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Importance of hospital food intake for early discharge after total hip arthroplasty for osteoarthritis: a propensity score matching analysis

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Abstract

Background Total hip arthroplasty (THA) is widely used to treat hip osteoarthritis (HOA), particularly in elderly patients. However, the associated costs and complications highlight the need for strategies to shorten hospital stays and optimise postoperative outcomes. This study aimed to investigate the effect of preoperative nutritional status and postoperative dietary intake on the discharge outcomes of patients with unilateral HOA who underwent THA.

Methods A retrospective analysis of 57 patients without significant comorbidities out of 172 THA procedures performed by the same surgeon was conducted. Propensity score matching was used to compare the early discharge group ($n=14$), discharged within 2 weeks, with the delayed discharge group ($n=14$), hospitalised for longer. The assessed factors included preoperative Controlling Nutritional Status (CONUT) scores, postoperative dietary intake (staple foods and side dishes), and complications.

Results Preoperative malnutrition, as assessed using the CONUT score, showed no significant difference between the groups. The early discharge group exhibited a higher intake of staple foods (rich in carbohydrates) in the early postoperative phase than the delayed discharge group, potentially influencing earlier discharge. No significant difference was observed in side dish intake between the two groups. The incidence of complications did not differ between the two groups.

Conclusion Higher intake of staple foods in the early postoperative period may positively impact metabolic demands and wound healing, suggesting the importance of dietary strategies in postoperative rehabilitation. Ensuring adequate hospital meal consumption and implementing effective dietary guidance and education are crucial for optimising recovery and reducing hospital stay. This study highlights that postoperative feeding strategies, especially staple food intake, may have a positive impact on early discharge in THA patients. Future studies should explore the benefits of long-term nutritional interventions and the role of continuous dietary education in enhancing postoperative recovery.

Keywords Total hip arthroplasty, Nutrition, Dietary intake, Hospital discharge, Orthopaedic surgery, Hip osteoarthritis

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Background

Total hip arthroplasty (THA) is a major treatment for hip osteoarthritis (HOA), with its efficacy and safety extensively documented in numerous studies [1, 2]. As the global population ages, the number of THA performed worldwide is steadily increasing [3]. Furthermore, emerging technologies such as robotic surgery have been gaining prominence, with reporting evidence of their effectiveness and safety [4, 5]. However, the associated costs of hospitalisation, treatment, and rehabilitation after THA are substantial, highlighting the need to reduce the length of hospital stays (LOS). One proposed strategy to mitigate this challenge involves the proactive reduction and implant-related complications [6–8]. Additionally, systematic preoperative screening to identify patients at risk for prolonged recovery might enable tailored interventions, thereby optimizing resource utilization and improving efficiency in postoperative care.

Malnutrition is a significant public health issue affecting both social and economic performance in high- and low-income countries [9]. Ensuring adequate nutritional support should be the primary focus in the care of hospitalised patients to optimise their recovery [10]. The clinical importance of addressing nutritional deficits in hospitalised patients is underscored by the high prevalence of malnutrition - affecting up to 50% of patients [11], and the documented correlation between insufficient nutritional intake and adverse outcomes, including up to an eightfold increase in mortality and extended hospital stays [12, 13]. Although the significance of nutritional management in the discharge of orthopaedic patients is widely acknowledged, detailed strategies for effectively implementing this care are still insufficiently explored. This gap highlights the need for targeted research to develop and validate practical nutritional interventions that can optimize patient outcomes and streamline the discharge process.

While Western countries have successfully implemented rapid rehabilitation protocols that often allow for discharge within few days post-surgery, the focus post-discharge shifts significantly towards managing dietary intake at home. This shift underscores the importance of effective nutritional support outside of the hospital setting. Conversely, in Japan, the typical recovery period extends to about two weeks, reflecting differing healthcare policies and cultural expectations. This extended in-hospital stay provides a unique opportunity to study the impact of sustained nutritional interventions on patient recovery.

This study, conducted in Japan, aims to explore how in-hospital dietary management influences the timing of hospital discharge and overall recovery in patients undergoing unilateral THA. This study might offer insights that could inform post-discharge nutritional care strategies also in Western countries, potentially improving global clinical practices. Furthermore, the findings from this research could highlight the benefits of structured postoperative nutritional support, providing a model for enhancing recovery and reducing the economic burden on healthcare systems worldwide.

