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Dietary Protein Distribution Across Meals as a Predictor of Muscle Strength and Functional Decline in Older Hospitalized Adults: A Prospective Cohort Study

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ABSTRACT

Background: Hospitalized older adults are often at risk for insufficient protein, acute catabolism, sedentary lifestyle and rapid muscle loss. When you consume protein throughout the day may be as important as how much protein you eat during the day.

Objective: To determine whether dietary protein distribution across meals predicts discharge muscle strength and 30-day functional decline in older hospitalized adults.

Methods: This was a prospective cohort study of 170 adults aged 65 years and above admitted to the medical wards of The University of Lahore Teaching Hospital. Three days of dietary intake were recorded. Protein distribution at breakfast, lunch, and dinner was calculated using the coefficient of variance and categorized as even or skewed distribution. Handgrip strength was measured after stabilization and before discharge, while physical performance was assessed using the Short Physical Performance Battery at baseline, discharge, and 30 days. Multivariable regression adjusted for demographic, nutritiona1, inflammatory, and clinical factors.

Results: Seventy-two participants had an even protein distribution, and 98 had a skewed pattern. Mean protein intake was 0.80 ± 0.23 g/kg/day. Participants with even distribution had greater discharge handgrip strength than those with skewed distribution (20.6 ± 6.2 vs 18.0 ± 6.0 kg; p = 0.007) and lower 30-day functional decline (20.8% vs 38.8%; p = 0.013). Even distribution independently predicted higher discharge strength and lower odds of functional decline.

Conclusion: A balanced distribution of dietary protein across meals was associated with better preservation of muscle strength and reduced short-term functional decline in older hospitalized adults across both sexes independently.

Keywords: dietary protein; meal distribution; handgrip strength; functional decline; older adults; hospitalization

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INTRODUCTION

Ageing is accompanied by progressive deterioration in skeletal muscle structure, neuromuscular function, and metabolic responsiveness. These changes may lead to reduced muscle strength, impaired physical performance, and eventual loss of independence. Sarcopenia is an important geriatric syndrome associated with falls, disability, institutionalization, prolonged healthcare use, and mortality [1].

Hospitalization may accelerate muscle deterioration in older adults. Acute inflammation, increased protein breakdown, restricted mobility, treatment-related fasting, swallowing difficulties, and poor appetite can collectively promote rapid reductions in muscle function. The older population is at a higher risk, as many are admitted with chronic illnesses, malnutrition, and reduced physiological reserves [2].

Loss of strength and mobility can be measurable after just a few days in the hospital. During bed rest, mechanical stimulation of skeletal muscle decreases, and during an acute illness, catabolic activity increases, and tissue recovery is limited. These effects can slow down

rehabilitation and make people more dependent after they leave the hospital [3]. Another significant cause of HAFD is inadequate dietary intake. Fatigue, nausea, pain, taste changes, problems feeding, or dissatisfaction with the hospital food are often reasons older patients eat only a portion of the food offered. As a result, they may be deficient in energy and protein in their diets for recovery [4].

Protein in the diet is necessary to maintain and repair skeletal muscle by providing the amino acids that are needed for muscle synthesis. Generally, geriatric nutrition guidelines suggest a minimum protein intake of 1.0 g/kg/day for healthy older people and 1.2-1.5 g/kg/day during acute or chronic illness [5]. Despite the above, it is very common for hospitalized older adults to not get enough protein. Direct dietary assessments revealed that nutritionally vulnerable patients could actually eat significantly less protein than is recommended, and this could place them at risk of muscle loss, slow recovery times, and physical deterioration [6].

The daily quantity of protein may not be the only factor determining the physiological impact of dietary protein—it may also be the number of times a person eats during the day. Older people tend to eat relatively little protein at breakfast and lunch and have a high percentage of their daily protein intake at dinner [7]. An anabolic pattern that is not equal throughout the day might mean that skeletal muscle is not given as many anabolic stimuli as it could be. If breakfast and lunch are low in protein, they may not be giving you enough essential amino acids to ensure an optimal muscle protein anabolic response [8].

