

Review Article

Nutritional considerations for postoperative recovery in orthopaedic surgeries

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ABSTRACT

India has witnessed a substantial increase in joint replacement surgeries over the past two decades. Despite surgical advances, suboptimal nutritional status remains a major determinant of poor postoperative outcomes, including delayed wound healing, muscle atrophy, and increased infection risk. Protein energy malnutrition (PEM) is a strong predictor of adverse outcomes and delayed wound healing. Supplementation with high quality protein, essential amino acids (EAAs), and β -hydroxy β -methylbutyrate (HMB) have demonstrated benefits in preserving muscle mass, promoting anabolic recovery and reducing postoperative complications. Emerging evidence suggests promising roles for collagen, hyaluronic acid, and plant-based nutraceuticals in orthopaedic recovery, though the extent of impact of these nutrients remain underexplored. Collagen peptides may enhance wound healing, connective tissue regeneration, and mitigate the relapse of osteoarthritis (OA). Hyaluronic acid, with its immunomodulatory and regenerative functions, shows potential in post-surgical tissue repair and symptom relief. Furthermore, plant-derived bioactives such as curcumin, *Boswellia serrata*, and palmitoylethanolamide (PEA) demonstrate anti-inflammatory and analgesic effects, offering alternatives to conventional NSAIDs with fewer adverse effects. This review evaluates the current evidence supporting perioperative nutritional strategies to enhance recovery following orthopaedic surgeries.

Keywords: Orthopaedic surgery, Postoperative nutrition, Essential amino acids, Collagen, HMB

INTRODUCTION

India has witnessed an exponential rise in joint replacement surgeries over the last two decades.¹ The Indian Joint Registry (IJR) reported a 26-fold increase in total knee replacements (TKR) and an 18-fold increase in total hip replacements (THR) from 2006 to 2019. TKR was reportedly higher in females (73%) than males, while THR was predominantly reported in males (60.9%).² OA was the predominant indication for TKR (98.6%), followed by rheumatoid arthritis (RA, 1.2%) and trauma (0.2%).^{1,2} In contrast, avascular necrosis (51.8%) was the leading cause

for THR, followed by OA (10.1%), RA (6.2%), and ankylosing spondylitis (5.6%).²

Increasing number of these surgeries can be attributed to various risk factors, including an aging population with improved life expectancy, lifestyle changes, nutritional deficiencies, and better medical facilities.³⁻⁷ Aging triggers a wide range of changes in structural integrity, composition, and functional properties of bones.³ This contributes to development of age-associated skeletal disorders, including OA, osteoporosis, and an increased susceptibility to fractures, which increases the demand for surgical interventions.³ Reports suggest that osteoporosis

increases risk of revision surgery after TKA, particularly for periprosthetic fractures, periprosthetic joint infection (PJI) and aseptic loosening.⁸

Postoperative outcomes after TKA or THA are adversely affected due to other modifiable risk factors such as low bone mineral density, diabetes mellitus, and malnutrition.^{9,10} Malnutrition is a strong predictor of postoperative outcomes, with a prevalence of 3.6%-50% in patients undergoing total joint arthroplasty (TJA).¹¹⁻¹³ Clinical evidence suggests that poor nutritional status of patients in orthopaedic surgeries has been attributed to increased length of stay (LOS) in hospitals, readmissions or emergency department visits,¹¹ PJI, post-operative infections,¹² aseptic loosening, periprosthetic fracture, dislocation, anaemia, and increased mortality.^{6,13}