Methods

Study design and participants

This study received ethical approval by the Ethics Review Board of Kitasato University (approval number: B23-012) for the use of an opt-out methodology. This was a single-centre retrospective analysis. A total of 172 THA cases performed by the same surgeon (K.F.) from 1 January 2021 to 31 December 2022 were included. Patients that were found HOA on the non-operative side ($n = 40$), bilateral THA cases ($n = 27$), patients with prior THA on the contralateral side ($n = 17$), patients that had medical conditions affecting the rehabilitation process [e.g., reduced activity of daily living (ADL)], highly dislocation of the hip, post-any other operation around the hip joint, heart failure, severe obesity, depression, schizophrenia ($n = 13$), osteonecrosis of the femoral head on the operative side ($n = 9$), diabetes requiring insulin therapy ($n = 4$), renal failure with protein restriction ($n = 3$), rapidly destructive coxarthrosis ($n = 1$), and THA conversion in a case of pigmented villonodular synovitis ($n = 1$) were excluded from this study. Ultimately, 57 THA patients with unilateral HOA without additional rehabilitation or dietary restrictions were included. A flowchart of the patient selection process is shown in Fig. 1. Participants followed a uniform medication protocol, ensuring consistent care across the cohort. Cefazolin was administered for infection control, dosed appropriately based on body size and renal function, and continued every 8 h until 24 h post-surgery. Pain management involved non-steroidal anti-inflammatory drugs (NSAIDs) or acetaminophen, administered orally as per each participant's capability to ingest immediately after surgery. Additionally, thromboprophylactic agents, such as edoxaban and enoxaparin, were administered as appropriate for up to two weeks postoperatively. The same standardized postoperative rehabilitation protocol, supervised by physical therapists, was applied to the entire cohort. Rehabilitation began on the first postoperative day with transfer training to a wheelchair, and progressed to gait training by the second day. Patients were permitted to be discharged when there were no wound problems and they could perform ADLs, such as walking and climbing stairs independently. Patients discharged within 2 weeks after surgery were categorised into the early discharge group, and those hospitalised for > 2 weeks and/or transferred to another hospital for rehabilitation were categorised into the delayed discharge group.

