which may have contributed to a decline in nutritional status in this cohort. Regardless of nutritional status at admission, careful consideration of meal content and continuous nutritional monitoring from the time of admission are essential to prevent unintended deterioration of nutritional status.

SUPPLEMENTARY MATERIALS

All supplementary tables and figures are available upon request from the editorial office, and are also accessible on the journal's webpage (apjcn.qdu.edu.cn).

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CONFLICT OF INTEREST AND FUNDING DISCLOSURE

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Table 1. Patient characteristics, nutritional management, biochemical parameters, and anthropometric measurements at admission

	All patients	Cardiovascular disease	Cerebrovascular disease	Respiratory disease	Musculoskeletal disease
Sex (Male/Female), n	125 / 97	21 / 16	37 / 11	56 / 32	11 / 38
[Proportion, %]	56.3 / 43.7	56.8 / 43.2	77.1 / 22.9	63.6 / 36.4	22.4 / 77.6
Length of hospital stay	26.2 ± 15.3	18.4 ± 8.2	22.4 ± 11.5	25.9 ± 16.8	36.2 ± 15.1
Age (years)	78.9 ± 7.6	80.3 ± 9.2	77.4 ± 7.3	78.5 ± 6.6	79.9 ± 8.2
MNA-SF					
Total Score (Maximum: 14)	10 (8.0–11.0)	11.0 (9.0–12.0)	10.0 (7.5–11.0)	9.5 (7.0–11.0)	10 (9.0–12.0)
Normal (12–14 points) [n/%]	54 / 24.3	13 / 35.1	8 / 16.7	14 / 15.9	19 / 38.8
At risk (8–11 points) [n/%]	124 / 55.9	21 / 56.8	28 / 58.3	49 / 55.7	26 / 53.1
Malnourished (0–7 points) [n/%]	44 / 19.8	3 / 8.1	12 / 25.0	25 / 28.4	4 / 8.2
Dietary type [n/%]					
Regular diets	87 / 39.2	3 / 8.1	8 / 16.7	63 / 71.6	13 / 26.5
Therapeutic diets	85 / 38.3	30 / 81.1	21 / 43.7	11 / 12.5	23 / 46.9
Other (Modified Texture Diets, PN, EN)	50 / 22.5	4 / 10.8	19 / 39.6	14 / 15.9	13 / 26.5
Estimated Energy Requirements (kcal/kg/day)	30.6 ± 6.7	27.5 ± 3.9	24.6 ± 3.8	36.6 ± 5.4	28.2 ± 3.5
Energy Intake (kcal/kg/day)	24.5 ± 8.5*	23.5 ± 6.4*	20.3 ± 5.9*	28.0 ± 8.6*	23.2 ± 9.2*
Biochemical parameters					
Hb (g/dL)	12.8 ± 1.9	12.8 ± 1.8	13.3 ± 2.0	12.9 ± 1.7	12.3 ± 1.9
Alb (g/dL)	3.7 ± 0.5	3.9 ± 0.4	3.9 ± 0.6	3.5 ± 0.6	3.8 ± 0.5
TLC (/µL)	1,323 ± 613	1,277 ± 639	1,549 ± 635	1,209 ± 535	1,349 ± 667
CRP (mg/dL)	0.38 (0.11–2.24)	0.11 (0.03–0.41)	0.24 (0.07–0.65)	1.52 (0.26–6.77)	0.38 (0.07–1.92)
Anthropometric parameters					
BMI (kg/m^2)	22 ± 4.1	22.8 ± 3.2	23.9 ± 3.7	20.3 ± 3.8	22.5 ± 4.2
AC (%)	99 ± 16	103 ± 14	105 ± 15	95 ± 18	98 ± 13
TSF (%)	94 ± 54	103 ± 40	120 ± 64	83 ± 52	81 ± 48
AMC (%)	100 ± 17	103 ± 12	103 ± 15	97 ± 21	102 ± 13
CC (%)	98 ± 13	102 ± 10	101 ± 13	93 ± 12	101 ± 12
BI	60 (30–100)	90 (60–100)	30 (25–60)	88 (45–100)	50 (30–95)

PN, parenteral nutrition; EN, enteral nutrition; Hb, haemoglobin; Alb, albumin; TLC, total lymphocyte count; CRP, C-reactive protein; MNA-SF, Mini Nutritional Assessment-Short Form; BMI, body mass index; AC, arm circumference; TSF, triceps skinfold thickness; AMC, arm muscle circumference; CC, calf circumference; BI, Barthel Index.

