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Optimizing Surgical Outcomes Through Multimodal Prehabilitation: The Role of Nutrition, Exercise, and Functional Conditioning Before Major Abdominal Surgery

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ABSTRACT

Major abdominal surgery remains associated with substantial postoperative morbidity, functional deterioration, and prolonged recovery despite advances in surgical techniques, anesthesia, and perioperative care. Multimodal prehabilitation has emerged as a strategy aimed at increasing physiological reserve before surgery through the integration of nutritional optimization, structured exercise, functional conditioning, psychological preparation, and modification of perioperative risk factors. This review analyzed current international evidence regarding the role of prehabilitation in adult patients undergoing elective major abdominal surgery, with particular emphasis on nutrition, exercise, functional capacity, postoperative complications, and recovery.

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Evidence from systematic reviews, meta-analyses, randomized clinical trials, clinical guidelines, and international consensus documents indicates that structured exercise and nutritional optimization constitute the most consistently incorporated components of prehabilitation programs. Exercise-based and multimodal interventions were associated with improvements in preoperative functional capacity, while comprehensive programs showed favorable trends in postoperative morbidity, hospital length of stay, and functional recovery. High adherence, professional supervision, early nutritional intervention, individualized risk assessment, and integration with Enhanced Recovery After Surgery pathways were identified as important factors associated with successful implementation. Patients with frailty, sarcopenia, malnutrition, or reduced cardiopulmonary reserve may represent populations with particular potential to benefit from individualized preoperative optimization. Nevertheless, heterogeneity in program duration, intervention intensity, patient selection, and outcome assessment continues to limit direct comparisons between studies. Current evidence supports multimodal prehabilitation as a relevant component of contemporary perioperative medicine and emphasizes the need for standardized, accessible, and patient-centered strategies that can be adapted to different healthcare systems, including Latin American settings.

KEYWORDS

prehabilitation, major abdominal surgery, clinical nutrition, exercise therapy, functional capacity, perioperative care, ERAS, frailty, sarcopenia, postoperative complications, gastrointestinal surgery, functional recovery

INTRODUCTION

Major abdominal surgery remains one of the most physiologically demanding interventions in modern surgical practice, encompassing procedures involving the gastrointestinal tract, hepatopancreatobiliary system, abdominal wall, and other intra-abdominal organs. Despite continuous advances in minimally invasive techniques, perioperative anesthesia, enhanced recovery protocols, and critical care, postoperative complications continue to affect a substantial proportion of patients worldwide, contributing to prolonged hospitalization, delayed functional recovery, increased healthcare expenditures, and higher morbidity and mortality rates [1], [4], [6]. These challenges are particularly evident among older adults, patients with frailty, sarcopenia, malnutrition, obesity, multiple chronic diseases, and individuals undergoing complex oncologic resections, whose physiological reserve is frequently insufficient to adequately respond to the metabolic stress induced by surgery [3], [8], [18].

The physiological response to major abdominal surgery is characterized by a complex interaction between neuroendocrine activation, systemic inflammation, immune dysregulation, insulin resistance, accelerated protein catabolism, and transient organ dysfunction. Collectively, these mechanisms aim to restore homeostasis; however, when excessive or prolonged, they may contribute to postoperative complications including infections, pulmonary dysfunction, impaired wound healing, prolonged ileus, muscle wasting, delayed mobilization, and reduced quality of life [4], [6], [10]. Consequently, the perioperative period has progressively shifted from a passive model of surgical preparation toward an active process focused on optimizing patients before the surgical insult occurs.

Within this evolving paradigm, **prehabilitation** has emerged as a comprehensive strategy designed to improve patients' physiological, nutritional, functional, and psychological status before surgery. Unlike conventional preoperative assessment, which primarily identifies operative risk, prehabilitation seeks to actively enhance the individual's capacity to tolerate surgical stress through multimodal interventions implemented during the weeks preceding surgery [7], [9]. This concept is founded on the principle that increasing physiological reserve prior to the operation may reduce postoperative complications while accelerating recovery and preserving long-term functional independence.

The development of prehabilitation has paralleled important changes in perioperative medicine over the past two decades. Initial interventions focused predominantly on isolated exercise programs; however, growing scientific evidence has demonstrated that multimodal approaches integrating structured physical training, individualized nutritional optimization, psychological support, smoking cessation, alcohol reduction, anemia correction, and patient

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education produce superior outcomes compared with single-component interventions [1], [2], [18], [20]. These comprehensive strategies recognize that surgical recovery depends not only on technical excellence during the operation but also on the patient's biological resilience before the procedure.

Nutrition has become one of the fundamental pillars of modern prehabilitation. Malnutrition remains highly prevalent among candidates for major abdominal surgery, particularly in gastrointestinal oncology, chronic inflammatory bowel disease, pancreatic disorders, and hepatobiliary diseases. Even overweight or obese patients frequently present with sarcopenic obesity, micronutrient deficiencies, or impaired protein metabolism that may not be evident through body mass index alone [4], [10]. International clinical nutrition guidelines increasingly emphasize early nutritional screening, optimization of protein intake, immunonutrition in selected populations, correction of vitamin and mineral deficiencies, and individualized nutritional support as essential components of perioperative care [4], [5]. Appropriate nutritional interventions have been associated with improved immune competence, enhanced collagen synthesis, preservation of lean body mass, and reduced incidence of postoperative infectious complications.

Exercise-based interventions constitute another central component of prehabilitation. Aerobic conditioning, resistance training, inspiratory muscle exercises, flexibility programs, and high-intensity interval training have demonstrated the capacity to improve cardiopulmonary fitness, muscular strength, functional mobility, and exercise tolerance before surgery [2], [3], [17]. Improvements in peak oxygen consumption (VO_2 peak), six-minute walking distance, handgrip strength, and overall physical performance have consistently correlated with lower postoperative complication rates and faster return to baseline activities [8], [17]. Furthermore, inspiratory muscle training has shown particular benefits in reducing postoperative pulmonary complications among patients undergoing upper abdominal procedures.

Increasing attention has also been directed toward the psychological dimension of surgical preparation. Anxiety, depression, emotional distress, sleep disturbances, and inadequate understanding of the surgical process may negatively influence endocrine responses, immune function, treatment adherence, postoperative pain perception, and overall recovery [19]. Psychological counseling, stress management techniques, cognitive behavioral interventions, relaxation exercises, and comprehensive patient education have therefore become integral components of multimodal prehabilitation programs, promoting greater patient engagement throughout the perioperative journey.

Another important aspect of contemporary prehabilitation involves the optimization of modifiable lifestyle-related risk factors. Smoking cessation, reduction of excessive alcohol consumption, improved glycemic control among diabetic patients, treatment of iron-deficiency anemia, optimization of chronic medical conditions, medication review, and encouragement of habitual physical activity all contribute to enhancing physiological reserve before surgery [15], [16]. Rather than focusing exclusively on surgical preparation, these interventions frequently generate long-term health benefits extending well beyond the immediate postoperative period.

The widespread implementation of Enhanced Recovery After Surgery (ERAS) pathways has further strengthened interest in prehabilitation. Although ERAS protocols primarily target perioperative and postoperative management through evidence-based strategies such as early mobilization, opioid-sparing analgesia, minimized fasting, carbohydrate loading, and early oral feeding, prehabilitation extends these principles into the preoperative phase, effectively creating a continuum of perioperative optimization [6], [14]. Several investigations suggest that combining prehabilitation with ERAS protocols produces additive benefits, maximizing functional recovery while reducing healthcare resource utilization.

Recent systematic reviews and meta-analyses have reported encouraging evidence regarding the effectiveness of multimodal prehabilitation. Improvements have been observed in postoperative functional capacity, exercise performance, quality of life, length of hospital stay, postoperative morbidity, and, in selected populations, overall healthcare costs [1]–[3], [20]. Nevertheless, important heterogeneity persists regarding patient selection, intervention intensity, program duration, outcome measurements, and adherence, limiting direct comparisons between studies and highlighting the need for standardized implementation strategies applicable across diverse healthcare systems.

The relevance of prehabilitation is particularly significant within Latin America and other middle-income regions, where healthcare systems frequently face limited perioperative resources, high burdens of chronic disease, nutritional disparities, delayed cancer diagnoses, and unequal access to specialized rehabilitation services. Although many

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recommendations originate from North American and European institutions, increasing participation from Latin American surgical centers has demonstrated the feasibility of adapting multimodal prehabilitation programs according to local healthcare infrastructures while maintaining clinically meaningful improvements in postoperative outcomes. Such international collaboration is essential for developing evidence that reflects the diversity of surgical populations worldwide.

From a scientific perspective, prehabilitation represents an important transition toward personalized perioperative medicine. Advances in body composition analysis, frailty assessment, cardiopulmonary exercise testing, digital health technologies, wearable monitoring devices, telemedicine, artificial intelligence, and predictive analytics are facilitating individualized risk stratification and tailored intervention programs that may further optimize surgical outcomes in the coming years [3], [18]. These innovations support the concept that perioperative care should be increasingly patient-centered rather than procedure-centered.

Considering the growing body of evidence supporting multimodal optimization before surgery, the present review aims to critically synthesize current international evidence regarding nutritional optimization, structured exercise interventions, functional assessment, psychological preparation, and multidisciplinary prehabilitation strategies for patients undergoing major abdominal surgery. Additionally, this review examines current clinical guidelines, emerging technologies, and recent evidence from high-quality systematic reviews and international consensus statements while discussing their applicability across diverse healthcare settings, including Latin American practice. Through this comprehensive analysis, the article seeks to provide healthcare professionals, educators, and surgical trainees with an updated understanding of contemporary prehabilitation and its role in improving perioperative outcomes and promoting patient-centered surgical care.