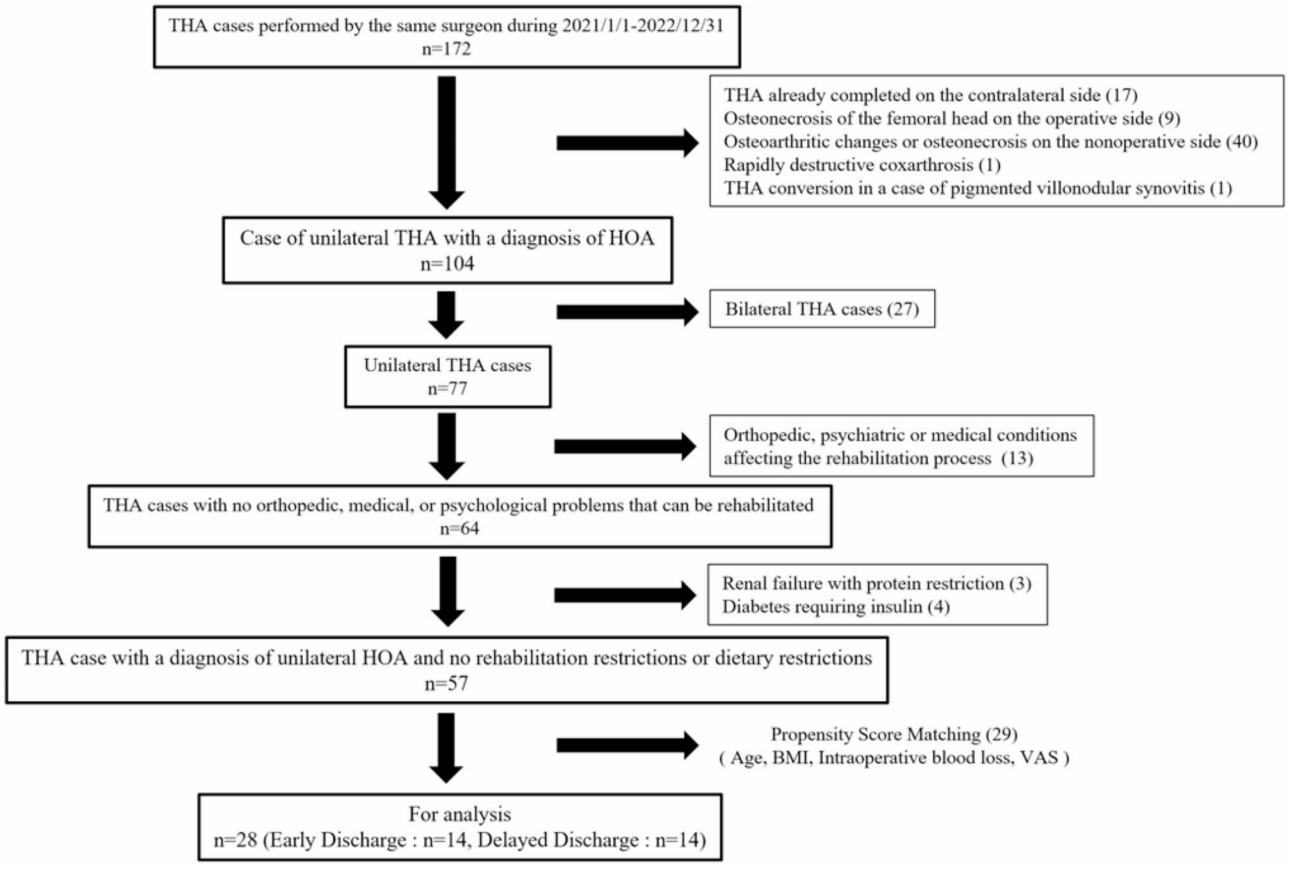

Fig. 1 Flowchart of patient selection, exclusion criteria and assignment. Data of 172 patients undergoing THA procedures performed by the same surgeon between 1 January 2021 and 31 December 2022 were extracted from the electronic medical records. Patients were selected based on the inclusion and exclusion criteria, and 57 patients who underwent unilateral THA were selected.

Table 1 CONUT score: assessment of malnutrition degree

Parameter				
Serum Albumin (g/dl)	≥ 3.50	3.00–3.49	2.50–2.99	< 2.5
Score (1)	0	2	4	6
Total lymphocyte count (/ml)	≥ 1600	1200–1599	800–1199	< 800
Score (2)	0	1	2	3
Total cholesterol (mg/dl)	≥ 180	140–179	100–139	< 100
Score (3)	0	1	2	
Malnutrition Degree	Normal	Light	Moderate	Severe
Total Score	0–1	2–4	5 – 8	9–12

Patient characteristics and data

Patient characteristics including age, sex, and body mass index (BMI) were obtained from electronic medical records. Additionally, preoperative blood test data (serum albumin, total lymphocyte count, and total cholesterol), intraoperative blood loss, postoperative food intake, and postoperative pain were assessed using a visual analogue scale (VAS).

Preoperative nutritional status was evaluated using the Controlling Nutritional Status (CONUT) score based on blood test data obtained from an examination conducted one month prior to surgery. The CONUT score is a screening tool used to assess malnutrition in hospitalized patients [14]. It was calculated using three parameters: serum albumin level, total lymphocyte count, and total cholesterol level, with scores ranging from 0 to 12. Higher scores indicated poorer nutritional status (Normal: 0–1, Mild malnutrition: 2–4, Moderate malnutrition: 5–8, Severe malnutrition: 9–12). The scoring table for the CONUT scores are shown in Table 1.

Postoperative food intake was recorded on a scale of 0–10 (0 = whole food leftover, 10 = total intake) as measured by a nurse or nursing assistant during meal cleanup. Food types were categorized into staple and side dishes to assess whether the type of nutrients consumed was associated with length of hospital stay. In Japanese food, staple foods typically consist of carbohydrate-rich ingredients (e.g., rice, bread, noodles, grains, and potatoes), whereas side dishes contain proteins, fats, vitamins, minerals, and dietary fibres (e.g., meat, seafood, vegetables, mushrooms, and fruits). A typical Japanese meal for inpatients includes one staple food (rice, bread, and noodles) and several side dishes (e.g., main dishes, salads, soup, and deserts).

Postoperative pain was measured using the VAS one week after surgery. A physical therapist recorded both dynamic and static pain.

Statistical analysis

The Shapiro-Wilk test was used to assess data normality. Age and body size influence preoperative albumin levels and dietary intake is known to be influenced by age and body size [15, 16]. Therefore, age, BMI, intraoperative blood loss, and postoperative pain VAS scores were included as covariates in the propensity score matching, as these were considered potential confounding factors affecting the rehabilitation course.