Continuous variables (e.g. length of hospital stay, age, BMI, estimated energy requirements, energy intake, Hb, TLC, AC, TSF, AMC, and CC) are presented as means ± standard deviation (SDs).

Categorical variables (e.g. sex, dietary type, and nutritional status by MNA-SF) were reported as frequencies and percentages (n [%]).

CRP, Barthel Index (BI), and MNA-SF scores were expressed as medians with interquartile ranges (IQR).

Anthropometric values (AC, TSF, AMC, and CC) are presented as percentages of the reference values (JARD, 2001).

*$p < 0.01$ for comparisons between estimated energy requirements and energy intake.

Table 2. Changes in nutrient intake, biochemical parameters, and functional status from admission to discharge

	All Patients (222)			Cardiovascular Disease (37)		
	At admission	At discharge	p-value	At admission	At discharge	p-value
Dietary category [n/%]						
Regular diets	87 / 39.2	97 / 43.7	<0.001	3 / 8.1	4 / 10.8	0.223
Therapeutic diets	85 / 38.3	104 / 46.8		30 / 81.1	32 / 86.5	
Other (Modified Texture Diets, PN, EN)	50 / 22.5	21 / 9.5		4 / 10.8	1 / 2.7	
Nutrient intake						
Energy (kcal/kg/day)	24.5 ± 8.5	27.3 ± 7.9	<0.001	23.5 ± 6.4	25.0 ± 5.6	0.073
Energy (kcal/day)	1272 ± 395	1391 ± 321	<0.001	1269 ± 339	1306 ± 261	0.412
Energy intake sufficiency (%)	80.0 (64.8–98.3)	84.0 (71.0–98.4)	0.081	89.0 (70.0–101.5)	83.0 (72.5–100.5)	0.506
Proportion exceeding estimated energy requirements (%)	23.0	31.1	0.001	24.3	32.4	0.453
Protein (g/kg/day)	0.98 ± 0.35	1.10 ± 0.34	<0.001	0.94 ± 0.28	0.96 ± 0.29	0.619
Protein (g/day)	50.4 ± 15.8	55.7 ± 12.9	<0.001	50.6 ± 13.9	49.7 ± 13.8	0.677
Fat (g/kg/day)	0.59 ± 0.23	0.67 ± 0.25	<0.001	0.54 ± 0.24	0.64 ± 0.29	0.039
Carbohydrates (g/kg/day)	3.71 ± 1.43	4.21 ± 2.69	0.002	3.36 ± 1.44	3.73 ± 1.32	0.012
Biochemical parameters						
Hb (g/dL)	12.8 ± 1.9	12.4 ± 1.8	<0.001	12.8 ± 1.8	12.3 ± 1.8	0.012
Alb (g/dL)	3.7 ± 0.5	3.5 ± 0.4	<0.001	3.9 ± 0.4	3.6 ± 0.3	<0.001
TLC (/µL)	1,323 ± 613	1,516 ± 633	<0.001	1,277 ± 639	1,319 ± 587	0.629
CRP (mg/dL)	0.38 (0.11–2.24)	0.30 (0.08–1.08)	<0.001	0.11 (0.03–0.41)	0.13 (0.04–0.44)	0.487
Anthropometric parameters						
BMI (kg/m^2)	22.0 ± 4.1	21.6 ± 3.9	<0.001	22.8 ± 3.2	22.2 ± 3.6	0.001
AC (%)	99 ± 16	94 ± 14	<0.001	103 ± 14	97 ± 15	<0.001
TSF (%)	94 ± 54	91 ± 55	0.224	103 ± 40	98 ± 37	0.138
AMC (%)	100 ± 17	100 ± 16	0.475	102 ± 12	102 ± 12	0.799
CC (%)	98 ± 13	97 ± 13	0.039	102 ± 10	100 ± 10	0.197
Functional assessment of daily living						
BI	60 (30–100)	90 (55–100)	<0.001	90 (60–100)	100 (70–100)	0.114