PHYSIOLOGICAL CHANGES DURING SURGERIES

Surgical procedures, of any kind, lead to a cascade of physiological events resulting in elevated inflammatory, immune, and metabolic responses, leading to a hypermetabolic-catabolic state.¹⁴ The state is driven by an increased energy demand for wound healing, upregulation of cortisol, glucagon and proinflammatory cytokines, and depletion of hepatic and muscle glycogen stores through gluconeogenesis.^{14,15} In otherwise healthy individuals, these metabolic changes can be reversed with insulin. However, during post-operative phase, higher insulin levels are required to achieve the same metabolic effects as the preoperative state, which may eventually lead to insulin resistance.^{16,17} Post-operative insulin resistance is strongly associated with adverse clinical outcomes, including delayed wound healing, increased infection risk and in-hospital mortality. Physiological stress during surgery induces a hypercatabolic state, characterised by increased protein turnover, urinary nitrogen losses, elevated circulating amino acids, and impaired amino acid uptake in skeletal tissues, leading to muscle wasting. These changes elevate protein requirements and may persist for several months' post-surgery recovery phase. While well-nourished young adults typically recover without significant consequences, older or malnourished patients are at increased risk of complications due to diminished functional and metabolic reserves.^{17,18} These physiological processes necessitate the need for adequate pre- and post-operative nutrition in mitigating surgical stress response and associated complications. This review examines the nutritional considerations necessary to enhance recovery and reduce postoperative complications in orthopaedic patients.

LITERATURE SEARCH

A comprehensive literature search was performed in electronic databases, including PubMed and Google Scholar, to identify relevant human studies. Search terms included but were not limited to: "nutrition," "nutritional support," "postoperative recovery," "surgery",

"orthopaedic surgery", "proteins", "essential amino acids", "collagen", "hyaluronic acid", "beta-hydroxy methyl butyrate", and "plant-based nutraceuticals".

PREOPERATIVE NUTRITION FOR IMPROVED POSTOPERATIVE OUTCOMES

Preoperative malnutrition is prevalent in nearly 50% of surgical patients, significantly impacting two-thirds of those undergoing major surgeries. Reports suggest that 8.5%-50% of patients undergoing TJA exhibit laboratory signs of malnutrition, which can be evaluated through albumin, transferrin, and total lymphocyte count.^{19,20} A systematic review of literature showed patients with preoperative albumin levels ≤ 3.5 g/dL were at a higher risk of developing postoperative wound complications.²⁰ Similarly, elderly malnourished patients undergoing elective orthopaedic surgeries showed a higher rate of reoperation and wound healing disorders.²¹

Emerging evidence indicates that nutritional supplementation targeting specific deficiencies improves malnutrition and reduces post-operative complications.⁶ A retrospective study highlighted that perioperative immunonutrients supplementation in elderly patients undergoing TKA or THA was associated with a significant reduction in LOS and incidence of infectious complications.²² A recent meta-analysis by Bao et al demonstrated that preoperative nutritional support markedly enhanced early wound healing and led to a notable reduction in scar formation in patients with complex fractures, 3 months post-surgery.²³

There is a strong body of evidence highlighting the importance of pre- and peri-operative nutrition in improving orthopaedic surgical outcomes.²² Nutritional status assessment prior to planning surgery is important, especially in the geriatric population.²⁴

POST-OPERATIVE NUTRITIONAL REQUIREMENTS

Post-operative catabolism may weaken immune function, delay wound healing, and cause loss of muscle strength, leading to prolonged LOS.²⁵ Early postoperative oral nutrition is recommended with continuation of a protein-rich diet through early rehabilitation to support anabolism and minimise nutritional store depletion.²⁴ Meta-analyses of randomised control trials (RCTs) have demonstrated that early oral nutrition after surgery, including a balanced diet and/or oral nutritional supplements, significantly lowers rate of complications, LOS and mortality.²⁶

ROLE OF PROTEINS AND AMINO ACIDS IN POSTOPERATIVE RECOVERY

Postsurgical immobilisation triggers rapid muscle atrophy due to reduced mechanical loading and amino acid efflux from muscle tissue to support metabolic demands like gluconeogenesis and immune function.^{18,27} Atrophy can

start within 48 hours, making early and adequate nutritional intervention critical to preserve muscle mass and support recovery.¹⁸

Proteins and amino acids have been commonly used as nutritional supplements to stimulate anabolism. Evidence suggests that higher protein intake is necessary to minimise muscle atrophy and maximise muscle strength.^{18,27} There is robust grade 1 level evidence indicating that a high protein diet (1.2-1.9 g/kg body weight), combined with EAAs and resistance training after TJA, has shown positive effects, particularly in patients with sarcopenia. Besides, EAA supplementation following TKA has been shown to increase satellite cells necessary for myofiber regeneration and reduce expression of pro-apoptotic mediators at cellular level, suggesting suppression of apoptosis and muscle atrophy.²⁸ Clinical studies have demonstrated that protein and amino acid supplementation after orthopaedic surgeries improved muscle atrophy and accelerated functional recovery (Table 1).²⁹⁻³³