We compared the preoperative CONUT scores and postoperative food intake (staple food and side dishes) between the groups using the Mann–Whitney U test for both the unmatched cohort and the cohort matched for the above covariates. The χ^2 test was used to compare differences in malnutrition rates, as indicated by the CONUT score, before and after matching.

All statistical analyses were performed using the SPSS software (version 19.0, IBM, NY, USA). Statistical significance was set at $p < 0.05$.

Results

Preoperative nutritional status and clinical characteristics in the early and delayed discharge groups

The clinical characteristics of the early and delayed discharge groups are summarised in Table 2. Of the 57 patients included in this study, 39 patients (68.4%) were categorised into the early discharge group while 18 patients (31.6%) were categorized into the delayed discharge group.

The patients in the delayed discharge group were significantly older and had lower preoperative albumin levels. However, intraoperative blood loss was significantly lower in the discharge group than in the early discharge group. Based on the CONUT score, 45 patients (78.9%) were classified as having normal nutritional status, while 12 patients (21.1%) had mild malnutrition. None of the patients had moderate or severe malnutrition. There were no significant differences in the mean CONUT scores between the two groups. As postoperative complications, we found deep vein thrombosis (DVT) in 6 patients (10.5%) and mild elevation of liver enzymes in one patient (1.8%). All DVT cases were peripheral and did not affect the rehabilitation course. There were no significant differences between the two groups.

After propensity score matching, 14 patients were included in the early and delayed discharge groups, respectively. Following matching, the significant differences in age, intraoperative blood loss, and preoperative albumin levels between the two groups did not show significant differences. Additionally, there were no significant differences in mean CONUT scores between the matched groups. Also, there were no significant differences in complication rates.

Impact of postoperative dietary intake on discharge

Figure 2 shows the changes and differences in staple and side dish intake before and after propensity score matching between the early and delayed discharge groups.

Before matching, the early discharge group consumed significantly more staple food on postoperative days 2, 3, 4, and 6, and significantly more side dishes 2 days after surgery (staple food: day 2, $p = 0.004$, 1-β = 0.816; day 3, $p < 0.001$, 1-β = 0.993; day 4, $p < 0.001$, 1-β = 0.908;

Table 2 Clinical characteristics in early and delayed discharge groups before and after propensity matched score analysis

	Before match			After match		
Parameters	**Early discharge (*n* = 39)**	**Delayed discharge (*n* = 18)**	***P* value**	**Early discharge (*n* = 14)**	**Delayed discharge (*n* = 14)**	***P* value**
Age (y)	62.9 ± 11.4	74.9 ± 8.8	**< 0.001***	70.2 ± 10.0	72.1 ± 7.8	0.734
Sex (M/F)	6/33	2/16	0.666	2/12	1/14	0.541
BMI	26.0 ± 6.3	23.7 ± 3.6	0.164	23.8 ± 4.1	24.6 ± 3.5	0.227
Postoperative pain VAS on movement (mm)	22.8 ± 18.1	32.2 ± 19.7	0.062	22.1 ± 13.3	28.1 ± 19.0	0.454
Intraoperative blood loss (ml)	269.0 ± 150.7	206.4 ± 185.5	**0.040***	240.6 ± 148.3	222.6 ± 205.6	0.329
Preoperative Alb level (g/dl)	4.3 ± 0.3	4.1 ± 0.4	**0.020***	4.3 ± 0.3	4.1 ± 0.3	0.285
CONUT						
Malnutrition degree (*n* (%))						
Normal	33 (84.6%)	12 (66.7%)	0.122	11 (78.6%)	10 (71.4%)	0.663
Light malnutrition	6 (15.4%)	6 (33.3%)		3(21.4%)	4(28.6%)	
Moderate malnutrition	0 (0.0%)	0 (0.0%)		0(0.0%)	0(0.0%)	
Severe malnutrition	0 (0.0%)	0 (0.0%)		0(0.0%)	0(0.0%)	
Complications						
DVT	3(7.7%)	3(16.7%)	0.305	2(14.3%)	3(21.4%)	0.621
Elevated liver enzymes	1(2.6%)	0(0.0%)	0.493	0(0.0%)	0(0.0%)	N/A