PN, parenteral nutrition; EN, enteral nutrition; Hb, haemoglobin; Alb, albumin; TLC, total lymphocyte count; CRP, C-reactive protein; MNA-SF, Mini Nutritional Assessment–Short Form; BMI, body mass index; AC, arm circumference; TSF, triceps skinfold thickness; AMC, arm muscle circumference; CC, calf circumference; BI, Barthel Index. Statistical analyses: Paired t-test (admission vs. discharge), McNemar–Bowker test (dietary type), McNemar test (proportion exceeding the estimated energy requirements), and Wilcoxon signed-rank test (CRP, BI).

Dietary types are presented as the number of individuals and percentages.

Energy (kcal/kg/day and kcal/day), protein (g/kg/day and g/day), fat, carbohydrates, Hb, Alb, TLC, BMI, AC, TSF, AMC, and CC are presented as mean ± standard deviation (SD).

CRP and BI and energy intake sufficiency (%) are expressed as median (interquartile range, IQR).

Energy intake sufficiency (%) was calculated as the ratio of energy intake to the estimated energy requirement, multiplied by 100.

AC, TSF, AMC, and CC are expressed as percentages of the Japanese Anthropometric Reference Data (JARD 2001).

Table 2. Changes in nutrient intake, biochemical parameters, and functional status from admission to discharge (cont.)

	Cerebrovascular Disease (48)			Respiratory Disease (88)		
	At admission	At discharge	p-value	At admission	At discharge	p-value
Dietary category [n/%]						
Regular diets	8 / 16.7	13 / 27.1	0.072	63 / 71.6	61 / 69.3	0.058
Therapeutic diets	21 / 43.7	25 / 52.1		11 / 12.5	18 / 20.5	
Other (Modified Texture Diets, PN, EN)	19 / 39.6	10 / 20.8		14 / 15.9	9 / 10.2	
Nutrient intake						
Energy (kcal/kg/day)	20.3 ± 5.9	22.8 ± 6.2	<0.001	28.0 ± 8.6	30.5 ± 8.2	<0.001
Energy (kcal/day)	1226 ± 381	1364 ± 340	0.002	1370 ± 408	1470 ± 343	0.003
Energy intake sufficiency (%)	85.0 (62.5–104.8)	85.0 (63.8–97.8)	0.659	77.5 (65.0–91.0)	84.0 (73.0–96.8)	0.001
Proportion exceeding estimated energy requirements (%)	29.2	43.8	0.065	14.8	21.6	0.031
Protein (g/kg/day)	0.78 ± 0.26	0.92 ± 0.25	<0.001	1.11 ± 0.37	1.22 ± 0.34	<0.001
Protein (g/day)	46.8 ± 15.8	54.2 ± 13.3	<0.001	53.7 ± 16.2	58.4 ± 12.7	0.003
Fat (g/kg/day)	0.60 ± 0.27	0.70 ± 0.28	<0.001	0.58 ± 0.24	0.66 ± 0.23	<0.001
Carbohydrates (g/kg/day)	3.79 ± 1.64	4.90 ± 5.20	0.002	3.60 ± 1.43	3.85 ± 1.26	0.012
Biochemical parameters						
Hb (g/dL)	13.3 ± 2.0	12.7 ± 1.9	0.01	12.9 ± 1.7	12.7 ± 1.6	0.147
Alb (g/dL)	3.9 ± 0.6	3.5 ± 0.5	<0.001	3.5 ± 0.6	3.4 ± 0.4	0.311
TLC (/µL)	1,549 ± 635	1,740 ± 462	0.043	1,209 ± 535	1,508 ± 658	<0.001
CRP (mg/dL)	0.24 (0.07–0.65)	0.25 (0.09–1.24)	0.395	1.52 (0.26–6.77)	0.44 (0.17–1.04)	<0.001
Anthropometric parameters						
BMI (kg/m²)	23.9 ± 3.7	23.5 ± 3.4	0.007	20.3 ± 3.8	20.0 ± 3.8	<0.001
AC (%)	105 ± 15	99 ± 10	<0.001	95 ± 18	92 ± 16	0.001
TSF (%)	120 ± 64	125 ± 77	0.324	83 ± 52	74 ± 47	0.054
AMC (%)	103 ± 15	98 ± 12	0.003	97 ± 21	100 ± 21	0.112
CC (%)	101 ± 13	100 ± 14	0.454	93 ± 12	93 ± 12	0.675
Functional assessment of daily living						
BI	30 (25–60)	90 (40–99)	<0.001	88 (45–100)	100 (50–100)	0.001