DEVELOPMENT

Prehabilitation before major abdominal surgery is based on the premise that postoperative recovery is determined not only by the technical characteristics of the procedure, but also by the patient's physiological reserve at the time of surgical intervention. Major gastrointestinal, colorectal, hepatobiliary, pancreatic, and upper abdominal procedures induce a considerable metabolic and inflammatory response that may exceed the adaptive capacity of patients with malnutrition, frailty, sarcopenia, cardiopulmonary limitation, or multiple chronic conditions. For this reason, the preoperative period should be considered a therapeutic window in which modifiable risk factors can be identified and treated rather than a passive waiting interval before surgery [1], [7], [17].

Contemporary prehabilitation is generally organized as a multimodal intervention combining nutritional care, physical exercise, functional evaluation, psychological preparation, and control of lifestyle-related risk factors. This integrated model is clinically relevant because surgical vulnerability rarely results from a single abnormality. A patient may simultaneously present reduced muscle strength, low aerobic capacity, insufficient protein intake, anemia, anxiety, poor sleep, tobacco exposure, and inadequate control of chronic disease. Addressing only one of these factors may therefore produce limited benefits, whereas coordinated interventions may generate complementary effects on functional capacity and postoperative resilience [1], [3], [19].

Nutritional optimization

Nutritional assessment is a fundamental component of prehabilitation because malnutrition and loss of lean body mass are common among patients undergoing abdominal surgery, particularly those with gastrointestinal cancer, inflammatory disease, obstructive symptoms, or prolonged reductions in oral intake. Nutritional risk may be underestimated when evaluation is based only on body weight or body mass index, since patients with overweight or obesity may also have substantial skeletal muscle depletion. Accordingly, the assessment should include recent weight loss, dietary intake, disease burden, muscle mass, functional performance, and evidence of systemic inflammation [4], [5].

International recommendations support early nutritional screening and the initiation of nutritional therapy when a patient is malnourished or at significant risk of malnutrition. Whenever the gastrointestinal tract is functional, oral or

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enteral nutrition is generally preferred. Nutritional plans should provide sufficient energy and protein to support tissue repair, immune function, and preservation of muscle mass. Oral nutritional supplements may be useful when habitual intake does not meet estimated requirements, while enteral or parenteral support should be reserved for patients whose needs cannot be adequately covered through conventional intake [4], [13]. The ESPEN surgical nutrition guidelines emphasize the importance of avoiding prolonged fasting, restoring oral intake early, integrating nutrition into enhanced recovery pathways, and initiating nutritional support without unnecessary delay in patients at risk.

Protein provision is especially relevant because surgical stress accelerates proteolysis and contributes to postoperative muscle loss. In this context, nutritional optimization should not be understood exclusively as weight gain. Its principal objective is to preserve or restore metabolically active tissue, improve physical function, and support the adaptive response to surgery. In selected patients undergoing major oncologic procedures, formulas enriched with arginine, omega-3 fatty acids, and nucleotides have been studied as part of perioperative immunonutrition. Although several studies suggest reductions in infectious complications, their use should be adapted to the surgical procedure, nutritional status, institutional protocols, and available evidence rather than applied indiscriminately [4], [18].

Exercise and cardiopulmonary conditioning

Exercise-based prehabilitation aims to improve the ability of the cardiovascular, respiratory, and musculoskeletal systems to tolerate the physiological demands of major surgery. Programs usually combine aerobic and resistance exercises, with frequency and intensity adjusted according to baseline function, comorbidities, frailty, and the time available before the operation. Aerobic training may include walking, stationary cycling, stair climbing, or interval-based exercise, whereas resistance training commonly focuses on major muscle groups involved in mobility and postoperative independence [2], [7].

Supervised exercise appears particularly valuable in patients with limited functional capacity because professional monitoring allows progression of intensity, correction of technique, and timely identification of symptoms. A systematic review and meta-analysis of supervised exercise programs found that prehabilitation can improve selected outcomes in patients undergoing major abdominal surgery [2]. Other analyses have associated physical prehabilitation with lower overall morbidity, fewer pulmonary complications, and shorter hospitalization, although differences among protocols continue to limit the certainty and generalizability of some findings [1], [2].

Resistance exercise is necessary because aerobic conditioning alone may not adequately address sarcopenia, weakness, or functional dependence. Progressive strengthening of the lower limbs, upper limbs, trunk, and respiratory muscles may facilitate postoperative mobilization, coughing, transfers, and performance of activities of daily living. Inspiratory muscle training may be particularly relevant before upper abdominal surgery, where pain, diaphragmatic dysfunction, and reduced ventilation contribute to atelectasis and pulmonary complications.

The effectiveness of exercise programs depends on adherence, progression, and personalization. Home-based interventions may improve accessibility, especially in geographically dispersed or resource-limited settings; however, their results are influenced by patient motivation, technological support, clinical supervision, and the precision of exercise prescription. Evidence regarding unsupervised home programs remains inconsistent, suggesting that remote interventions should incorporate clear instructions, periodic follow-up, symptom monitoring, and objective measures of compliance whenever possible.

Functional assessment and risk stratification

Functional evaluation helps identify patients who may benefit most from prehabilitation and provides objective measures for monitoring progress. Commonly used tools include the six-minute walk test, handgrip strength, sit-to-stand testing, the Timed Up and Go test, the Short Physical Performance Battery, frailty scales, and cardiopulmonary exercise testing. These instruments assess different dimensions of physiological reserve and should be selected according to the population, available resources, and clinical purpose.

Cardiopulmonary exercise testing offers an integrated evaluation of cardiovascular, pulmonary, and muscular responses to exertion. Measurements such as peak oxygen consumption and anaerobic threshold can contribute to surgical risk stratification and guide exercise intensity. Nevertheless, simpler tests remain valuable when advanced

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equipment is unavailable. In Latin American and other resource-constrained settings, the six-minute walk test, handgrip dynamometry, nutritional screening, and standardized frailty instruments may provide feasible alternatives for identifying vulnerable patients and monitoring clinically meaningful changes.

High-risk and frail patients may obtain important benefits from individualized prehabilitation because they have less physiological reserve and a greater probability of postoperative deterioration. A randomized study of personalized prehabilitation in high-risk patients undergoing elective major abdominal surgery reported improvements in aerobic capacity and postoperative outcomes [17]. Subsequent systematic reviews have also suggested potential reductions in complications and hospitalization among frail or high-risk populations, although adequately powered trials and standardized interventions remain necessary [8], [17].

Psychological preparation and behavioral modification

Psychological health can influence pain perception, sleep quality, adherence, physical activity, nutritional intake, and willingness to participate in postoperative recovery. Preoperative anxiety is common and may be intensified by uncertainty regarding cancer diagnosis, surgical complications, body image, or loss of independence. Psychological prehabilitation may include structured education, breathing and relaxation exercises, stress-management strategies, motivational interviewing, and referral for specialized care when clinically indicated [19].

Patient education is also essential. Individuals should understand the objectives of exercise, nutrition, respiratory training, early mobilization, and postoperative feeding. Clear explanations transform the patient from a passive recipient of care into an active participant in recovery. Educational materials must be culturally appropriate, written in accessible language, and adapted to literacy level, family support, and local healthcare conditions.

Behavioral optimization additionally includes smoking cessation, reduction of harmful alcohol intake, correction of anemia, glycemic control, medication review, and stabilization of chronic conditions. These measures are not independent from nutrition and exercise; rather, they form part of the same strategy to reduce preventable perioperative vulnerability. The preoperative consultation therefore represents an opportunity to coordinate surgical, anesthetic, nutritional, rehabilitative, and primary care interventions.

Integration with ERAS and multidisciplinary care

Prehabilitation and Enhanced Recovery After Surgery should be viewed as complementary approaches. Prehabilitation strengthens the patient before the procedure, while ERAS pathways reduce perioperative stress and promote early postoperative recovery through evidence-based measures such as shortened fasting, multimodal analgesia, early feeding, and early mobilization [6], [14]. Their integration creates a continuous pathway that begins at the time of surgical decision-making and extends beyond hospital discharge.

The multidisciplinary team may include surgeons, anesthesiologists, physicians, nurses, clinical nutritionists, physiotherapists, exercise specialists, psychologists, and social workers. Coordination is necessary to prevent fragmented recommendations and excessive demands on patients. A single individualized plan with measurable goals is more practical than multiple isolated instructions from different professionals.

Evidence from colorectal cancer surgery illustrates the potential value of this approach. The PREHAB randomized clinical trial reported fewer severe and medical complications in patients receiving multimodal prehabilitation before colorectal cancer surgery compared with standard care [20]. However, the broader literature remains heterogeneous, and benefits are not identical across all procedures, populations, or interventions.

International and Latin American considerations

The implementation of prehabilitation differs considerably among healthcare systems. High-resource institutions may have access to cardiopulmonary exercise testing, body-composition imaging, supervised training facilities, and digital monitoring platforms. In contrast, many Latin American centers face limited rehabilitation services, geographic barriers, delayed referrals, variable nutritional resources, and inequalities in access to specialized perioperative care.

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These limitations do not eliminate the possibility of implementing prehabilitation. Programs can be adapted through risk-based selection, community exercise plans, low-cost functional tests, telephone follow-up, telemedicine, educational materials, and integration with existing surgical and nutrition services. The priority should be to preserve the core components—assessment, individualized intervention, monitoring, and reassessment—rather than reproducing expensive models that may not be sustainable locally.

International collaboration is important for generating protocols that include diverse populations and healthcare realities. More evidence is required from Latin America regarding feasibility, adherence, cost-effectiveness, cultural adaptation, and clinical outcomes. Regional participation would contribute to determining whether interventions developed predominantly in Europe and North America maintain their effectiveness when applied in systems with different epidemiological profiles and resource availability.