NUTRACEUTICALS IN POST-OPERATIVE RECOVERY IN ORTHOPAEDIC SURGERY

Postoperative pain after orthopaedic surgery can hinder recovery and quality of life. Though NSAIDs are effective, long-term use carries significant risks, including gastrointestinal issues, cardiovascular complications, delayed bone healing, perioperative bleeding, and renal impairment.³⁴ Nutraceuticals like HMB, hyaluronic acid (HA), collagen, PEA, along with other botanical extracts offer safer alternatives, potentially reducing NSAID dependence while supporting pain relief and functional recovery.

HMB supplementation in post-surgical recovery

HMB, a natural metabolite of EAA leucine, plays a crucial role in protein metabolism, muscle hypertrophy, and insulin modulation, particularly in stressful physiological situations, such as surgery or injury.^{35,36} Dietary intake typically ranges from 0.25-1 g daily, but supplementation has gained attention for its ergogenic effects, including enhanced performance and muscle mass gains.³⁵

Recently, HMB has been studied for its potential to improve post-operative outcomes in post-traumatic and post-surgical patients. Evidence suggests HMB supplementation enhances wound healing, preserves fat-free mass, improves body composition and grip strength, shortens immobilisation periods, reduces dependence on bed rest, and mitigates complications associated with prolonged bed rest, without any reported adverse effects (Table 2).^{35,37}

Recent reports suggest combining a high-protein supplement with HMB helps maintain muscle mass and strength, especially post-hospital rehabilitation and recovery.³⁸

Collagen in postoperative recovery

Collagen is a key structural protein in skin, tendons and bones, forming the main component of extracellular matrix (ECM). Of the five common types (I-V), type I is the most abundant, making up over 90% of body's collagen. Type II collagen, crucial in cartilage, is linked to disorders like skeletal dysplasia, RA, and OA.³⁹

Major surgeries can impair subcutaneous collagen accumulation, indicating reduced systemic wound-healing capacity.⁴⁰ To address this deficiency and enhance post-surgical recovery, collagen supplementation is currently used in specific cases and holds potential for broader applications in orthopaedic postoperative care.

Collagen supplementation in postoperative wound healing

Oral collagen administration has emerged as a potential treatment for enhancing wound healing. Recent preclinical and clinical studies have demonstrated positive effects of bioactive collagen peptides on matrix synthesis and skin physiology.³⁹ Experimental research further highlights the role of collagen peptides in attracting skin fibroblasts⁴¹, promoting their migration and proliferation, and increasing HA synthesis.^{42,43}

Since surgical incisions, sutures, and post-surgical care are common to all surgeries, the proven benefits of collagen in dermatological procedures suggest a similar potential for enhancing wound healing after orthopaedic surgeries due to a similar surgical cascade seen after these surgeries.^{44,45} A study demonstrated effectiveness and tolerability of hydrolysed collagen supplementation in promoting healing after arthroscopic ACL reconstruction, suggesting possible benefit of collagen after other orthopaedic procedures.⁴⁶

Role of collagen in OA relapse after TKA surgery

Among type-2 collagen, collagen hydrolysates and undenatured type II collagen (UC-II), UC-II exerts its effects through oral tolerance mechanisms and activates regulatory T cells in gut-associated lymphoid tissue, reducing immune-mediated cartilage damage, inflammation, and degradation. Multiple clinical trials have demonstrated that UC-II supports joint health in both individuals with OA and healthy adults.⁴⁷

Although collagen supplementation has shown positive effects in patients with osteoporosis and OA, data on its postoperative utilisation in orthopaedic surgeries is scarce. Evidence suggests osteoporosis remains underdiagnosed and undertreated among osteoporosis patients awaiting primary TKA, with only 15.1% of patients receiving pharmacological treatment.⁴⁸ Hence, to manage post-TKA outcomes in underdiagnosed or untreated cases as well as in patients with relapse OA, collagen-based therapeutics hold promise as a future approach, though further research is warranted.