The skeletal muscle of older people is less responsive to lower protein intake, known as anabolic resistance. This suggests older individuals may need more protein per meal to have the same muscle-building effect as younger individuals [9]. Ingestion of around 25-30 g of high-quality protein (0.4 g of protein per kg of body weight) has been suggested as a convenient protein intake to stimulate MPS in many older adults. But these needs depend on several factors such as body size, severity of the disease, level of physical activity, energy intake, renal function, and protein quality [10].

Spreading protein over breakfast, lunch, and dinner can be beneficial to stimulate muscle protein synthesis several times during the day. However, eating most protein at the end of the day, after most meals, may not make up for the lack of protein at earlier meals [11]. The finding of an association between a protein distribution more evenly spread across the day and increased muscle strength and lean body mass in community-dwelling older adults has been reported in observational studies. These findings indicate that protein intake for a meal could be a valuable piece of information in addition to protein intake over the course of the day [12].

However, the evidence is not conclusive. There are some studies on the effects of evenly distributed protein intake on lean mass, muscle strength, anabolic response, and/or physical performance, where all groups consumed the same amount of protein per day, and no significant differences were observed [13]. Previous studies have been conducted mainly with healthy elderly living alone. The results may not apply to hospitalized patients, who are in a state of acute catabolism, have decreased appetite, lack mobility, and are at higher risk for rapid functional decline [14].

There is still little information on the relationship between protein distribution, discharge muscle strength, and early functional decline in hospitalized populations in South Asia. This study aimed to find out if the dietary protein distribution at the main meals is associated with handgrip strength and short-term functional decline in older people admitted to The University of Lahore Teaching Hospital in Lahore, Pakistan [15].

MATERIALS AND METHODS

This prospective observational cohort study was conducted over 12 months by the University Institute of Diet and Nutritional Sciences, The University of Lahore, Lahore, Pakistan. The medical wards of The University of Lahore Teaching Hospital, Lahore, were selected to recruit the participants. This study was approved by the Institutional Review Board of The University of Lahore (IRB-UOL/UIDNS/2024/127). All study procedures were conducted with accepted ethical principles for human research, with written informed consent obtained from each participant (or legally authorized representative).

The adults aged 65 years or above were hospitalized patients who were enrolled by consecutive sampling, totaling 170. Patients were eligible if they were admitted to a general medical ward, were taking oral food, were expected to be in hospital for 72 hours or more, and could be assessed for muscle-strength and physical-performance following clinical stabilisation. Patients who were fed exclusively with enteral or parenteral nutrition, admitted to intensive care, and terminally ill, severely cognitively impaired, with upper limb disability and unable to assess hand grip, and were severely renal or hepatically diseased with a strict protein restriction were excluded. Also excluded were those who were discharged, transferred, or died before completion of the dietary assessment.

Dietary intake was evaluated after clinical stabilization on three consecutive days in the hospital. All hospital meals, snacks, beverages, oral nutritional supplements, and family-brought foods were documented by trained research nutritionists. The amount of food consumed was estimated directly and by a standardised plate waste technique. Hospital recipes and portion sizes were used to determine energy and protein intakes from standard food-composition data. The amount of total protein intake was calculated per day and per kg body weight.

The amount of protein consumed at breakfast, lunch, and dinner was calculated individually. The variability of protein distribution over the three main meals was measured

by the coefficient of variation (CV), defined as the standard deviation of the protein intake at each meal divided by the mean protein intake at the three meals. A CV of ≤0.50 was used as an indicator of a relatively uniform protein distribution, and a CV>0.50 was used as an indicator of a skewed protein distribution. The number of meals that contained at least 0.30 g protein per kg body weight was also counted as another measure of meal-level protein sufficiency.

Muscle strength was evaluated with a calibrated digital handgrip dynamometer on clinical stabilization and then within 24 hours before discharge. Participants sat in a comfortable position with their shoulders neutral, their elbows flexed at around 90 degrees, and their wrists in a comfortable position. Two measurements were made from each hand, separated by a brief rest period, the largest being used for analysis.

Physical performance was assessed via the Short Physical Performance Battery (SPPB), which included standing balance, usual walking speed, and the repeated chair-rise test. The score was between 0 and 12; a higher score showed better physical function. Assessments were performed at baseline, at hospital discharge, and 30 days after discharge. Functional decline was defined as a reduction of at least one point in the Short Physical Performance Battery score between baseline and the 30-day follow-up assessment.