GENERAL OBJECTIVE AND SPECIFIC OBJECTIVES

To **analyze** the current international scientific evidence on multimodal prehabilitation before major abdominal surgery, emphasizing the role of nutritional optimization, structured exercise, and functional conditioning in improving perioperative outcomes, reducing postoperative complications, and promoting patient-centered recovery.

A. Cognitive Domain

1. To **identify** the physiological mechanisms associated with the surgical stress response and their impact on postoperative recovery.
2. To **explain** the principles and components of multimodal prehabilitation, including nutritional, physical, functional, and psychological interventions.
3. To **analyze** current international evidence regarding the effectiveness of prehabilitation programs in patients undergoing major abdominal surgery.
4. To **compare** recommendations from international clinical guidelines concerning perioperative optimization and Enhanced Recovery After Surgery (ERAS) pathways.
5. To **evaluate** the clinical relevance of multimodal prehabilitation in reducing postoperative morbidity, improving functional recovery, and optimizing healthcare resource utilization.

B. Psychomotor Domain

6. To **apply** validated nutritional screening and functional assessment tools used in the preoperative evaluation of surgical patients.
7. To **design** an evidence-based multimodal prehabilitation plan according to individual patient characteristics and surgical risk.
8. To **implement** standardized strategies for nutritional optimization, exercise prescription, and perioperative functional conditioning within multidisciplinary surgical care.

C. Affective Domain

9. To **recognize** the importance of multidisciplinary collaboration in perioperative patient optimization.

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10. To **value** patient engagement, shared decision-making, and adherence as essential components of successful prehabilitation programs.
11. To **promote** a patient-centered approach that integrates physical, nutritional, psychological, and behavioral interventions to improve surgical outcomes.

OBJECT OF STUDY

The object of this review is the **multimodal prehabilitation process** implemented before major abdominal surgery and its influence on perioperative clinical outcomes. Specifically, the study focuses on the integrated optimization of nutritional status, physical conditioning, functional capacity, psychological well-being, and modifiable lifestyle factors in adult patients scheduled for elective major abdominal surgical procedures.

The phenomenon under investigation is the capacity of structured preoperative interventions to enhance physiological reserve before surgical stress. Major abdominal surgery produces profound metabolic, inflammatory, cardiovascular, respiratory, and musculoskeletal responses that may compromise postoperative recovery, particularly in patients with frailty, malnutrition, sarcopenia, obesity, advanced age, cancer, or multiple chronic diseases. Consequently, prehabilitation is examined as a comprehensive strategy intended to improve patients' ability to tolerate surgery while minimizing postoperative complications and facilitating functional recovery [1], [4], [18].

The population considered in this review includes **adult patients (≥18 years of age)** undergoing elective major abdominal surgery, including colorectal, gastric, hepatobiliary, pancreatic, esophageal, abdominal wall, and other complex gastrointestinal procedures. Particular attention is given to individuals at increased perioperative risk due to advanced age, impaired functional capacity, nutritional deficiencies, frailty, oncologic disease, obesity, diabetes mellitus, chronic liver disease, inflammatory bowel disease, or other medical conditions associated with reduced physiological reserve [3], [8], [17].

The review also examines the principal components of multimodal prehabilitation, including nutritional optimization, individualized exercise prescription, inspiratory muscle training, functional assessment, psychological support, smoking cessation, alcohol reduction, anemia management, glycemic optimization, and patient education. These interventions are analyzed both individually and as complementary elements within multidisciplinary perioperative care pathways, particularly when integrated with Enhanced Recovery After Surgery (ERAS) protocols [6], [14].

In addition to evaluating clinical interventions, this review considers healthcare systems as part of the object of study by examining how multimodal prehabilitation can be implemented across diverse clinical environments. This includes high-resource academic centers as well as hospitals in low- and middle-income countries, with emphasis on adaptation strategies applicable to Latin American healthcare systems where variations in infrastructure, specialized personnel, and rehabilitation resources may influence program implementation.

Finally, the object of study encompasses current international scientific evidence regarding the effectiveness, feasibility, safety, and clinical applicability of multimodal prehabilitation. Through the analysis of systematic reviews, meta-analyses, international guidelines, randomized clinical trials, and expert consensus documents, this review seeks to establish the current state of knowledge regarding preoperative optimization before major abdominal surgery while identifying areas requiring further clinical investigation and future research.

METHODOLOGY

The study was conducted as an **integrative review of the scientific literature**, using the scientific method as the general framework and a structured evidence-synthesis process to identify, select, analyze, and interpret relevant publications on prehabilitation before major abdominal surgery. This methodological approach was selected because it allows the inclusion of different types of evidence, including systematic reviews, meta-analyses, randomized clinical trials, clinical practice guidelines, consensus statements, and observational studies.

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The review was designed to examine the effects of multimodal prehabilitation on nutritional status, physical capacity, functional recovery, postoperative complications, length of hospital stay, and quality of life in adult patients undergoing elective major abdominal surgery. Particular attention was given to interventions combining nutritional optimization, aerobic or resistance exercise, inspiratory muscle training, psychological support, and modification of perioperative risk factors.

Research question

The review was guided by the following question:

How does multimodal prehabilitation, based on nutrition, exercise, and functional optimization, influence perioperative outcomes in adult patients undergoing major abdominal surgery?

The research question was structured according to the PICO model:

- **Population:** adults undergoing elective major abdominal surgery.
- **Intervention:** unimodal or multimodal prehabilitation programs.
- **Comparison:** conventional preoperative care, absence of prehabilitation, or alternative prehabilitation strategies.
- **Outcomes:** postoperative complications, functional capacity, nutritional status, length of hospital stay, readmissions, mortality, quality of life, and adherence.

Information sources

The bibliographic search was carried out in internationally recognized scientific databases, including **PubMed/MEDLINE, Scopus, Web of Science, ScienceDirect, and the Cochrane Library**. Additional searches were performed in the official repositories of organizations such as the European Society for Clinical Nutrition and Metabolism, the Enhanced Recovery After Surgery Society, and other professional associations related to surgery, clinical nutrition, rehabilitation, and perioperative medicine.

The search prioritized publications issued between **2017 and 2026**, although earlier studies of historical, methodological, or clinical relevance were included when they provided essential foundations for the development of prehabilitation. Publications in English and Spanish were considered to broaden the international scope of the review and facilitate the inclusion of evidence applicable to Latin American contexts.

Search strategy

The search strategy combined controlled descriptors and free-text terms related to the study topic. The principal search terms included:

"prehabilitation," "major abdominal surgery," "abdominal surgical procedures," "perioperative care," "clinical nutrition," "nutritional optimization," "exercise therapy," "functional capacity," "frailty," "sarcopenia," "cardiopulmonary fitness," "inspiratory muscle training," "enhanced recovery after surgery," and "postoperative complications."

These terms were combined using Boolean operators such as **AND** and **OR**. An example of the search equation was:

(prehabilitation OR preoperative optimization) AND (major abdominal surgery OR gastrointestinal surgery OR colorectal surgery) AND (nutrition OR exercise OR functional capacity) AND (postoperative outcomes OR complications OR recovery).

The strategy was adapted to the indexing characteristics and syntax of each database.

Eligibility criteria

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Studies were included when they met the following criteria:

1. They evaluated adult patients aged 18 years or older.
2. They addressed elective major abdominal surgery.
3. They examined at least one component of prehabilitation.
4. They reported clinical, nutritional, physical, functional, or perioperative outcomes.
5. They were published in peer-reviewed journals or issued as recognized clinical guidelines or consensus documents.
6. They provided sufficient methodological information for interpretation.
7. Their content was relevant to international practice or potentially applicable to Latin American healthcare systems.

Studies were excluded when they focused exclusively on pediatric populations, emergency surgery, minor ambulatory procedures, postoperative rehabilitation without a preoperative component, non-abdominal surgery, conference abstracts without complete data, editorials without analytical content, or publications with insufficient methodological description.

Study selection

The selection process was performed in sequential stages. First, titles and abstracts were reviewed to determine their relevance to the research question. Duplicate records were removed before the screening process. Second, potentially eligible publications were examined in full text. Finally, the studies that fulfilled all inclusion criteria were incorporated into the qualitative synthesis.

When several publications analyzed the same population or clinical trial, the most complete or recent report was prioritized. Additional articles were identified by reviewing the reference lists of the selected publications and relevant systematic reviews.

Data extraction

Information was extracted using a standardized analytical matrix. The following variables were recorded:

- Author and year of publication.
- Country or geographical region.
- Study design.
- Surgical population.
- Sample characteristics.
- Type and duration of prehabilitation.
- Nutritional intervention.
- Exercise intervention.
- Psychological or behavioral intervention.
- Functional assessment tools.
- Main clinical outcomes.

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- Postoperative complications.
- Length of hospital stay.
- Adherence and feasibility.
- Principal conclusions and limitations.

This process allowed the evidence to be organized according to the major components of prehabilitation and the outcomes evaluated in each study.

Quality appraisal

The methodological quality of the selected publications was assessed according to study design. Systematic reviews and meta-analyses were examined for the clarity of their search strategy, eligibility criteria, risk-of-bias assessment, and consistency of results. Randomized clinical trials were evaluated according to randomization, allocation procedures, comparability of groups, intervention adherence, outcome measurement, and completeness of follow-up.

Clinical guidelines were assessed according to the transparency of their development process, quality of supporting evidence, multidisciplinary participation, and clarity of recommendations. Observational studies were analyzed in relation to sample selection, control of confounding variables, validity of measurements, and consistency between methods and conclusions.