PN, parenteral nutrition; EN, enteral nutrition; Hb, haemoglobin; Alb, albumin; TLC, total lymphocyte count; CRP, C-reactive protein; MNA-SF, Mini Nutritional Assessment–Short Form; BMI, body mass index; AC, arm circumference; TSF, triceps skinfold thickness; AMC, arm muscle circumference; CC, calf circumference; BI, Barthel Index. Statistical analyses: Paired t-test (admission vs. discharge), McNemar–Bowker test (dietary type), McNemar test (proportion exceeding the estimated energy requirements), and Wilcoxon signed-rank test (CRP, BI).

Dietary types are presented as the number of individuals and percentages.

Energy (kcal/kg/day and kcal/day), protein (g/kg/day and g/day), fat, carbohydrates, Hb, Alb, TLC, BMI, AC, TSF, AMC, and CC are presented as mean ± standard deviation (SD).

CRP and BI and energy intake sufficiency (%) are expressed as median (interquartile range, IQR).

Energy intake sufficiency (%) was calculated as the ratio of energy intake to the estimated energy requirement, multiplied by 100.

AC, TSF, AMC, and CC are expressed as percentages of the Japanese Anthropometric Reference Data (JARD 2001).

Table 2. Changes in nutrient intake, biochemical parameters, and functional status from admission to discharge (cont.)

	Musculoskeletal Disease (49)		
	At admission	At discharge	p-value
Dietary category [n/%]			
Regular diets	13 / 26.5	19 / 38.8	0.007
Therapeutic diets	23 / 46.9	29 / 59.2	
Other (Modified Texture Diets, PN, EN)	13 / 26.5	1 / 2.0	
Nutrient intake			
Energy (kcal/kg/day)	23.2 ± 9.2	27.6 ± 7.8	<0.001
Energy (kcal/day)	1142 ± 389	1339 ± 275	<0.001
Energy intake sufficiency (%)	87.0 (53.0–106.0)	84.0 (68.0–103.5)	0.412
Proportion exceeding estimated energy requirements (%)	30.6	34.7	0.625
Protein (g/kg/day)	0.97 ± 0.34	1.16 ± 0.30	<0.001
Protein (g/day)	47.9 ± 15.7	56.7 ± 10.6	<0.001
Fat (g/kg/day)	0.62 ± 0.18	0.70 ± 0.21	0.006
Carbohydrates (g/kg/day)	4.10 ± 1.13	4.52 ± 1.33	0.005
Biochemical parameters			
Hb (g/dL)	12.3 ± 1.9	11.5 ± 1.70	<0.001
Alb (g/dL)	3.8 ± 0.5	3.5 ± 0.5	<0.001
TLC (/µL)	1,349 ± 667	1,460 ± 718	0.271
CRP (mg/dL)	0.38 (0.07–1.92)	0.28 (0.06–1.19)	0.285
Anthropometric parameters			
BMI (kg/m²)	22.5 ± 4.2	22.2 ± 3.7	0.023
AC (%)	98 ± 13	90 ± 13	<0.001
TSF (%)	81 ± 48	82 ± 40	0.853
AMC (%)	102 ± 13	99 ± 14	0.054
CC (%)	101 ± 12	100 ± 11	0.051
Functional assessment of daily living			
BI	50 (30–98)	80 (53–100)	<0.001