Demographic and clinical data included age, sex, body mass index, smoking status, admission diagnosis, duration of hospitalization, medication use, and pre-existing medical conditions. Comorbidity burden was assessed using the Charlson Comorbidity Index. Nutritional status was evaluated using the Mini Nutritional Assessment–Short Form, and participants were classified as having normal nutritional status, being at risk of malnutrition, or being malnourished. Available laboratory measurements, including serum albumin, haemoglobin, creatinine, C-reactive protein, and vitamin D levels, were recorded from hospital files.

Pre-admission independence was assessed using the Barthel Index. Information regarding in-hospital mobility, physiotherapy exposure, feeding assistance, and use of oral nutritional supplements was also documented because these factors could influence muscle strength and functional recovery. The primary outcome was handgrip strength measured before hospital discharge, while the main secondary outcome was functional decline within 30 days after discharge. Additional outcomes included change in handgrip strength from baseline to discharge, discharge physical-performance score, 30-day physical-performance score, length of hospital stay, and hospital readmission within 30 days.

Data were analysed using IBM SPSS Statistics. Continuous variables were assessed for normality and presented as mean with standard deviation or median with interquartile range, as appropriate. Categorical variables were reported as frequencies and percentages. Comparisons between participants with even and skewed protein distributions were performed using the independent-samples t test or Mann–Whitney U test for continuous variables and the chi-square test or Fisher exact test for categorical variables.

Correlation analysis was used to examine relationships among total protein intake, protein-distribution coefficient, handgrip strength, and physical-performance scores. Multivariable linear regression was performed to determine whether protein distribution independently predicted discharge handgrip strength. Potential confounders included baseline handgrip strength, age, sex, total protein intake, energy intake, body mass index, nutritional status, comorbidity burden, C-reactive protein concentration, physiotherapy exposure, and length of hospital stay. Binary logistic regression was used to identify independent predictors of 30-day functional decline. Adjusted regression coefficients and odds ratios were reported with 95% confidence intervals, and a p-value of less than 0.05 was considered statistically significant.

RESULTS

A total of 193 older hospitalized adults were assessed for eligibility. Twelve patients did not meet the inclusion criteria, six declined participations, and five were discharged before completion of the dietary assessment. The final analysis included 170 participants, comprising 79 males (46.5%) and 91 females (53.5%). The mean age of the study population was 74.6 ± 6.7 years.

Based on the coefficient of variation of protein intake across breakfast, lunch, and dinner, 72 participants were classified as having an even protein distribution, while 98 had a skewed distribution. The even-distribution group included 35 males (48.6%) and 37 females (51.4%), whereas the skewed-distribution group included 44 males (44.9%) and 54 females (55.1%). No significant difference was observed in the proportions of males and females between the two groups.

Participants with a skewed protein distribution were significantly older and had lower Mini Nutritional Assessment–Short Form scores than those with an even distribution. Body mass index, smoking status, comorbidity burden, nutritional-risk category, serum albumin, C-reactive protein, baseline handgrip strength, baseline Short Physical Performance Battery score, pre-admission Barthel Index, and hospital stay did not differ significantly between groups. The baseline characteristics of male and female participants are presented in Table 1.

The mean energy intake of the overall population was 22.5 ± 5.7 kcal/kg/day, while the mean daily protein intake was 0.80 ± 0.23 g/kg/day. Only 41 participants (24.1%) achieved a protein intake of at least 1.0 g/kg/day. Breakfast contributed the smallest proportion of daily protein, while dinner provided the largest proportion.

Participants with an even distribution consumed significantly more total protein than those with a skewed distribution. This difference was observed in both males and females. Males with an even distribution consumed 0.90 ± 0.21 g/kg/day compared with 0.76 ± 0.22 g/kg/day among males with a skewed distribution. Among females, the corresponding values were 0.86 ± 0.23 and 0.72 ± 0.20 g/kg/day.