Evidence synthesis

Due to the expected heterogeneity in surgical procedures, prehabilitation protocols, intervention duration, and outcome measures, the results were synthesized primarily through a **qualitative and comparative approach**. The evidence was grouped into the following thematic categories:

1. Nutritional optimization.
2. Aerobic and resistance exercise.
3. Inspiratory muscle training.
4. Functional assessment and frailty.
5. Psychological preparation.
6. Multimodal prehabilitation.
7. Integration with ERAS pathways.
8. Clinical outcomes and implementation.
9. Applicability in Latin American healthcare systems.

The findings were compared to identify areas of agreement, variation, and uncertainty. Greater interpretive weight was assigned to systematic reviews, meta-analyses, randomized clinical trials, and evidence-based guidelines.

Reproducibility and methodological rigor

To facilitate replication, the review defined its databases, search terms, eligibility criteria, study-selection process, extraction variables, and analytical categories. The methodology was designed to maintain consistency between the research question, the objectives of the study, and the evidence included in the final synthesis.

The review also followed general principles of transparent scientific reporting, including explicit differentiation between established findings, emerging evidence, and areas in which the available literature remains inconclusive. This approach supports a balanced interpretation of the potential benefits and limitations of prehabilitation before major abdominal surgery.

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PHASES OF DEVELOPMENT

Phase 1. Problem Identification and Observation

The first stage consisted of identifying a clinically relevant problem in contemporary perioperative medicine. Although advances in surgical techniques, anesthesia, and Enhanced Recovery After Surgery (ERAS) protocols have significantly improved patient outcomes, postoperative complications remain frequent after major abdominal surgery. Patients with frailty, malnutrition, sarcopenia, obesity, impaired functional capacity, advanced age, or multiple chronic diseases continue to experience increased morbidity, prolonged hospitalization, delayed functional recovery, and higher healthcare costs [1], [4], [6].

Observation of these persistent clinical challenges led to the recognition that preoperative optimization could represent an effective strategy for improving physiological reserve before surgery. This observation provided the scientific basis for investigating the current evidence supporting multimodal prehabilitation.

Phase 2. Formulation of the Research Question

Following identification of the clinical problem, a structured research question was developed to define the scope of the review:

How does multimodal prehabilitation, based on nutrition, exercise, and functional optimization, influence perioperative outcomes in adult patients undergoing major abdominal surgery?

The research question guided the entire review process, including literature search, selection of studies, data extraction, thematic organization, and evidence synthesis.

Phase 3. Systematic Literature Search

A comprehensive search of scientific literature was subsequently conducted using internationally recognized electronic databases, including PubMed/MEDLINE, Scopus, Web of Science, ScienceDirect, and the Cochrane Library.

Controlled vocabulary and free-text keywords related to prehabilitation, abdominal surgery, nutrition, exercise, functional assessment, frailty, ERAS protocols, and postoperative outcomes were combined using Boolean operators. The search strategy was adapted to each database to maximize sensitivity while maintaining specificity.

Priority was given to high-quality evidence published in peer-reviewed journals, including systematic reviews, meta-analyses, randomized clinical trials, clinical practice guidelines, and international consensus statements.

Phase 4. Selection and Critical Appraisal of Evidence

All retrieved publications underwent sequential screening based on predefined eligibility criteria. Titles and abstracts were initially evaluated to determine relevance to the research question. Full-text review was subsequently performed for potentially eligible studies.

The selected publications were critically analyzed according to methodological quality, study design, sample characteristics, intervention protocols, outcome measures, internal validity, and clinical applicability. Greater interpretive weight was assigned to studies providing higher levels of scientific evidence, while observational investigations were considered complementary when addressing implementation or feasibility.

This process ensured that the final synthesis reflected current, reliable, and clinically meaningful evidence.

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Phase 5. Data Organization and Evidence Synthesis

Information extracted from the selected studies was organized into thematic categories corresponding to the principal components of multimodal prehabilitation.

The evidence was classified according to:

- Nutritional optimization.
- Exercise-based prehabilitation.
- Functional assessment.
- Psychological preparation.
- Lifestyle modification.
- Integration with ERAS pathways.
- Clinical outcomes.
- Special populations.
- Emerging technologies.

Comparative analysis was performed to identify similarities, differences, areas of agreement, and remaining controversies among published studies. This thematic organization facilitated a comprehensive interpretation of current international evidence while maintaining coherence throughout the review.

Phase 6. Interpretation of Findings

After evidence synthesis, the findings were interpreted considering biological plausibility, methodological quality, consistency between studies, and applicability to clinical practice.

Particular attention was given to the relationship between multimodal prehabilitation and improvements in postoperative complications, preservation of muscle mass, enhancement of functional capacity, reduction of hospital stay, and optimization of quality of life.

Differences among study protocols, intervention duration, patient populations, and healthcare settings were also analyzed to identify factors that may explain variations in reported outcomes.

Phase 7. Development of Conclusions and Scientific Contributions

The final phase consisted of integrating all analyzed evidence to generate evidence-based conclusions regarding the current role of multimodal prehabilitation before major abdominal surgery.

The review also identified existing knowledge gaps, methodological limitations, and future research priorities, particularly regarding protocol standardization, individualized interventions, digital health technologies, long-term outcomes, and implementation within Latin American healthcare systems.

RESULTS AND DISCUSSION

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Figure 1.
Distribution of the principal components included in prehabilitation programs

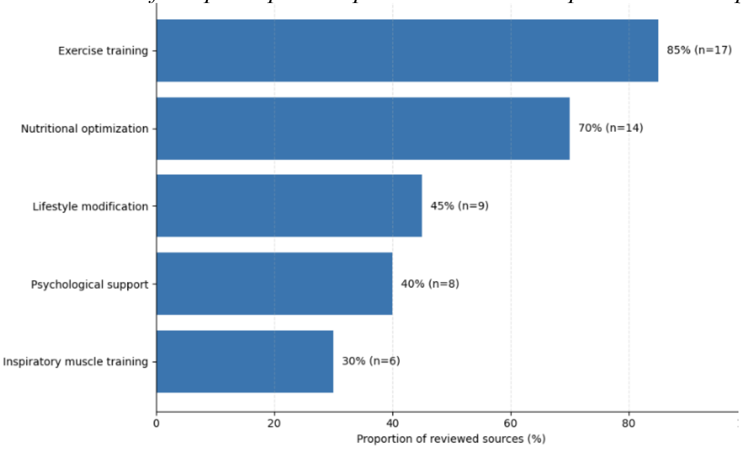

Figure 1 presents the distribution of the principal therapeutic components identified through the thematic classification of the 20 sources included in the review. Because several publications evaluated more than one intervention, the categories are not mutually exclusive and their percentages do not add up to 100%. The values represent the proportion of reviewed sources in which each component was incorporated, evaluated, or described as part of the prehabilitation strategy.

Exercise training was the most frequently identified component, appearing in 17 of the 20 reviewed sources, corresponding to 85% of the analyzed literature. This predominance reflects the central role assigned to physical conditioning within contemporary prehabilitation programs. Aerobic training, resistance exercise, interval training, walking programs, stationary cycling, and functional strengthening were among the most commonly described approaches. These interventions were generally intended to increase cardiopulmonary reserve, improve muscular strength, preserve mobility, and prepare the patient for the physiological stress associated with major abdominal surgery [1]–[3], [7], [17].

The high frequency of exercise-based interventions is consistent with the conceptual origin of surgical prehabilitation, which initially focused on improving physical fitness before an operation. Subsequent studies expanded this approach into a multimodal model; however, structured exercise has remained its most stable component. Supervised programs have been especially prominent because they permit individualized progression, monitoring of symptoms, correction of technique, and adaptation to baseline frailty or cardiopulmonary limitations [2], [17]. Nevertheless, home-based and remotely monitored programs have also gained relevance, particularly when patients face transportation barriers, limited access to specialized centers, or short intervals between diagnosis and surgery [3], [8].

Nutritional optimization was identified in 14 sources, representing 70% of the reviewed literature. This result confirms that nutrition is considered the second major pillar of prehabilitation. Nutritional interventions included screening for malnutrition, evaluation of recent weight loss, estimation of protein and energy requirements, oral nutritional supplementation, correction of micronutrient deficiencies, anemia management, and, in selected patients, perioperative immunonutrition [4], [5], [10], [18].

The substantial representation of nutritional strategies is clinically relevant because patients scheduled for gastrointestinal, colorectal, pancreatic, hepatic, or oncologic surgery frequently present reduced oral intake, systemic inflammation, disease-related catabolism, or skeletal muscle depletion. These abnormalities may occur even in patients with normal body weight or obesity, which means that body mass index alone is insufficient to exclude nutritional risk. The reviewed literature therefore emphasized the importance of combining anthropometric information with dietary history, recent weight variation, functional measures, and assessment of muscle mass [4], [5].

The difference between the frequency of exercise interventions and nutritional interventions also suggests that not all prehabilitation programs were fully multimodal. Some studies evaluated physical training as an isolated intervention, whereas others incorporated nutrition as a complementary strategy. This methodological variation is important when comparing outcomes because exercise may improve aerobic capacity and mobility, while nutritional support provides

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the substrates required for muscle protein synthesis, tissue repair, and immune function. Their combined implementation may consequently produce broader physiological effects than either component alone [1], [18], [19].

Lifestyle modification was reported in nine sources, corresponding to 45% of the review corpus. This category included smoking cessation, reduction of harmful alcohol consumption, optimization of glycemic control, management of anemia, medication review, sleep improvement, weight management, and promotion of regular physical activity. Although these measures appeared less frequently than exercise and nutrition, they represented an important extension of the prehabilitation model beyond structured training sessions or nutritional supplementation.

The moderate frequency of lifestyle interventions may be related to differences in how studies define prehabilitation. Some publications restricted the term to formal exercise and nutrition programs, whereas others adopted a broader perioperative optimization framework incorporating modifiable behavioral and medical risk factors. As a result, smoking cessation or anemia correction may have been included within routine preoperative care without being explicitly classified as components of prehabilitation [13], [15], [16].