PN, parenteral nutrition; EN, enteral nutrition; Hb, haemoglobin; Alb, albumin; TLC, total lymphocyte count; CRP, C-reactive protein; MNA-SF, Mini Nutritional Assessment–Short Form; BMI, body mass index; AC, arm circumference; TSF, triceps skinfold thickness; AMC, arm muscle circumference; CC, calf circumference; BI, Barthel Index. Statistical analyses: Paired t-test (admission vs. discharge), McNemar–Bowker test (dietary type), McNemar test (proportion exceeding the estimated energy requirements), and Wilcoxon signed-rank test (CRP, BI).

Dietary types are presented as the number of individuals and percentages.

Energy (kcal/kg/day and kcal/day), protein (g/kg/day and g/day), fat, carbohydrates, Hb, Alb, TLC, BMI, AC, TSF, AMC, and CC are presented as mean ± standard deviation (SD).

CRP and BI and energy intake sufficiency (%) are expressed as median (interquartile range, IQR).

Energy intake sufficiency (%) was calculated as the ratio of energy intake to the estimated energy requirement, multiplied by 100.

AC, TSF, AMC, and CC are expressed as percentages of the Japanese Anthropometric Reference Data (JARD 2001).

Table 3. Comparison of baseline characteristics between groups with sufficient and insufficient energy intake at discharge

	Adequate group	Inadequate group	p-value	Mean difference (95% CI)	Hedges' g (95% CI)
Age (years)	80.1 ± 7.5	78.3 ± 7.6	0.115	1.8(-0.4 – 3.9)	0.23 (-0.56 – 0.51)
Sex (male/female), [n/%]	25 / 44 (36.2 / 63.8)	100 / 53 (65.4 / 34.6)	<0.001	–	–
Length of hospital stay (days)	26.9 ± 14.8	25.9 ± 15.7	0.654	1.0 (-3.4–5.4)	0.06 (-0.22–0.35)
Disease category, [n/%]					
Cardiovascular/ Cerebrovascular/ Respiratory/ Musculoskeletal	12 / 21 / 19 / 17 (17.4 / 30.4 / 27.5 / 24.6)	25 / 27 / 69 / 32 (16.3 / 17.6 / 45.1 / 20.9)	0.054	–	–
MNA-SF score (max 14)	10.0 (8.0–11.0)	10.0 (8.0–12.0)	0.060	–	–
Dietary type, [n/%]					
Regular diets / Therapeutic diets / Others	24 / 29 / 16 (34.8 / 42.0 / 23.2)	63 / 56 / 34 (41.2 / 36.6 / 22.2)	0.643	–	–
EER (kcal/kg/day)	31.0±5.2	33.0±5.4	0.009	–	–
Energy intake at admission (kcal/kg/day)	29.7 ± 7.8	22.2 ± 7.8	<0.001	7.6 (5.3 – 9.8)	0.97 (0.67 – 1.27)
Biochemical parameters					
Hb (g/dL)	12.8 ± 1.9	12.8 ± 1.9	0.707	-0.1 (-0.6 – 0.4)	-0.05 (-0.34 – 0.23)
Alb (g/dL)	3.8 ± 0.5	3.7 ± 0.6	0.194	0.0 (-0.1 – 0.3)	0.19 (-0.10 – 0.47)
TLC (/µL)	1,162 ± 642	1,240 ± 650	0.405	-78.3 (-263.4 – 106.8)	-0.12 (-0.40 – 0.16)
CRP (mg/dL)	0.26 (0.05–1.02)	0.62 (0.13–3.12)	<0.001	–	–
Anthropometric parameters					
BMI (kg/m²)	21.1 ± 4.3	22.4 ± 3.9	0.026	-1.3 (-2.5 – -0.2)	-0.33 (-0.61 – -0.04)
AC (%)	96.5 ± 14.3	100.0 ± 16.2	0.079	-4.0 (-8.5 – 0.5)	-0.25 (-0.54 – 0.03)
TSF (%)	81.6 ± 53.3	99.3 ± 54.0	0.024	-17.7 (-33.1 – 2.3)	-0.33 (-0.61 – -0.04)
AMC (%)	99.8 ± 14.6	100.1 ± 18.0	0.684	-1.0 (-5.8 – 3.8)	-0.06 (-0.47 – 0.10)
CC (%)	96.4 ± 14.1	98.7 ± 11.8	0.206	-2.3 (-5.9 – 1.3)	-0.18 (-0.41 – 0.16)
BI: functional assessment of daily living	45 (30–100)	65 (35–100)	0.253	–	–