Breakfast and lunch protein intake were significantly greater in the even-distribution group in both sexes. In contrast, dinner protein intake was slightly higher among participants with a skewed pattern, indicating that protein intake in this group was concentrated later in the day. Twenty-nine participants with an even distribution consumed at least two meals providing 0.30 g protein/kg, compared with 14 participants in the skewed-distribution group, as presented in Table 2.

Discharge handgrip strength was significantly greater among participants with an even protein distribution. Among males, mean discharge handgrip strength was 25.3 ± 4.8 kg in the even-distribution group and 22.3 ± 5.0 kg in the skewed-distribution group. Among females, discharge handgrip strength was 16.2 ± 3.6 and 14.5 ± 3.7 kg, respectively.

Both male and female participants with an even distribution experienced a smaller reduction in handgrip strength during hospitalization. The 30-day Short Physical Performance Battery score was also higher in males and females with an even protein distribution. Dietary intake and functional outcomes according to sex are shown in Table 2.

Functional decline within 30 days was identified in 53 participants (31.2%), including 19 of 79 males (24.1%) and 34 of 91 females (37.4%). Among males, functional decline occurred in 14.3% of those with an even protein distribution and 31.8% of those with a skewed distribution. Among females, the corresponding proportions were 27.0% and 44.4%. Although the direction of association was similar in males and females, the sex-specific comparisons did not reach statistical significance because of the smaller number of participants in each subgroup.

The protein-distribution coefficient was negatively correlated with discharge handgrip strength in males ($r = -0.36$; $p = 0.001$) and females ($r = -0.29$; $p = 0.005$). It was also negatively correlated with the 30-day Short Physical Performance Battery score in males ($r = -0.30$; $p = 0.007$) and females ($r = -0.25$; $p = 0.018$). Total daily protein intake demonstrated positive correlations with discharge handgrip strength in males ($r = 0.33$; $p = 0.003$) and females ($r = 0.28$; $p = 0.007$).

After adjustment for baseline handgrip strength, age, sex, total protein intake, energy intake, nutritional status, comorbidity burden, C-reactive protein, physiotherapy exposure, and length of hospital stay, an even protein distribution remained independently associated with greater handgrip strength at discharge. An even distribution was associated with an adjusted increase of 1.47 kg in discharge strength. Total protein intake and baseline handgrip strength were also positive predictors, while increasing age and higher C-reactive protein were associated with lower discharge strength.

Table 1: Baseline characteristics according to dietary protein distribution

Characteristic	Even distribution (n = 72)	Skewed distribution (n = 98)	p value
Age, years	73.4 ± 6.3	75.5 ± 6.8	0.041
Male participants, n (%)	35 (48.6)	44 (44.9)	0.634
Female participants, n (%)	37 (51.4)	54 (55.1)	0.634
Age of males, years	72.9 ± 6.1	74.8 ± 6.5	0.184
Age of females, years	73.9 ± 6.5	76.1 ± 7.0	0.139
Body mass index, kg/m²	24.3 ± 4.0	23.7 ± 4.2	0.349
Body mass index in males, kg/m²	24.5 ± 3.8	23.9 ± 4.0	0.499
Body mass index in females, kg/m²	24.1 ± 4.2	23.5 ± 4.4	0.518
Current smokers, n (%)	11 (15.3)	18 (18.4)	0.596
Charlson Comorbidity Index	4.0 ± 1.6	4.3 ± 1.8	0.267
Mini Nutritional Assessment–Short Form score	9.8 ± 2.2	8.9 ± 2.5	0.016
At nutritional risk or malnourished, n (%)	34 (47.2)	58 (59.2)	0.123
At nutritional risk or malnourished among males, n/N (%)	14/35 (40.0)	23/44 (52.3)	0.275
At nutritional risk or malnourished among females, n/N (%)	20/37 (54.1)	35/54 (64.8)	0.304
Serum albumin, g/dL	3.43 ± 0.50	3.32 ± 0.54	0.179
C-reactive protein, mg/L	30.8 (13.1–61.4)	35.7 (14.9–70.2)	0.294
Baseline handgrip strength in males, kg	26.2 ± 5.1	24.1 ± 5.3	0.078
Baseline handgrip strength in females, kg	17.1 ± 3.8	15.9 ± 4.0	0.158
Baseline Short Physical Performance Battery score in males	7.0 ± 2.1	6.5 ± 2.3	0.322
Baseline Short Physical Performance Battery score in females	6.4 ± 2.3	6.0 ± 2.4	0.430
Pre-admission Barthel Index	88.3 ± 12.4	85.7 ± 13.8	0.207
Length of hospital stay, days	7.0 ± 2.7	7.5 ± 3.0	0.265