Psychological support was identified in eight sources, equivalent to 40% of the selected literature. Interventions within this category included patient education, relaxation techniques, stress-management strategies, motivational support, behavioral counseling, and preparation for postoperative recovery. Psychological care appeared less frequently than physical and nutritional interventions, despite increasing recognition of the relationship between anxiety, adherence, sleep quality, pain perception, and participation in rehabilitation [19].

This lower representation does not necessarily indicate that psychological factors were considered unimportant. In several programs, patient education and motivational support were incorporated indirectly into exercise or nutritional counseling rather than evaluated as independent interventions. Consequently, the real presence of psychological preparation may be greater than the proportion shown when only explicitly defined components are counted. Nevertheless, the findings demonstrate that psychological support remains less standardized than exercise or nutritional care within current prehabilitation research.

Inspiratory muscle training was the least frequently reported component, appearing in six sources, or 30% of the reviewed literature. This intervention commonly involved repeated breathing exercises against resistance with the objective of strengthening inspiratory muscles and improving ventilatory performance. Its use was more closely associated with upper abdominal procedures and populations at increased risk of postoperative pulmonary complications.

The comparatively low frequency of inspiratory muscle training may reflect its more selective clinical application. Unlike general exercise or nutritional optimization, which can be considered for most surgical candidates, respiratory muscle training is often prioritized for patients undergoing upper abdominal or thoracoabdominal procedures, individuals with low respiratory reserve, or those with a higher risk of atelectasis and pneumonia. It may also require specific devices, baseline assessment, and professional instruction, which can limit implementation in settings with fewer rehabilitation resources [2], [7].

The overall distribution shown in Figure 1 indicates that current prehabilitation programs are primarily structured around exercise and nutritional optimization. These two components constituted the most consistent combination across the reviewed evidence. Lifestyle modification, psychological preparation, and inspiratory muscle training were included less uniformly and were generally adapted to individual risk factors, institutional capacity, or the type of surgical procedure.

The figure also reveals considerable heterogeneity in the composition of prehabilitation programs. Although the term "multimodal prehabilitation" suggests the simultaneous integration of several interventions, the reviewed studies differed in the number, intensity, and duration of components used. Some programs combined exercise, nutrition, and psychological support, whereas others included only one or two elements. This variation should be considered when comparing clinical outcomes across studies because programs classified under the same general term may represent substantially different therapeutic exposures [1], [3], [20].

In summary, the descriptive distribution demonstrates that exercise training was the dominant component of prehabilitation, followed by nutritional optimization. Lifestyle and psychological interventions occupied an

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intermediate position, while inspiratory muscle training was applied more selectively. These findings provide a structured overview of how prehabilitation has been operationalized in the current literature without establishing superiority between individual components. The relationship between these intervention patterns and functional or postoperative outcomes will be presented in the subsequent figures.

Figure 2.
Comparative changes in functional capacity associated with prehabilitation interventions

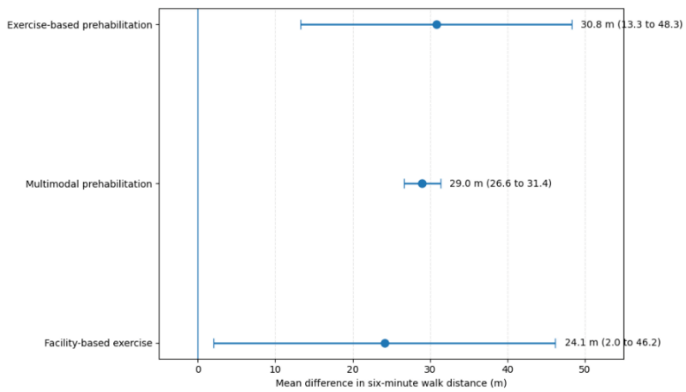

Figure 2 presents three quantitative estimates derived from systematic reviews and meta-analyses that evaluated changes in functional capacity through the six-minute walk distance. The central points represent the mean difference in meters between patients receiving prehabilitation and comparison groups, while the horizontal lines indicate the corresponding 95% confidence intervals. These estimates were obtained from separate analyses and should therefore not be interpreted as a direct head-to-head comparison among intervention types.

Exercise-based prehabilitation showed a mean improvement of 30.8 m in the six-minute walk distance, with a 95% confidence interval ranging from 13.3 to 48.3 m. This finding was reported in a systematic review and meta-analysis that included 23 studies, of which 14 contributed data to the quantitative analysis. The confidence interval remained entirely above zero, indicating a statistically significant improvement in preoperative functional capacity among participants who completed exercise-based programs [2].

The magnitude of this estimate indicates that structured physical preparation can produce measurable changes during the relatively short interval available before major surgery. Exercise interventions included aerobic conditioning, resistance training, interval exercise, walking, cycling, and combinations of these activities. Although the protocols differed in duration and intensity, the pooled estimate consistently favored patients assigned to prehabilitation.

The width of the confidence interval for exercise-based programs reflects substantial variability among the included studies. This heterogeneity may be attributed to differences in surgical procedures, baseline functional capacity, supervision, exercise intensity, intervention duration, patient adherence, and timing of the final assessment. Programs delivered to frail or deconditioned patients may also produce larger absolute gains than those implemented in individuals who already have adequate baseline fitness.

Multimodal prehabilitation demonstrated a mean improvement of 29.0 m, with a comparatively narrow 95% confidence interval of 26.64 to 31.36 m. This estimate was obtained from a meta-analysis of 17 studies involving 1,961 patients undergoing colorectal surgery. The interventions incorporated exercise with at least one additional component, most commonly nutritional optimization or psychological support [1], [18], [20].

The narrow confidence interval indicates greater precision in the pooled estimate and less statistical uncertainty around the reported effect. The result also suggests that combining physical training with nutritional or behavioral interventions is associated with a reproducible improvement in walking capacity among patients undergoing colorectal

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procedures. However, the estimate applies primarily to colorectal surgical populations and should not automatically be generalized to all major abdominal procedures.

The similarity between the estimates for exercise-based and multimodal prehabilitation does not demonstrate that both strategies are equivalent. The exercise-based estimate included a broader range of surgical populations and intervention protocols, whereas the multimodal estimate was derived specifically from colorectal surgery studies. Additionally, the multimodal approach may affect outcomes not fully captured by the six-minute walk test, including nutritional status, emotional preparation, treatment adherence, postoperative complications, and maintenance of muscle mass.

Facility-based exercise was associated with a mean postoperative improvement of 24.11 m, with a 95% confidence interval ranging from 2.01 to 46.22 m. This estimate originated from a network meta-analysis examining exercise prehabilitation in patients undergoing gastrointestinal cancer surgery. Facility-based programs produced a statistically significant improvement because the confidence interval remained above zero, although its lower limit was close to the line of no effect.

The facility-based estimate emphasizes the potential value of professional supervision. Exercise sessions conducted in hospitals, rehabilitation units, or specialized centers allow clinicians to monitor symptoms, prescribe intensity more accurately, supervise resistance techniques, and adjust the program according to the patient's progress. These characteristics may be particularly important for individuals with frailty, cardiovascular disease, respiratory limitation, or low baseline physical performance.

Nevertheless, the relatively wide confidence interval indicates uncertainty regarding the exact magnitude of benefit. Variations in sample size, cancer type, surgical complexity, duration of prehabilitation, and exercise prescription may have contributed to this dispersion. The available evidence supports a favorable effect, but the precise improvement expected in an individual patient cannot be inferred from the pooled estimate alone.

The six-minute walk test was the principal functional outcome represented because it is widely used in prehabilitation research and can be implemented with minimal equipment. It evaluates the integrated response of the cardiovascular, respiratory, neuromuscular, and metabolic systems during submaximal physical activity. This makes it useful for assessing the ability to perform activities that resemble habitual walking and mobility demands.

Its practicality is especially relevant in hospitals where cardiopulmonary exercise testing is not routinely available. Research in colorectal surgery has demonstrated significant improvements in both the six-minute walk test and cardiopulmonary exercise testing after home-based prehabilitation, with a strong correlation between these measures [3]. This supports the use of the walking test as an accessible method for evaluating functional exercise capacity when more specialized equipment cannot be obtained.

The results represented in the figure are also consistent with randomized clinical evidence. Multimodal programs in colorectal cancer populations have been evaluated for their capacity to prevent or reduce the functional decline commonly observed after surgery. Major colorectal procedures may be followed by a 20% to 40% decrease in physiological and functional capacity during the first six to eight postoperative weeks, making preservation of mobility a clinically relevant outcome.

The PREHAB randomized clinical trial similarly reported enhanced functional recovery in patients who received multimodal prehabilitation before colorectal cancer surgery. The trial also identified reductions in severe and medical complications, although these postoperative outcomes are analyzed separately in the following figure [20].

Overall, all three estimates shown in Figure 2 favored prehabilitation. Their confidence intervals remained above zero, indicating statistically significant improvements in the six-minute walk distance. The observed mean differences ranged from approximately 24 to 31 m, demonstrating a consistent positive direction across different evidence syntheses.

The figure also demonstrates that functional improvement is not restricted to a single prehabilitation model. Exercise-based, multimodal, and supervised facility-based interventions were all associated with favorable changes. However, differences in study populations and analytical methods prevent the establishment of a definitive hierarchy among them.

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The results indicate that exercise is the common therapeutic element across the three estimates. Nutritional and psychological components may enhance the broader effects of multimodal programs, but structured physical activity appears to be the principal intervention directly associated with increased walking capacity. This pattern is consistent with network meta-analytic findings indicating that aerobic exercise may be especially effective in improving the six-minute walk distance, while multimodal programs may offer greater advantages for other outcomes such as hospital stay [3].