Hb, haemoglobin; Alb, albumin; TLC, total lymphocyte count; CRP, C-reactive protein; MNA-SF, Mini Nutritional Assessment–Short Form; BMI, body mass index; AC, arm circumference; TSF, triceps skinfold thickness; AMC, arm muscle circumference; CC, calf circumference; BI, Barthel Index; EER, estimated energy requirement

Student's t-test was used for continuous variables, and the Mann–Whitney U test was used for non-normally distributed variables (CRP, MNA-SF score, and BI). Categorical variables were compared using the chi-squared test or Fisher's exact test, as appropriate.

Effect size: Hedges' g (95% CI) represents the small-sample-corrected standardised mean difference calculated using the pooled standard deviation; values of 0.2, 0.5, and 0.8 correspond to small, medium, and large effects, respectively.

Data presentation: Continuous variables are presented as mean ± standard deviation (SD), and CRP, BI, and MNA-SF total score are presented as median (interquartile range, IQR). Categorical variables are presented as numbers (percentages).

MNA-SF classification: 0–7 (malnourished), 8–11 (at risk), and 12–14 (normal).

EER: estimated energy requirement calculated using sex-specific equations proposed by the National Institute of Health and Nutrition, Japan.

Anthropometric indices (AC, TSF, AMC, and CC) are presented as percentages of reference values (JARD, 2001).

Table 4. Factors at admission associated with energy sufficiency at discharge

Variable	Model 1			Model 2			Model 3		
	OR	95% CI (lower – upper)	p-value	OR	95% CI (lower – upper)	p-value	OR	95% CI (lower – upper)	p-value
Age (per 10-year increase)	1.77	1.09 – 2.90	0.022	1.66	1.01 – 2.71	0.044	2.02	1.16 – 3.52	0.014
Sex (female vs male)	3.61	1.77 – 7.35	<0.001	3.36	1.64 – 6.88	<0.001	7.35	2.86 – 18.93	<0.001
CRP at admission (log-transformed)	0.64	0.52 – 0.79	<0.001	0.63	0.51 – 0.78	<0.001	0.69	0.55 – 0.88	0.002
Energy intake at admission (per 5 kcal/kg/day increase)	2.16	1.64 – 2.83	<0.001	2.21	1.68 – 2.91	<0.001	3.64	2.46 – 5.39	<0.001
CC at admission (per 10% increase)	0.94	0.69 – 1.28	0.974						
TSF at admission (per 10% increase)				1.02	0.95 – 1.09	0.614			
MNA-SF score at admission				0.90	0.77 – 1.05	0.195			
Disease category (ref: Cardiovascular)									
Cerebrovascular							15.58	3.84 – 63.14	<0.001
Respiratory							0.31	0.08 – 1.20	0.089
Musculoskeletal							0.86	0.22 – 3.30	0.824