Table 2: Dietary intake and functional outcomes according to protein distribution and sex

Variable	Even distribution (n = 72)	Skewed distribution (n = 98)	p value
Energy intake, kcal/kg/day	23.7 ± 5.5	21.6 ± 5.7	0.018
Energy intake in males, kcal/kg/day	24.1 ± 5.3	22.0 ± 5.5	0.087
Energy intake in females, kcal/kg/day	23.3 ± 5.7	21.3 ± 5.9	0.111
Total protein intake, g/kg/day	0.88 ± 0.22	0.74 ± 0.21	<0.001
Total protein intake in males, g/kg/day	0.90 ± 0.21	0.76 ± 0.22	0.005
Total protein intake in females, g/kg/day	0.86 ± 0.23	0.72 ± 0.20	0.002
Breakfast protein in males, g/kg	0.21 ± 0.07	0.11 ± 0.05	<0.001
Breakfast protein in females, g/kg	0.19 ± 0.06	0.09 ± 0.05	<0.001
Lunch protein in males, g/kg	0.29 ± 0.09	0.22 ± 0.08	<0.001
Lunch protein in females, g/kg	0.27 ± 0.09	0.21 ± 0.08	0.001
Dinner protein in males, g/kg	0.30 ± 0.10	0.35 ± 0.12	0.049
Dinner protein in females, g/kg	0.29 ± 0.10	0.34 ± 0.12	0.041
Protein-distribution coefficient of variation	0.36 ± 0.09	0.71 ± 0.16	<0.001
Males consuming ≥2 meals with ≥0.30 g/kg, n/N (%)	15/35 (42.9)	7/44 (15.9)	0.008
Females consuming ≥2 meals with ≥0.30 g/kg, n/N (%)	14/37 (37.8)	7/54 (13.0)	0.006
Overall discharge handgrip strength, kg	20.6 ± 6.2	18.0 ± 6.0	0.007
Discharge handgrip strength in males, kg	25.3 ± 4.8	22.3 ± 5.0	0.008
Discharge handgrip strength in females, kg	16.2 ± 3.6	14.5 ± 3.7	0.031
Change in handgrip strength in males, kg	−0.9 ± 1.4	−1.8 ± 1.7	0.014
Change in handgrip strength in females, kg	−0.9 ± 1.5	−1.7 ± 1.8	0.028
Discharge Short Physical Performance Battery score in males	6.8 ± 2.2	5.8 ± 2.3	0.049
Discharge Short Physical Performance Battery score in females	6.0 ± 2.3	5.1 ± 2.4	0.077
Thirty-day Short Physical Performance Battery score in males	7.2 ± 2.2	6.0 ± 2.4	0.025
Thirty-day Short Physical Performance Battery score in females	6.4 ± 2.4	5.4 ± 2.5	0.049
Functional decline among males, n/N (%)	5/35 (14.3)	14/44 (31.8)	0.069
Functional decline among females, n/N (%)	10/37 (27.0)	24/54 (44.4)	0.091
Readmission among males, n/N (%)	4/35 (11.4)	8/44 (18.2)	0.397
Readmission among females, n/N (%)	5/37 (13.5)	10/54 (18.5)	0.528

Table 3: Multivariable predictors of discharge handgrip strength and 30-day functional decline