Table 1: Post-operative outcome of protein and amino acid supplementation in orthopaedic surgeries.

Authors	Study details	Surgery	Intervention	Outcomes
Li et al²⁹	Design: RCT (n=62) Duration: 12 weeks	TKA	Intervention (n=32): Whey protein daily (30 g)# + CET Control (n=30): Placebo daily + CET	After 12 weeks, whey protein supplementation showed significant improvement in muscle strength (p=0.001), VAS scores (p=0.002), range of motion (p=0.001), AKS scores (p=0.001) and leg circumference (p=0.001) compared with placebo.
Ueyama et al³⁰	Design: Double-blinded RCT (n=52) Duration: 2 years	Unilateral TKA for primary knee OA	EAA (n=26): 9 g/day Placebo (n=26): Powdered lactose, 9 g/day Intake duration: Preoperative: 1 week Post-operative: 2 weeks	EAA supplementation significantly improved recovery of rectus femoris muscle volume (134%±31% vs. 114±27%) and quadriceps muscle strength (159±54% and 125±40%) when compared to placebo (p<0.05).
Liao et al³¹	Design: Systematic review and meta-analysis (5 RCTs, n=242)	TJR, THA, TKA	Intervention (n=123): Protein supplements (including milk protein, whey protein, leucine, BCAA, and casein, whether consumed alone or in combination with other nutrients, such as amino acids and creatine) + ET Control (n=119): Placebo, including protein supplements alone, ET alone, or regular care	Protein supplements + ET showed significant results: In patients after TKR increased quadriceps muscle volume in both involved leg (weighted MD=7.38%, p<0.0001) and uninvolved leg (weighted MD=6.11%, p=0.0002) Improved hamstring muscle volume in both operative leg (weighted MD=7.71%, p<0.00001) and uninvolved leg (weighted MD=6.08%, p<0.0001). Improved number of quadriceps myofibers in uninvolved leg (MD=19.8, p<0.01) but not involved leg. In patients after THR Prevented postoperative upper-arm muscle atrophy (MD=1.4 cm ² ; p<0.05) In patients after TJR Improved lower-limb muscle strength in both involved (SMD=0.44, p=0.04; I ² =52%) and uninvolved leg (SMD=0.54, p=0.01; I ² =0%). Improved postoperative physical mobility, walking capability (SMD=0.75, p=0.003; I ² =0%), timed up-and-go performance (SMD=0.66, p=0.01; I ² =0%), and stair climbing performance (SMD=0.84, p=0.002; I ² =4%)
Ueyama et al³²	Design: Double-blind, placebo-controlled, RCT (n=60) Duration: 8 weeks	Unilateral TKA for primary knee OA	EAA** (n=30): 3 g thrice daily Placebo (n=30): Powdered lactose, 3 g thrice daily Intake duration: Preoperative: 1 week Post-operative: 2 weeks	EAA supplementation prevented rectus femoris muscle atrophy (p<0.05) and accelerated functional recovery (Shorter mean time to recovery of ADLs with EAA compared to placebo (p=0.005).
Muyskens et al³³	Design: Two-arm, parallel, RCT (n=41) Duration: 7 weeks	Primary TKA	EAA (n=19): 20 g Placebo (n=22): 20 g Alanine Intake duration: Twice daily Preoperative: 1 week Post-operative: 6 weeks	EAA supplementation decreased muscle atrophy after TKA, along with inflammatory markers. Satellite cells proportion increased significantly with EAA compared to placebo before surgery in both operative leg (p=0.05 for type I associated cells) and nonoperative leg (p=0.02 for type II associated cells).