CC, calf circumference; CRP, C-reactive protein; MNA-SF, Mini Nutritional Assessment–Short Form; TSF, triceps skinfold thickness; OR, odds ratio; CI, confidence interval.
Statistical analysis. Multivariable binary logistic regression was performed to identify factors associated with sufficient energy intake at discharge (⩾100% of estimated energy requirement).
All explanatory variables were assessed at admission unless otherwise specified.
Model 1 included age, sex, log-transformed CRP, energy intake (kcal/kg/day), and calf circumference (CC).
Model 2 included age, sex, log-transformed CRP, energy intake (kcal/kg/day), triceps skinfold thickness (TSF), and MNA-SF score.
Model 3 included age, sex, log-transformed CRP, energy intake (kcal/kg/day), and disease category (cardiovascular [reference], cerebrovascular, respiratory, musculoskeletal).
Continuous variables were rescaled for interpretability: age per 10-year increase, energy intake per 5 kcal/kg/day increase, and CC and TSF per 10% increase (expressed as ratios relative to the JARD2001 reference, where 1.00 = 100%). CRP was log-transformed because of its right-skewed distribution.
Model discrimination for the fully adjusted model was summarised using the area under the ROC curve (AUC = 0.914; 95% CI, 0.878–0.951).
Reference categories: male for sex; cardiovascular for disease category.
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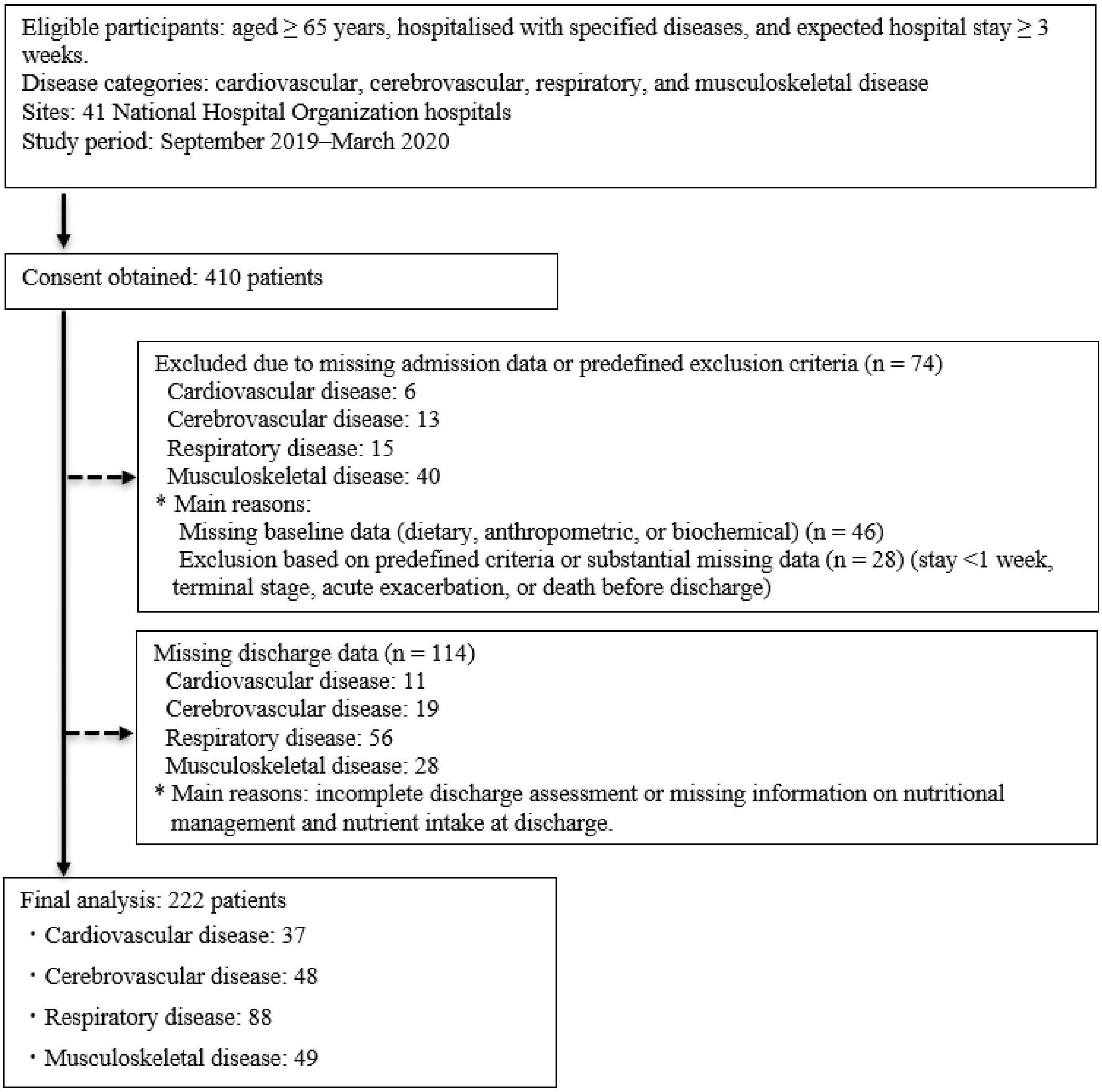
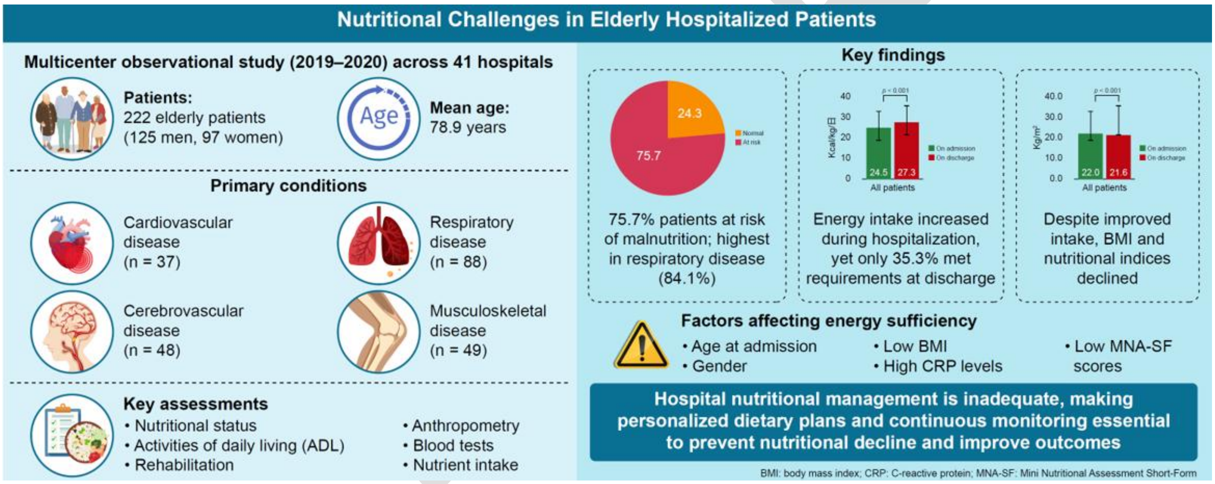