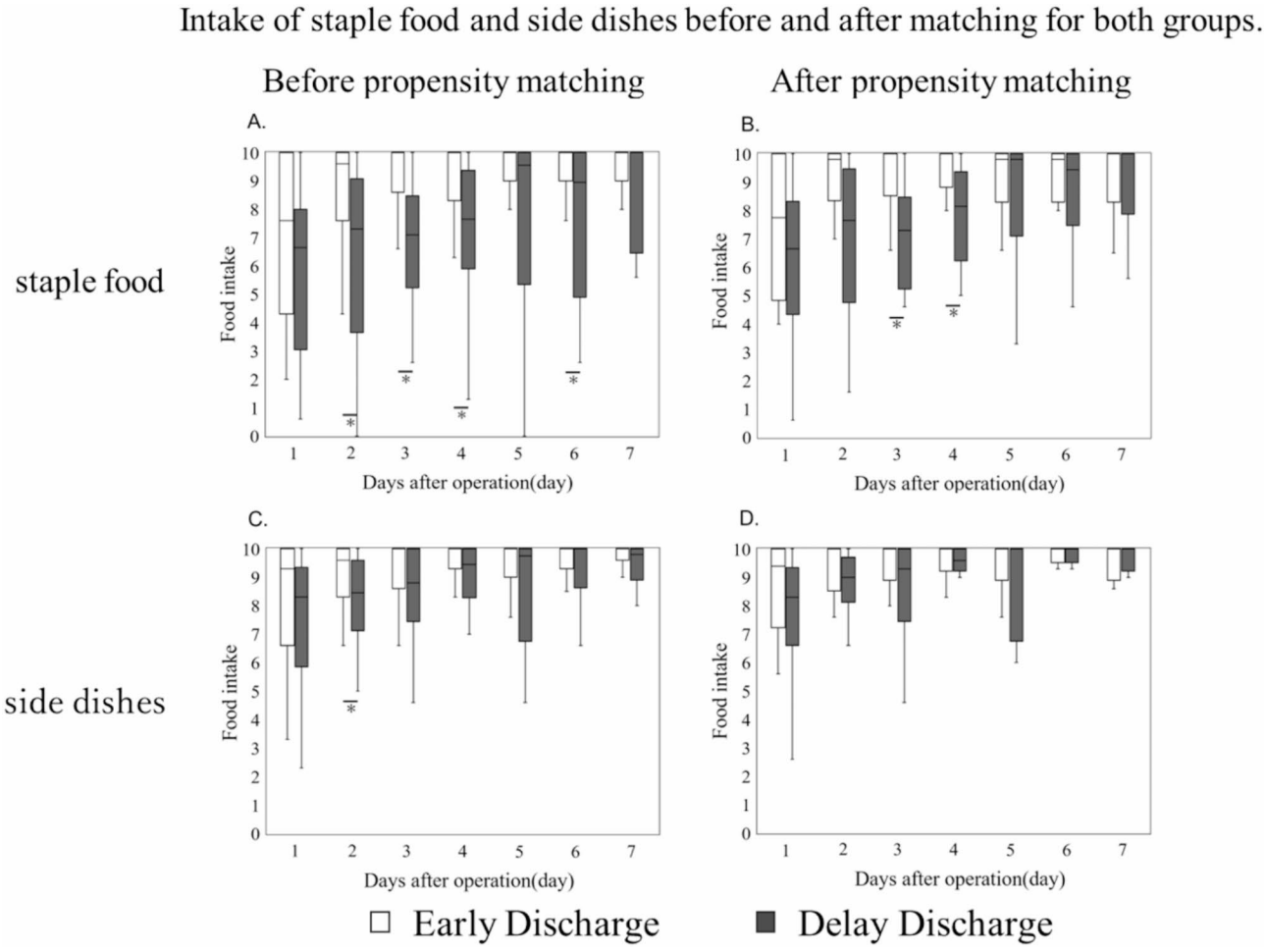

Fig. 2 Intake of staple food and side dishes before and after matching for both groups. Before matching, the intake was significantly higher on postoperative days 2, 3, 4, and 6 for staple foods, and significantly higher on postoperative day 2 for side foods. After matching (age, BMI, intraoperative blood loss, and postoperative pain VAS), the intake was significantly higher on the third and fourth postoperative days for the staple food, and the significance disappeared for the side dishes

day 6, $p = 0.016$, $1\text{-}\beta = 0.808$; side dishes: day 2, $p = 0.022$, $1\text{-}\beta = 0.511$).