*ACLR: Anterior Cruciate ligament reconstruction; ADLs: Activities of daily living; AKS: American Knee Society; BCAA: Branched chain amino acids; CET: Conventional rehabilitation training; EAA: Essential amino acid; ET: Exercise training; N: Number of patients; OA: Osteoarthritis; RCT: Randomised controlled trials; THA: Total hip arthroplasty; TJR: Total joint replacement; TKA: Total knee arthroplasty; VAS: Visual analog scale. #Whey protein (30 g) was mixed with 100-150 ml of warm water and administered within 30 minutes of each training session. **3 g EAA included isoleucine (603 mg, 6.7%), leucine (684 mg, 7.6%), lysine (756 mg, 8.4%), methionine (603 mg, 6.7%), phenylalanine (405 mg, 4.5%), threonine (405 mg, 4.5%), tryptophan (207 mg, 2.3%), valine (603 mg, 6.7%), arginine (630 mg, 7%), histidine (315 mg, 3.5%), and starch (1,089 mg, 12.1%).

Table 2: Effect of HMB supplementation on post-operative recovery following orthopaedic surgery.

Author	Study Details	Surgery	Intervention	Outcomes
Han et al³⁷	Design: pragmatic, prospective observational study (n=177) Duration: 3 months	Hip replacement surgery	HMB + RT: 43 HMB alone: 44 RT alone: 45 Negative control: 45 HMB dose and duration: 3 g/day for 3 months postoperatively	Both RT + HMB and RT alone significantly improved body composition and grip strength (p<0.05). Treatment with HMB alone alleviated decline of muscle strength, muscle mass, and grip strength when compared with negative controls.
Hendrickson et al³⁵	Design: prospective RCT (n=400) Duration: 12 weeks	Fixation of pelvis and extremity fractures	CEAA (n=200): 1.5 g HMB, 7 g arginine, 7 g glutamine Control (n=200): Standard nutrition Intake duration: Twice daily for 2 weeks postoperatively	CEAA supplementation has a protective effect against common complications (30.5% vs. 43.8%; adjusted RR 0.71; p=0.008) and early skeletal muscle wasting (fat free mass maintained after 6 weeks)

*CEAA: Conditionally essential amino acids, HMB: Beta-hydroxy-beta-methylbutyric acid, RT: Resistance training

HA in wound healing and post-surgery recovery

HA is a major constituent of ECM, present abundantly in connective tissues. It supports wound healing and tissue repair by stimulating growth factors, fibroblast activity, and keratinocyte proliferation.

Its incorporation into nutritional support after orthopaedic surgery may enhance recovery outcomes by accelerating healing processes, making HA a promising adjunct in post-surgical care and tissue regeneration strategies.⁴⁹

HA has also exhibited a nutritive role in facilitating recovery after arthroscopic reconstruction of ACL.

A prospective, multicentre, randomised, open-label trial demonstrated that HA, when included in a dietary supplement containing collagen, chondroitin sulphate, and plasma proteins, contributed to a reduced recovery time and improved quality of life following ACL reconstruction.⁴⁶

Botanical extracts for wound healing and pain management

Surgical wound complications are one of the major causes of morbidity and can negatively impact patients’ quality of life.⁵⁰ Optimal wound healing follows a structured process, including rapid haemostasis, controlled inflammation, mesenchymal cell differentiation, migration, angiogenesis, re-epithelialization and proper collagen synthesis to strengthen healing tissue.⁵¹ Certain nutraceuticals, with their antioxidant and anti-inflammatory properties, may support this process and help reduce need for pharmaceutical pain relievers (Table 3). Emerging evidence indicates that plant-based nutraceuticals, with their anti-inflammatory and antioxidant properties, may enhance postoperative wound healing and pain management. However, there is a paucity of data specific to orthopaedic surgeries. Given their proven role in other surgeries and pain management in OA, nutraceuticals may support postoperative recovery in orthopaedic patients, but further clinical research is needed to validate their impact.

Table 3: Key nutraceuticals for optimising postoperative wound healing and pain relief.