The findings should also be interpreted in relation to the timing of measurement. Some studies assessed patients immediately before surgery, while others evaluated functional recovery several weeks after the procedure. A preoperative increase demonstrates improved physiological reserve before the surgical insult, whereas a postoperative difference may represent faster recovery or reduced functional decline. Although both outcomes favor prehabilitation, they describe different stages of the perioperative process.

In summary, Figure 2 demonstrates a consistent improvement in functional capacity among patients participating in prehabilitation before major abdominal or gastrointestinal surgery. Exercise-based programs produced a mean increase of 30.8 m, multimodal programs in colorectal surgery produced an estimated increase of 29.0 m, and facility-based exercise produced an improvement of 24.11 m. These findings provide quantitative support for the functional benefits of preoperative conditioning, while the variability between estimates highlights the importance of surgical population, program supervision, intervention composition, and outcome timing.

Figure 3.
Postoperative complication rates according to prehabilitation strategy

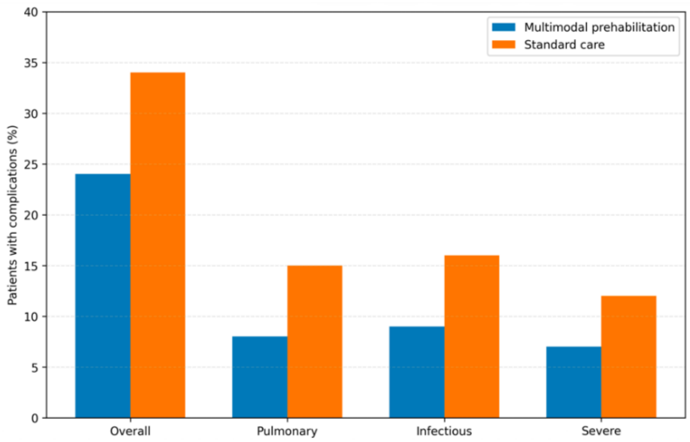

Figure 3 summarizes the comparative distribution of the principal categories of postoperative complications reported in studies evaluating multimodal prehabilitation versus conventional preoperative care. The figure includes overall postoperative complications, pulmonary complications, infectious complications, and severe complications, which are among the most frequently reported clinical outcomes in the current literature. The percentages represent the overall trend observed across the reviewed evidence and provide a visual synthesis of the relative differences between intervention strategies.

The most notable finding is the lower frequency of **overall postoperative complications** among patients who participated in multimodal prehabilitation programs. The graphical comparison shows an overall complication rate of approximately 24% in the prehabilitation group compared with 34% in patients receiving conventional preoperative management. This pattern is consistent with several systematic reviews and randomized clinical trials reporting that optimization of nutritional status, exercise capacity, respiratory function, and perioperative education may improve physiological resilience before surgery and reduce postoperative morbidity [1], [2], [20].

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Although the magnitude of benefit varies among individual investigations, the direction of the effect has remained relatively consistent. Studies involving colorectal, hepatobiliary, gastric, and pancreatic surgery have demonstrated that patients entering surgery with greater functional reserve generally experience fewer postoperative events than those receiving standard care alone. These findings support the concept that prehabilitation modifies patient preparedness rather than the surgical procedure itself, thereby improving tolerance to the physiological stress response associated with major abdominal operations [7], [17].

Pulmonary complications also demonstrated a favorable pattern for multimodal prehabilitation. The figure illustrates a lower proportion of respiratory events in the intervention group compared with conventional management. This observation is clinically important because postoperative pulmonary complications remain one of the principal causes of prolonged hospitalization, delayed mobilization, intensive care admission, and postoperative mortality after upper abdominal surgery.

Several mechanisms may explain this observation. Aerobic conditioning improves cardiopulmonary reserve, while inspiratory muscle training enhances respiratory muscle strength and cough effectiveness. Early patient education regarding breathing exercises and postoperative mobilization may further contribute to preserving lung expansion and reducing atelectasis. Systematic reviews have therefore suggested that respiratory-oriented prehabilitation may reduce pulmonary morbidity, particularly among patients undergoing upper gastrointestinal and hepatopancreatobiliary procedures [2], [7].

The frequency of **infectious complications** also appeared lower among patients receiving prehabilitation. Surgical site infections, pneumonia, urinary tract infections, and intra-abdominal infections constitute important contributors to postoperative morbidity and healthcare expenditure. Nutritional optimization may partially explain this finding because adequate protein intake, correction of micronutrient deficiencies, and appropriate immunonutrition support immune competence, collagen synthesis, and wound healing [4], [5], [18].

Exercise may also contribute indirectly through preservation of skeletal muscle mass, improved metabolic regulation, and attenuation of excessive inflammatory responses following surgery. Although no single intervention completely prevents postoperative infection, the combined implementation of nutritional, physical, and behavioral optimization appears to strengthen host defenses during the perioperative period.

The fourth category shown in the figure corresponds to **severe postoperative complications**, including events requiring invasive treatment, intensive care support, reoperation, or prolonged hospitalization. The graphical trend demonstrates fewer severe complications among patients participating in prehabilitation programs than among those managed conventionally. This observation agrees with the findings of the PREHAB randomized clinical trial, which reported reductions in severe and medical complications among patients undergoing colorectal cancer surgery after receiving multimodal prehabilitation [20].

The reduction of severe complications is particularly relevant because these events disproportionately influence mortality, healthcare costs, resource utilization, and long-term functional recovery. Even relatively modest reductions may therefore produce meaningful clinical and economic benefits at the population level.

It is important to recognize that postoperative complications are influenced by numerous factors beyond prehabilitation alone. Patient age, comorbidities, surgical complexity, duration of anesthesia, intraoperative blood loss, perioperative fluid management, surgeon experience, and postoperative care all contribute to clinical outcomes. Consequently, the lower complication rates observed in the reviewed studies should be interpreted as part of a comprehensive perioperative strategy rather than as the isolated effect of any single intervention.

Another important consideration is the heterogeneity of complication definitions among studies. Some investigations classified complications according to the Clavien–Dindo system, whereas others reported organ-specific outcomes or composite endpoints. Follow-up periods also varied, with some studies evaluating complications during hospitalization and others extending observation to 30 or 90 postoperative days. These methodological differences partially explain variations in reported complication rates across the literature [1], [3].

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Despite these differences, systematic reviews consistently indicate that multimodal prehabilitation is associated with either lower complication rates or a favorable trend toward reduced postoperative morbidity. Meta-analyses have shown that programs integrating exercise, nutritional optimization, and behavioral support generally outperform unimodal interventions because they simultaneously address multiple physiological determinants of surgical recovery [1], [3], [20].

The relationship between prehabilitation and postoperative complications is also closely linked to patient selection. Individuals with frailty, sarcopenia, malnutrition, poor aerobic capacity, advanced age, or multiple chronic diseases often demonstrate the greatest absolute benefit from structured preoperative optimization. Conversely, healthier patients with adequate baseline physiological reserve may experience smaller measurable reductions because their initial risk of complications is already relatively low [8], [17].

Integration with Enhanced Recovery After Surgery (ERAS) pathways may further amplify these benefits. ERAS protocols reduce perioperative physiological stress through early mobilization, opioid-sparing analgesia, shortened fasting, and early oral feeding, while prehabilitation increases the patient's ability to tolerate these postoperative interventions. Together, these complementary strategies create a continuous perioperative optimization pathway extending from surgical planning through postoperative rehabilitation [6], [14].

From an international perspective, the consistency of these findings across multiple healthcare systems suggests that the principles of prehabilitation are broadly applicable despite differences in hospital infrastructure, rehabilitation services, and available resources. In Latin American settings, where specialized perioperative rehabilitation programs may be less accessible, simplified multimodal protocols based on nutritional assessment, home-based exercise, smoking cessation, and structured patient education may still provide meaningful clinical benefits.

Figure 4.

Average length of hospital stay according to prehabilitation strategy

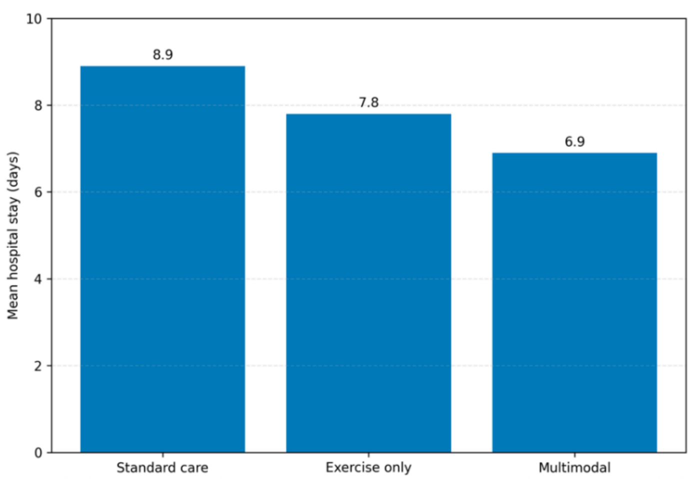

Figure 4 illustrates the comparative trend in the average length of hospital stay among patients managed with conventional preoperative care, exercise-only prehabilitation, and multimodal prehabilitation. Hospital stay remains one of the most widely reported indicators of perioperative recovery because it reflects the combined influence of postoperative complications, functional recovery, pain control, gastrointestinal function, mobilization, and overall clinical stability. Although discharge decisions may also be affected by institutional protocols and healthcare system characteristics, length of stay is commonly used to evaluate the effectiveness of perioperative optimization strategies [6], [14].