Predictor	Adjusted β for discharge handgrip strength (95% CI)	p value	Adjusted OR for functional decline (95% CI)	p value
Even protein distribution	1.47 (0.39 to 2.55)	0.008	0.48 (0.24 to 0.96)	0.038
Skewed protein distribution	Reference	—	Reference	—
Total protein intake, per 0.10 g/kg/day	0.36 (0.06 to 0.66)	0.019	0.89 (0.79 to 0.99)	0.044
Baseline handgrip strength, per 1 kg	0.78 (0.70 to 0.86)	<0.001	—	—
Protein-distribution coefficient, per 0.10 increase	−0.33 (−0.56 to −0.10)	0.005	1.18 (1.05 to 1.34)	0.006
Number of meals providing ≥0.30 g/kg	0.63 (0.12 to 1.14)	0.016	0.64 (0.42 to 0.97)	0.036
Age, per year	−0.11 (−0.20 to −0.02)	0.017	1.05 (1.00 to 1.11)	0.049
Male sex	Reference	—	Reference	—
Female sex compared with male sex	−1.34 (−2.34 to −0.34)	0.009	1.28 (0.64 to 2.57)	0.482
C-reactive protein, per 10 mg/L	−0.16 (−0.30 to −0.02)	0.025	1.07 (1.00 to 1.15)	0.046
Nutritional risk or malnutrition	−0.76 (−1.68 to 0.16)	0.105	1.69 (0.86 to 3.33)	0.128
Baseline Short Physical Performance Battery score	—	—	0.76 (0.64 to 0.90)	0.002
Male sex × even protein distribution	Reference	—	Reference	—
Female sex × even protein distribution	0.28 (−0.74 to 1.30)	0.588	1.12 (0.46 to 2.73)	0.804

Male sex was used as the reference category in the adjusted models. Female sex was independently associated with lower absolute discharge handgrip strength, but it was not associated with significantly greater odds of 30-day functional decline after adjustment. The interaction between sex and protein-distribution pattern was not statistically significant, indicating that the association between even protein distribution and functional outcomes was comparable in males and females.

An even protein distribution was associated with a 52% reduction in the adjusted odds of functional decline. Each 0.10 increase in the protein-distribution coefficient was associated with an 18% increase in the odds of deterioration. A greater number of meals supplying at least 0.30 g protein/kg and a higher baseline Short Physical Performance Battery score were associated with reduced odds of functional decline, as shown in Table 3.

Overall, both males and females with an even distribution of dietary protein demonstrated higher protein intake during breakfast and lunch, better preservation of handgrip strength, higher physical-performance scores, and a lower frequency of 30-day functional decline than participants with a skewed distribution. The lack of a significant sex interaction indicated that the relationship between protein distribution and functional recovery was not restricted to either male or female participants.

DISCUSSION

The present study demonstrated that the distribution of dietary protein across meals was associated with muscle strength and short-term functional recovery among older hospitalized adults [1]. Participants with a relatively even protein distribution had greater handgrip strength at discharge, experienced a smaller reduction in strength during hospitalization, and achieved higher physical-performance scores than those whose protein intake was concentrated mainly at dinner [2]. These relationships remained significant after adjustment for total protein intake, baseline strength, age, sex, nutritional status, inflammatory burden, comorbidities, physiotherapy exposure, and length of hospital stay. The findings are consistent with Pikosky et al. And Han et al. observational evidence showing that a balanced mealtime protein pattern is independently associated with greater muscle strength in older adults [1,3].

The overall protein intake of the study population was below the amounts commonly recommended for older adults during acute illness [4]. Only about one-quarter of the participants achieved an intake of at least 1.0 g/kg/day, while those with a skewed distribution consumed particularly small quantities at breakfast and lunch [5]. Reduced appetite, illness-related fatigue, feeding difficulties, medical procedures, and limited availability of protein-rich breakfast options may have contributed to this pattern. Similarly, Dent et al. reported inadequate protein intake among hospitalised older adults at nutritional risk, suggesting that routine hospital diets may not provide sufficient protein to support muscle maintenance during acute illness [6].

Hospitalization exposes older adults to a combination of inflammation, metabolic stress, inactivity, and reduced food intake [7]. These factors can accelerate muscle protein breakdown and produce clinically meaningful deterioration within a relatively short period. In the present study, participants with skewed protein intake experienced nearly twice the reduction in handgrip strength observed among those with an even distribution. The higher frequency of 30-day functional decline in the skewed group also suggests that the consequences of inadequate meal-level protein intake may continue beyond hospital discharge. This interpretation is compatible with the concept of acute sarcopenia, in which illness and muscle disuse interact to cause a rapid decline in muscle mass and function during hospitalization [8].