Nutraceutical	Clinical evidence
Curcumin	29 RCTs (n=2396) illustrated that curcumin intake (dosage: 120 mg-1500 mg; duration: 4-35 weeks) significantly reduced VAS (SMD=-2.03; p<0.0001) and WOMAC score (SMD=-0.69; p<0.00001) among arthritis patients compared to controls. ⁵² A meta-analysis (23 RCTs; n=2175) found that curcumin, alone and in combination with other drugs, significantly reduced VAS pain score (MD=-1.63, p<0.05) and total WOMAC score (MD=-18.85; p<0.05) in patients with knee OA compared to placebo. ⁵³
Boswellia serrata	A systematic review and meta-analysis (7 trials, n=545) reported Boswellia or its extract (100 mg-250 mg for ≥4 weeks) significantly relieved pain in patients with OA when compared to controls [VAS: (WMD=-8.33; p<0.00001); WOMAC score: (WMD=-14.22; p=0.0006)], WOMAC stiffness (p=0.0007) and joint function (p<0.0001). ⁵⁴ A randomized, double-blind, placebo-controlled study (n=98) in patients with knee OA demonstrated a significant reduction in VAS scores from day 30 to 105 (p<0.001) and in WOMAC pain and physical activity scores from day 30 to 90 (p<0.001) in both BSE (150 mg and 300 mg) groups compared to baseline. ⁵⁵

Continued.

Nutraceutical	Clinical evidence
Bromelain	In six trials (n=774), OEC (trypsin, bromelain, rutoside) and diclofenac significantly improved LAFI score (OEC: 12.6±2.4 to 9.1±3.9; diclofenac: 12.7±2.4 to 9.1±4.2; both p<0.001) and pain (OEC: 6.4±1.9 to 3.8±2.7; diclofenac: 6.6±1.8 to 3.9±2.5; both p<0.001). OEC had fewer adverse events (14.7% vs 21.1%, p=0.022) compared to diclofenac. ⁵⁶
PEA	An observational study showed that after one month of treatment with TDP + PGB, VAS decreased from 5.7±0.12 to 4.3±0.11 (p<0.0001), but no significant subjective improvement was noted. Adding um-PEA led to a further significant reduction in pain, with VAS dropping to 2.7±0.09 and 1.7±0.11 after 2 and 3 months, respectively (p<0.0001) in patients with failed back surgery syndrome. ⁵⁷ A double-blind, placebo-controlled study indicated that PEA supplementation (dosage: 300mg and 600mg) significantly improved WOMAC pain score (300 mg, p=0.0074; 600mg, p<0.001) and stiffness score (300mg, p<0.0490; 600 mg, p=0.001) compared to placebo. NRS pain evaluations for "worst pain" and "least pain" showed significant reductions in both PEA 300 mg (p<0.001, p=0.005) and 600 mg (p<0.001, p<0.001) groups. ⁵⁸

*BSE: β -boswellic acids; LAFI: Lequesne algofunctional index; NRS: Numerical rating scale score; OA: Osteoarthritis; OEC: Oral enzyme combinations; PEA: Palmitoylethanolamide; PGB: Pregabalin; RCTs: Randomised controlled trials; TPD: Tapentadol; um-PEA: Ultramicronised palmitoylethanolamide; VAS: Visual analog scale; WOMAC: Western Ontario and McMaster universities osteoarthritis index. BSE: Boswellin® Super Extra is a standardised extract of *B. serrata* containing not less than 30% 3-acetyl-11-keto- β -boswellic acid, 7.5% β -boswellic acid, 3.5% of 3-O-acetyl- β boswellic acid, and 1.5% 11-Keto- β -boswellic acid as analysed by HPLC.

CONCLUSION

Pre- and post-operative nutritional supplementation plays a vital role in enhancing recovery following orthopaedic surgeries by reducing complications, optimising functional outcomes, and supporting wound healing, immune function, and muscle preservation. Protein and essential amino acid supplementation mitigate muscle atrophy and postoperative complications accelerating rehabilitation. Micronutrients contribute to collagen synthesis, oxidative stress reduction, and immune modulation, enhancing surgical site healing and reducing infection risk. Additionally, compounds/nutraceuticals such as HMB, PEA and collagen have shown promising effect in improving muscle strength, reducing oxidative stress, and enhancing tissue repair. While evidence supports the efficacy of these interventions, further research is needed to establish precise dosing strategies and individualised supplementation protocols for optimal postoperative recovery.

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