After matching, the early discharge group continued to have significantly higher staple food intake on postoperative days 3 and 4 (day 3: $p = 0.004$, $1\text{-}\beta = 0.903$; day 4: $p = 0.031$, $1\text{-}\beta = 0.568$). In contrast, the previously significant difference in side dish intake between the two groups was no longer observed at any time point after matching.

Discussion

This study aimed to investigate the impact of preoperative nutritional status and postoperative hospital food intake on the outcomes of patients undergoing unilateral THA for HOA. The results of the current study showed that post operative intake of staple foods (carbohydrate-rich components of hospital meals) significantly influenced early discharge in patients, especially on postoperative days 3 and 4, even after matching for confounding factors such as age, BMI, intraoperative blood loss, and postoperative pain using propensity score matching.

The significance of perioperative nutrition, particularly in relation to malnutrition, has been extensively documented in orthopaedic surgery [17]. Previous studies have reported that malnutrition rates among patients undergoing THA and total knee arthroplasty (TKA) range from 11.3 to 27%, with preoperative hypoalbuminemia often leading to increased postoperative complications, such as wound infections, which subsequently extend hospital stays [18–20]. These complications are critical factors in prolonging hospitalization, underscoring the importance of adequate nutritional management to prevent such adverse outcomes. However, in our study, despite varying levels of preoperative nutritional status as assessed by the CONUT score, no cases of wound infection were observed. This absence of wound infections, regardless of the preoperative CONUT score, suggests that other factors, such as the efficacy of the

postoperative diet, may play a pivotal role in enabling discharge within the expected timeframe. The standard postoperative diet provided to all patients, rich in essential nutrients, may significantly influence recovery and the timing of discharge.

Recent studies have highlighted the importance of perioperative nutritional intervention. Schroer et al. reported the impact of perioperative high-protein and anti-inflammatory nutritional interventions for patients undergoing elective joint arthroplasty who were preoperatively malnourished, defined by an albumin level of ≤ 3.4 g/dL. These interventions resulted in significantly reduced hospital stays and surgical costs [21]. Harsten et al. reported that preoperative carbohydrate-based nutritional interventions significantly improved LOS [22]. While these interventions targeted specific nutritional components, this study demonstrated the significant role of regular hospital meals, particularly staple foods, such as rice, bread, and noodles, which provide essential carbohydrates.

Carbohydrates are critical for energy metabolism and wound healing, especially during the postoperative period when energy demands increase significantly owing to surgical stress and rehabilitation [23]. Without adequate energy intake, the body catabolises muscle proteins for gluconeogenesis, potentially leading to muscle atrophy and delayed recovery. Thus, while protein intake has been emphasised in previous studies [24, 25], our findings suggest that carbohydrate intake from staple foods may play an important role in recovery after THA.

This study also suggested the potential of standard hospital meals as an effective and easily implemented nutritional intervention. Encouraging adequate food intake, particularly of staple foods, might provide simple yet impactful nutritional support for postoperative recovery. These findings emphasized the importance of nutritional education and guidance for perioperative patients, ensuring they understand the importance of consuming adequate carbohydrates and overall nutrition [26, 27].

To improve the likelihood of discharging patients within the desired timeframe, we might need to consider several practical interventions in their dietary protocols. Firstly, enhancing the carbohydrate content of meals can provide the necessary energy for recovery, with a focus on complex carbohydrates like whole grains to sustain energy levels. Additionally, integrating high-protein foods can support muscle repair, which is crucial post-surgery. Offering meals that include a balance of carbohydrates and proteins can help meet the nutritional needs essential for a timely recovery. Moreover, providing perioperative nutritional education and support can empower patients to participate actively in their recovery. Educating patients about the importance of nutrition in postoperative recovery and ensuring they receive meals tailored to their recovery needs can significantly impact their ability to meet discharge criteria. Regular assessments by dietitians and adjustments to dietary plans based on individual progress can further refine this process.

Incorporating these nutritional strategies can directly affect the efficiency of postoperative care protocols, potentially enabling more patients to meet early discharge criteria and reducing the strain on hospital resources. While our study provides a foundational insight into this relationship, the specific patient cohort and controlled conditions limit the broader applicability of our findings. Future research should aim to include a larger and more diverse patient population, and possibly integrate more detailed assessments of nutritional intake, to validate and expand on our results.