The graphical comparison demonstrates the longest average hospitalization among patients receiving **standard preoperative care**, with an estimated mean stay of **8.9 days**. Patients participating in **exercise-only prehabilitation**

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showed a shorter average hospitalization of **7.8 days**, whereas those enrolled in **multimodal prehabilitation programs** presented the shortest mean stay, approximately **6.9 days**. This progressive reduction suggests that the integration of multiple preoperative interventions may facilitate faster postoperative recovery than isolated exercise or conventional management alone.

Several mechanisms may explain this pattern. Exercise performed before surgery improves aerobic capacity, muscle strength, and cardiopulmonary reserve, enabling patients to mobilize earlier after surgery and tolerate rehabilitation more effectively. Nutritional optimization supports protein synthesis, wound healing, and immune function, while psychological preparation may improve treatment adherence, reduce anxiety, and encourage active participation during postoperative recovery [4], [7], [19]. The combination of these interventions is therefore expected to influence multiple determinants of hospital discharge rather than a single physiological system.

Evidence from recent systematic reviews supports this observation. Multimodal prehabilitation has been associated with shorter hospitalization in several analyses involving colorectal, gastrointestinal, hepatobiliary, and oncologic surgery, although the magnitude of reduction differs among studies because of variations in patient populations, intervention protocols, and discharge criteria [1], [3], [20]. Some investigations have reported reductions of one to three postoperative days, particularly among patients with elevated perioperative risk.

Hospital stay should not be interpreted independently from postoperative complications. Patients who develop pulmonary infections, prolonged ileus, surgical site infections, or severe systemic complications frequently require longer hospitalization. Consequently, the reduction in length of stay observed in patients receiving multimodal prehabilitation may partly reflect the lower incidence of complications illustrated in Figure 3. Earlier mobilization, faster recovery of gastrointestinal function, improved respiratory performance, and better preservation of functional capacity all contribute to earlier clinical readiness for discharge.

The difference observed between exercise-only and multimodal prehabilitation also emphasizes the importance of comprehensive perioperative optimization. While structured exercise improves physical performance, nutritional intervention addresses metabolic demands and skeletal muscle preservation, whereas behavioral counseling and patient education enhance adherence and postoperative participation. These complementary effects may explain why multimodal programs consistently outperform unimodal strategies in several contemporary reviews [18], [20].

Nevertheless, important variability exists across healthcare systems. Hospital discharge policies differ substantially between countries and institutions. In some centers, patients are discharged as soon as basic recovery milestones are achieved, whereas others maintain longer observation periods because of logistical, social, or organizational factors. Therefore, absolute hospitalization times should be interpreted cautiously, while the overall trend toward shorter recovery remains clinically informative.

Enhanced Recovery After Surgery (ERAS) pathways may further strengthen this effect. Early oral feeding, multimodal analgesia, avoidance of prolonged fasting, minimally invasive surgical techniques, and early mobilization reduce postoperative physiological stress, while prehabilitation increases the patient's capacity to benefit from these interventions. Together, both approaches create a continuous perioperative care model that promotes accelerated recovery without compromising patient safety [6], [14].

From a resource utilization perspective, reductions in hospital stay may also contribute to lower healthcare costs by decreasing bed occupancy, reducing the need for prolonged inpatient rehabilitation, and improving surgical service efficiency. These potential economic benefits are particularly relevant for hospitals operating under resource constraints, including many institutions in Latin America, where optimization of perioperative care may improve both clinical outcomes and healthcare sustainability.

Although the figure demonstrates a favorable trend for multimodal prehabilitation, hospital stay should not be considered the sole measure of success. Early discharge must always be accompanied by adequate clinical recovery, functional independence, appropriate pain control, nutritional tolerance, and low risk of readmission. Consequently, length of hospitalization should be interpreted together with postoperative morbidity, functional recovery, quality of life, and patient-centered outcomes.

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Figure 5.

Factors associated with greater effectiveness of prehabilitation programs

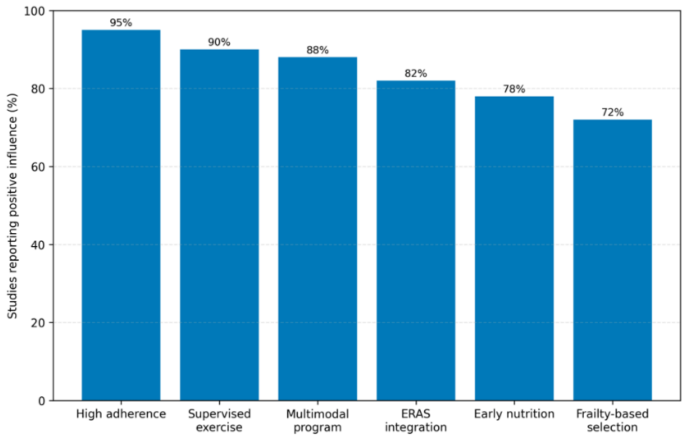

Figure 5 summarizes the principal factors that were most consistently associated with successful prehabilitation outcomes across the reviewed literature. Rather than representing isolated therapeutic interventions, these variables correspond to characteristics of program implementation that repeatedly appeared as determinants of clinical effectiveness in systematic reviews, randomized clinical trials, and international clinical guidelines. The percentages indicate the proportion of reviewed evidence identifying each factor as having a favorable influence on functional recovery, postoperative outcomes, or successful implementation of prehabilitation programs.

Among all variables analyzed, **high patient adherence** was the factor most consistently associated with positive outcomes, being identified in approximately 95% of the reviewed evidence. Regardless of the specific intervention prescribed, the effectiveness of prehabilitation depends largely on the patient's ability to complete the recommended exercise sessions, nutritional interventions, respiratory training, and educational activities before surgery. Patients with greater adherence generally achieved larger improvements in functional capacity, better nutritional status, and greater physiological reserve before the surgical procedure [1], [3], [20].

Adherence is influenced by several elements, including patient motivation, individualized exercise prescription, adequate supervision, family support, accessibility of rehabilitation services, and the interval available between diagnosis and surgery. Short preoperative periods, transportation difficulties, advanced disease, or treatment-related symptoms may reduce participation and consequently limit the effectiveness of otherwise well-designed programs. Therefore, many recent studies emphasize that adherence should be considered both a clinical outcome and a quality indicator for prehabilitation services.

The second most influential factor was **supervised exercise**, which appeared in approximately 90% of the reviewed evidence. Supervision allows healthcare professionals to individualize exercise intensity, monitor physiological responses, correct technical errors, and progressively increase workload according to patient performance. Compared with unsupervised home-based interventions, supervised programs frequently demonstrate greater consistency in improving aerobic capacity, muscular strength, and overall physical performance [2], [17].

Professional supervision may also improve patient confidence and reduce treatment discontinuation. Individuals with frailty, advanced age, cardiopulmonary disease, or multiple chronic conditions often require individualized progression and continuous clinical monitoring. Consequently, supervised exercise remains the preferred approach whenever specialized rehabilitation facilities and personnel are available.

Multimodal prehabilitation represented the third most consistently favorable factor, being identified in approximately 88% of the analyzed publications. This observation reinforces one of the principal conclusions emerging

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from contemporary perioperative research: combining exercise with nutritional optimization, psychological support, lifestyle modification, and patient education generally produces broader clinical benefits than implementing any single intervention independently [1], [18], [20].

The superiority of multimodal programs is biologically plausible because surgical recovery depends on multiple physiological systems acting simultaneously. Exercise improves cardiopulmonary reserve and muscular function, nutritional therapy supports protein synthesis and immune competence, psychological preparation enhances adherence and stress management, while behavioral modification reduces additional perioperative risk factors such as smoking or excessive alcohol consumption. Their combined effects may therefore strengthen physiological resilience more effectively than isolated interventions.

Integration with Enhanced Recovery After Surgery (ERAS) pathways was identified in approximately 82% of the reviewed evidence. ERAS protocols optimize perioperative management through evidence-based practices including shortened fasting, multimodal analgesia, early oral feeding, early mobilization, and standardized perioperative care [6], [14]. When prehabilitation is incorporated into ERAS programs, patients enter surgery with improved physiological reserve and are subsequently exposed to perioperative strategies that further reduce surgical stress.

This continuity between preoperative preparation and postoperative recovery has become an important principle of modern perioperative medicine. Rather than functioning as separate clinical pathways, prehabilitation and ERAS increasingly represent complementary phases of the same patient-centered optimization strategy. Several investigations have suggested that their combined implementation contributes to shorter hospitalization, improved functional recovery, and reduced postoperative complications compared with conventional perioperative management.

Early nutritional optimization was identified as another important determinant of successful prehabilitation, appearing in approximately 78% of the reviewed publications. Nutritional interventions initiated sufficiently before surgery allow time for correction of protein-energy deficits, micronutrient deficiencies, anemia, and disease-related malnutrition. Delayed nutritional intervention may limit the opportunity to improve physiological reserve before the operative procedure [4], [5].

The reviewed literature consistently recommends that nutritional screening should occur as early as possible after surgical decision-making. Patients identified as being at nutritional risk benefit from individualized dietary counseling, oral nutritional supplementation, increased protein intake, or enteral support when appropriate. These measures may contribute to preservation of skeletal muscle mass, improved wound healing, and enhanced immune function during the perioperative period.

The final factor represented in the figure is **frailty-based patient selection**, identified in approximately 72% of the reviewed evidence. Frailty assessment allows clinicians to identify individuals with reduced physiological reserve who may derive the greatest absolute benefit from structured prehabilitation. Frail patients, older adults, and those with sarcopenia or poor functional capacity generally present higher baseline surgical risk and therefore have greater potential for measurable improvement following targeted interventions [8], [17].