The associations observed in the present study were evident in both males and females. Although males had greater absolute handgrip strength, even protein distribution was associated with better strength preservation and physical-performance scores in both sexes [9]. The absence of a significant interaction between sex and protein distribution indicates that the potential benefit of a balanced dietary pattern was not restricted to one sex. Nevertheless, the findings should be interpreted cautiously because randomized evidence has not consistently demonstrated that redistributing protein across meals improves muscle mass, anabolic response, strength, or functional performance when total daily protein intake is maintained at an adequate level [10].

The results of the present study are relevant to nutrition care in hospital settings. Eggs, milk, yogurt, cheese, legumes, meat products, or protein-enriched oral supplements can be used to increase the protein content at breakfast and lunch without significantly increasing the volume of food ingested [11,12]. Protein redistribution should not be used as a substitute for achieving an adequate total daily protein intake, ensuring adequate energy intake, feeding support, and early mobilization or resistance-based rehabilitation, however. Harris et al. showed that protein distribution appears to be more consistently associated with muscle mass than with muscle strength or protein turnover; therefore, well-designed intervention trials in hospitalised populations are needed [13].

An important finding was that the relationship with functional recovery was not restricted to the overall category of even or skewed protein intake. A higher protein-distribution coefficient (PDC) (more variation in protein intake between meals) was independently associated with lower discharge handgrip strength and higher risk of 30-day functional decline. On the other hand, more meals with a protein content of ≥0.30 g/kg was associated with better strength maintenance and reduced risk of declines. In the mid- to long-term, Salinas-Rodríguez et al. reported a significant association of food insecurity with sarcopenia, which indicates that chronic food insecurity can play a role in the loss of muscle function in older adults [14].

In another study, Moradi Baniasadi et al. performed a systematic review and dose-response meta-analysis of prospective cohort studies that examined the relationship between protein intake and the risk of frailty, and they concluded that total protein, animal protein, and plant

protein intake are linked to the risk of frailty, and emphasized the need for adequate protein intake in maintaining physical resilience in the elderly [15]. While these studies were not designed to specifically assess protein distribution among meals, the results of these studies provide evidence for the overall clinical importance of nutritional adequacy for maintaining muscle function and minimizing the risk for functional decline. The observed associations were not simply due to the greater total protein intake in the even-distribution group as the protein-distribution coefficient and the number of protein-sufficient meals were significant after the multivariable adjustment. However, it should be noted that this study was an observational study and it was not possible to conclude that the intent to raise protein intake at breakfast and lunch directly contributed to better muscle strength and functional recovery.

The strengths of this study were the prospective dietary assessment, direct observation of food eaten at meals, separate estimation of protein intake for each principal meal, standardisation of handgrip measurement, the presence of both male and female subjects, and the evaluation of function after discharge [14,15]. Important nutritional and clinical variables were also adjusted for, further strengthening the analysis. But the nature of the observation does not lend itself to establishing causality. Better appetite, less disease severity, and more independence may have led to the increased likelihood of balanced meals being consumed. Three-day dietary information is not necessarily reflective of the entire hospital stay, and protein quality and leucine intake have not been fully captured, as well as pre-admission dietary intake and objectively measured physical activity levels. However, the study took place in one teaching hospital, so the results may not apply to other doctors or hospitals [16].

CONCLUSION

Among hospitalized older adults, a more even distribution of food protein intake at breakfast, lunch, and dinner was independently associated with higher handgrip strength at discharge and fewer functional declines within 30 days. The association was observed in both sexes and was independent of the major clinical and nutritional factors and of total protein intake. The assessment of protein intake at the meal level may, therefore, be useful in addition to the assessment of protein intake at the day level. Hospital nutrition programs should be aware of providing additional protein during breakfast and lunch, and also providing sufficient protein and energy. Randomized clinical trials are needed to ascertain whether there is a direct link between deliberate dietary protein re-distribution and muscle and functional recovery after hospitalization.

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Data Availability: The datasets generated and analysed during the current study are available from the corresponding author upon reasonable request.

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