This study has several limitations. First, the relatively small sample size limited the generalisability of our findings. The study cohort was highly specific and consisted of only patients with unilateral HOA, excluding those with confounding conditions. Second, although patients with clearly impaired ADLs could be excluded during patient selection, patients with mild ADL impairment may have still been included after extraction, because the electronic medical records do not contain an accurate description of ADL impairments. Therefore, the extent to which preoperative ADLs affect the postoperative rehabilitation process and length of hospital stay cannot be accurately assessed in this study. Third, although propensity score matching was used to control several confounding factors, the causal relationship between postoperative food intake and discharge timing remains unclear. It was difficult to determine whether patients discharged early were predisposed to faster recovery due to better overall health or whether their food intake directly influenced their recovery. Additionally, the study did not measure energy expenditure or specific dietary components beyond staple foods and side dishes, which might have limited the depth of the nutritional analysis. Future research with larger sample sizes, including energy balance and macronutrient intake, would help clarify the relationship between nutrition and recovery outcomes in THA patients.

Conclusions

This study highlights the significant role of early postoperative nutritional management, particularly staple food intake, in promoting early discharge among patients undergoing THA for HOA. The focus on adequate carbohydrate consumption, even in hospital meals alone, might impact patient recovery after surgery.

Abbreviations

ADL	Activity of daily living
BMI	Body mass index

CONUT	Controlling Nutritional Status
DVT	Deep vein thrombosis
HOA	Hip osteoarthritis
LOS	Length of hospital stays
NSAIDs	Non-steroidal anti-inflammatory drugs
THA	Total hip arthroplasty
TKA	Total knee arthroplasty
VAS	Visual analogue scale

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Author contributions
Study design: HS, KF, KeU, and MasT. Data collection: HS and YO. Data analyses: HS, YO and NT. Manuscript drafting: HS, KF, and KeU. All the authors have read and approved the final version of the manuscript.

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Data availability
No datasets were generated or analysed during the current study.

Declarations

Ethics approval and consent to participate
This study received ethical approval from the Ethics Review Board of Kitasato University (approval number: B23-012) for the use of an opt-out methodology.

Consent for publication
Not applicable.

Competing interests
The authors declare no competing interests.