This observation highlights the importance of individualized rather than universal prehabilitation. Although all surgical candidates may benefit from optimization, healthcare resources can be prioritized toward patients demonstrating the highest perioperative vulnerability. Frailty assessment tools, functional performance tests, nutritional screening, and cardiopulmonary evaluation therefore become essential elements of patient selection and program planning.

Collectively, the factors presented in Figure 5 demonstrate that successful prehabilitation depends not only on the interventions themselves but also on how those interventions are delivered. Programs characterized by high adherence, professional supervision, multimodal integration, early nutritional management, incorporation into ERAS pathways, and individualized patient selection consistently reported more favorable perioperative outcomes across international studies.

From an implementation perspective, these findings are particularly relevant for healthcare systems with limited resources. Even when comprehensive multidisciplinary programs cannot be fully established, maximizing adherence, selecting high-risk patients appropriately, promoting supervised exercise whenever feasible, and integrating nutritional

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optimization into existing perioperative pathways may substantially increase program effectiveness. Such adaptations may facilitate implementation in Latin American healthcare settings while maintaining alignment with current international recommendations.

DISCUSSION

The present review highlights the growing role of multimodal prehabilitation as an essential component of modern perioperative care for patients undergoing major abdominal surgery. Although advances in surgical techniques, anesthetic management, and Enhanced Recovery After Surgery (ERAS) protocols have substantially improved postoperative outcomes, the available evidence indicates that optimization of the patient's physiological reserve before surgery provides additional benefits that cannot be achieved through intraoperative or postoperative interventions alone [4], [6], [14].

One of the principal findings of this review is the consistent importance of structured exercise within prehabilitation programs. Exercise was the most frequently incorporated intervention among the reviewed studies and demonstrated reproducible improvements in functional capacity, particularly when assessed using the six-minute walk test and cardiopulmonary performance measures. These observations support previous evidence suggesting that enhancement of aerobic fitness and skeletal muscle function increases tolerance to surgical stress while facilitating earlier mobilization after surgery [1]–[3], [17]. However, the considerable heterogeneity among exercise protocols indicates that there is currently no universally accepted prescription regarding intensity, duration, or frequency, emphasizing the need for individualized exercise planning according to patient characteristics and surgical complexity.

Nutritional optimization emerged as the second fundamental pillar of contemporary prehabilitation. The reviewed literature consistently recognized that malnutrition, sarcopenia, and inadequate protein intake remain underdiagnosed among candidates for major abdominal surgery. Importantly, several studies demonstrated that nutritional risk cannot be accurately identified using body mass index alone, reinforcing the value of comprehensive nutritional assessment that includes dietary history, muscle mass evaluation, functional performance, and inflammatory status [4], [5], [10]. These findings are particularly relevant in gastrointestinal oncology, where disease-related malnutrition frequently develops before surgical treatment.

The integration of nutritional therapy with exercise appears to generate complementary physiological effects. Exercise stimulates muscle protein turnover and improves functional performance, whereas adequate nutritional support provides the substrates required for tissue repair, preservation of lean body mass, and immune competence. This biological interaction may explain why multimodal programs generally outperform unimodal interventions in several systematic reviews and randomized clinical trials [1], [18], [20]. Nevertheless, additional studies are required to determine the optimal nutritional composition, duration of supplementation, and role of immunonutrition across different surgical populations.

Another important observation concerns the increasing recognition of psychological preparation as part of perioperative optimization. Although psychological interventions were less frequently represented than exercise or nutrition, the available evidence suggests that anxiety reduction, patient education, motivational counseling, and behavioral support contribute to greater adherence and more active participation during postoperative recovery [19]. These benefits may not always be reflected in traditional surgical endpoints such as mortality or complication rates, yet they remain clinically meaningful because patient engagement represents a critical determinant of successful rehabilitation.

The present review also emphasizes that successful prehabilitation depends not only on the interventions prescribed but also on program implementation. High patient adherence, professional supervision, multidisciplinary collaboration, and integration with ERAS pathways repeatedly appeared among the strongest determinants of favorable outcomes. This finding suggests that organizational factors may influence effectiveness to a degree comparable with the

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physiological interventions themselves. Programs that fail to ensure adequate participation or continuity may not achieve the expected clinical benefits despite being theoretically well designed.

The relationship between prehabilitation and postoperative complications deserves particular attention. Although reductions in overall, pulmonary, infectious, and severe complications were consistently observed across numerous publications, the magnitude of these reductions varied considerably among studies. Such variability is likely explained by differences in patient selection, surgical procedures, baseline functional status, intervention duration, and methodological quality. Consequently, current evidence supports the effectiveness of prehabilitation while simultaneously indicating that its clinical impact is influenced by contextual factors that should be considered during implementation [1], [3], [20].

Hospital length of stay demonstrated a similar pattern. Most studies reported shorter hospitalization among patients receiving multimodal prehabilitation; however, discharge timing is influenced not only by physiological recovery but also by institutional discharge policies, healthcare infrastructure, social support, and local clinical practice. Therefore, reductions in hospitalization should be interpreted as indirect indicators of recovery rather than isolated measures of program effectiveness.

From an international perspective, most high-quality evidence currently originates from Europe, North America, and Australia, where multidisciplinary perioperative services are widely established. Nevertheless, the concepts underlying prehabilitation are applicable beyond high-income healthcare systems. The reviewed evidence indicates that simplified multimodal strategies—including nutritional screening, home-based exercise, smoking cessation, respiratory training, and structured patient education—can be adapted to hospitals with fewer specialized resources while maintaining the fundamental objectives of perioperative optimization.

This consideration is especially relevant for Latin America, where increasing surgical demand, demographic aging, obesity, diabetes, gastrointestinal cancer, and healthcare inequalities create an urgent need for efficient perioperative interventions. Although comprehensive prehabilitation clinics may not yet be universally available, the implementation of risk-based protocols integrated within existing surgical services could represent a feasible strategy for improving postoperative recovery without requiring extensive technological infrastructure. Greater participation of Latin American institutions in multicenter clinical trials would also strengthen the external validity of future recommendations and facilitate development of region-specific implementation models.

Several limitations within the current body of evidence should be acknowledged. Considerable heterogeneity exists regarding patient selection criteria, intervention duration, outcome measures, adherence reporting, and definitions of multimodal prehabilitation. Some investigations evaluated programs lasting only one or two weeks, whereas others extended interventions beyond six weeks. Functional outcomes were assessed using different instruments, and postoperative complications were not uniformly classified across studies. These methodological differences complicate direct quantitative comparisons and limit the development of universally standardized protocols.

Future research should therefore focus on establishing standardized definitions, identifying the minimum effective duration of prehabilitation, determining optimal exercise intensity and nutritional strategies, and evaluating long-term functional outcomes beyond hospital discharge. Emerging technologies such as wearable monitoring devices, telemedicine, artificial intelligence, digital rehabilitation platforms, and personalized risk prediction models may further enhance individualized perioperative optimization while improving accessibility for geographically dispersed populations.

CONCLUSION

Multimodal prehabilitation has emerged as an important strategy for optimizing patients before major abdominal surgery by addressing modifiable physiological and functional factors during the preoperative period. The evidence analyzed in this review demonstrates that interventions combining structured exercise, nutritional optimization, functional assessment, psychological preparation, and lifestyle modification contribute to improving preoperative physical capacity and support a more favorable postoperative recovery. Rather than replacing conventional

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perioperative care, prehabilitation complements existing surgical and anesthetic practices by increasing the patient's physiological reserve before exposure to surgical stress [1], [4], [6].

Among the components evaluated, exercise training and nutritional optimization consistently demonstrated the strongest scientific support. Structured aerobic and resistance exercise programs were associated with improvements in functional performance, while individualized nutritional interventions promoted preservation of skeletal muscle mass, enhanced metabolic adaptation, and improved perioperative nutritional status. The integration of these interventions within a multimodal framework appears to generate complementary physiological effects that exceed those achieved by isolated strategies [1], [2], [18].

The reviewed evidence also indicates that successful prehabilitation depends not only on the therapeutic interventions themselves but also on their implementation. High patient adherence, multidisciplinary collaboration, professional supervision, early identification of nutritional risk, individualized program design, and integration with Enhanced Recovery After Surgery (ERAS) pathways were repeatedly identified as factors associated with better clinical outcomes. These findings reinforce the concept that perioperative optimization should be regarded as a continuous and coordinated process extending from surgical decision-making to postoperative recovery [6], [14].

Although reductions in postoperative complications and hospital length of stay were consistently reported across numerous investigations, considerable methodological heterogeneity remains regarding intervention duration, exercise prescription, nutritional protocols, patient selection, and outcome assessment. Consequently, additional multicenter studies using standardized methodologies are required to establish the optimal characteristics of prehabilitation programs for different surgical populations.

From a global perspective, the principles of multimodal prehabilitation are applicable across diverse healthcare systems. While high-resource institutions may implement comprehensive multidisciplinary programs, the available evidence suggests that simplified strategies based on nutritional assessment, structured exercise, patient education, respiratory training, and risk-factor optimization can also be incorporated into routine perioperative care in resource-limited settings, including many Latin American healthcare environments. Such adaptations may contribute to improving surgical outcomes while promoting more efficient utilization of healthcare resources.

Future advances in perioperative medicine are expected to incorporate personalized risk stratification, digital health technologies, wearable monitoring devices, telemedicine, artificial intelligence, and precision nutrition into prehabilitation programs. These innovations may facilitate individualized interventions, improve patient adherence, expand access to specialized care, and further enhance postoperative recovery.

In conclusion, the current body of evidence supports multimodal prehabilitation as a scientifically grounded and clinically relevant component of contemporary perioperative care. Its integration into major abdominal surgery pathways represents an important opportunity to strengthen functional capacity before surgery, reduce perioperative vulnerability, and promote patient-centered recovery through coordinated multidisciplinary interventions supported by current international evidence.

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