Figure 1. Flowchart of study participants. This figure illustrates the flow of patient selection in the study, including inclusion and exclusion criteria, and the final population included in the analysis.



Nutritional Challenges in Elderly Hospitalized Patients

Multicenter observational study (2019–2020) across 41 hospitals

Patients:
222 elderly patients
(125 men, 97 women)

Age

Mean age:
78.9 years

Primary conditions

Cardiovascular disease (n = 37)

Respiratory disease (n = 88)

Cerebrovascular disease (n = 48)

Musculoskeletal disease (n = 49)

Key assessments

- Nutritional status
- Activities of daily living (ADL)
- Rehabilitation
- Anthropometry
- Blood tests
- Nutrient intake

Key findings

75.7% patients at risk of malnutrition; highest in respiratory disease (84.1%)

Energy intake increased during hospitalization, yet only 35.3% met requirements at discharge

Despite improved intake, BMI and nutritional indices declined

Factors affecting energy sufficiency

- Age at admission
- Gender
- Low BMI
- High CRP levels
- Low MNA-SF scores

Hospital nutritional management is inadequate, making personalized dietary plans and continuous monitoring essential to prevent nutritional decline and improve outcomes

BMI: body mass index; CRP: C-reactive protein; MNA-SF: Mini Nutritional Assessment Short-Form

Graphical abstract