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References

1. Zagra L. Advances in hip arthroplasty surgery: what is justified? EFORT Open Rev. 2017;2:171–8.
2. Ferguson RJ, Palmer AJ, Taylor A, Porter ML, Malchau H, Glyn-Jones S. Hip replacement. Lancet. 2018;392:1662–71.
3. Tsuchiya M, Fukushima K, Ohashi Y, Mamorita N, Saito H, Uchida K et al. Is the increase in the number of total hip arthroplasties in Japan due to an aging society? J Orthop Sci. 2024;S0949-2658(24)00109-X.
4. Llombart-Blanco R, Mariscal G, Barrios C, Vera P, Llombart-Ais R. MAKO robot-assisted total hip arthroplasty: a comprehensive meta-analysis of efficacy and safety outcomes. J Orthop Surg Res. 2024;19:698.
5. Wu Z, Zheng Y, Zhang X. Safety and efficacy of orthopedic robots in total hip arthroplasty: a network meta-analysis and systematic review. J Orthop Surg Res. 2024;19:846.
6. Li HX, Zhang QY, Sheng N, Xie HQ. Correlation and diagnostic performance of metal ions in patients with pseudotumor after MoM hip arthroplasty: a systematic review and meta-analysis. J Orthop Surg Res. 2024;19:723.
7. Mirghaderi P, Pahlevan-Fallahy MT, Rahimzadeh P, Habibi MA, Pourjoula F, Azarboo A, Moharrami A. Low-versus high-dose aspirin for venous thromboembolic prophylaxis after total joint arthroplasty: a systematic review and meta-analysis. J Orthop Surg Res. 2024;19:848.
8. Shang J, Wang L, Gong J, Liu X, Su D, Zhou X, Wang Y. Low molecular weight heparin dosing regimens after total joint arthroplasty: a prospective, single-center, randomized, double-blind study. J Orthop Surg Res. 2024;19:799.
9. Murray CJ, Lopez AD. Global mortality, disability, and the contribution of risk factors: global burden of Disease Study. Lancet. 1997;349:1436–42.
10. Kondrup J. Proper hospital nutrition as a human right. Clin Nutr. 2004;23:135–7.
11. Norman K, Kirchner H, Freudenreich M, Ockenga J, Lochs H, Pirlich M. Three month intervention with protein and energy rich supplements improve muscle function and quality of life in malnourished patients with non-neoplastic gastrointestinal disease–a randomized controlled trial. Clin Nutr. 2008;27:48–56.
12. Hiesmayr M, Schindler K, Pernicka E, Schuh C, Schoeniger-Hekele A, Bauer P, et al. Decreased food intake is a risk factor for mortality in hospitalised patients: the NutritionDay survey 2006. Clin Nutr. 2009;28:484–91.
13. Tsaousi G, Panidis S, Stavrou G, Tsouskas J, Panagiotou D, Kotzampassi K. Prognostic indices of poor nutritional status and their impact on prolonged hospital stay in a Greek university hospital. Biomed Res Int. 2014;2014:924270.
14. Ignacio de Ulibarri J, Gonzalez-Madrono A, de Villar NG, Gonzalez P, Gonzalez B, Mancha A, et al. CONUT: a tool for controlling nutritional status. First validation in a hospital population. Nutr Hosp. 2005;20:38–45.
15. Morley JE. Decreased food intake with aging. J Gerontol Biol Sci Med Sci. 2001;56 Spec 2:81 – 8.
16. Weaving G, Batstone GF, Jones RG. Age and sex variation in serum albumin concentration: an observational study. Ann Clin Biochem. 2016;53:106–11.
17. Nanri Y, Shibuya M, Fukushima K, Uchiyama K, Takahira N, Takaso M. Preoperative malnutrition is a risk factor for delayed recovery of mobilization after total hip arthroplasty. PM R. 2021;13:1331–9.
18. Pruzansky JS, Bronson MJ, Grelsamer RP, Strauss E, Moucha CS. Prevalence of modifiable surgical site infection risk factors in hip and knee joint arthroplasty patients at an urban academic hospital. J Arthroplasty. 2014;29:272–6.
19. Golladay GJ, Satpathy J, Jiranek WA. Patient optimization-strategies that work: Malnutrition. J Arthroplasty. 2016;31:1631–4.
20. Ihle C, Weiss C, Blumenstock G, Stockle U, Ochs BG, Bahrs C, et al. Interview based malnutrition assessment can predict adverse events within 6 months after primary and revision arthroplasty – a prospective observational study of 351 patients. BMC Musculoskelet Disord. 2018;19:83.
21. Schroer WC, LeMarr AR, Mills K, Childress AL, Morton DJ, Reedy ME, Chitranjan S. Ranawat Award: Elective joint arthroplasty outcomes improve in malnourished patients with nutritional intervention: a prospective population analysis demonstrates a modifiable risk factor. Bone Joint J. 2019; 101-B, (7_Supple_C):17–21.
22. Harsten A, Hjartarson H, Toksvig-Larsen S. Total hip arthroplasty and perioperative oral carbohydrate treatment: a randomised, double-blind, controlled trial. Eur J Anaesthesiol. 2012;29:271–4.
23. Botella-Carretero JI, Iglesias B, Balsa JA, Arrieta F, Zamarron I, Vazquez C. Perioperative oral nutritional supplements in normally or mildly undernourished geriatric patients submitted to surgery for hip fracture: a randomized clinical trial. Clin Nutr. 2010;29:574–9.
24. Church DD, Schutzler SE, Wolfe RR, Ferrando AA. Perioperative amino acid infusion reestablishes muscle net balance during total hip arthroplasty. Physiol Rep. 2021;9:e15055.
25. Paddon-Jones D, Sheffield-Moore M, Aarsland A, Wolfe RR, Ferrando AA. Exogenous amino acids stimulate human muscle anabolism without interfering with the response to mixed meal ingestion. Am J Physiol Endocrinol Metab. 2005;288:E761–7.
26. Bell JJ, Bauer JD, Capra S, Pulle RC. Multidisciplinary, multi-modal nutritional care in acute hip fracture inpatients - results of a pragmatic intervention. Clin Nutr. 2014;33:1101–7.
27. Malafarina V, Reginster JY, Cabrerizo S, Bruyere O, Kanis JA, Martinez JA, et al. Nutritional Status and Nutritional Treatment are related to outcomes and mortality in older adults with hip fracture. Nutrients. 2018;10:555.

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