BMC Geriatrics

RESEARCH

Open Access

The effect of perioperative multimodal rehabilitation on the frailty state of older people patients with frailty gastrointestinal surgery: a randomized controlled trial

Ya-Ling Yan[1,2], Tao-Qin Yao[3], Chun-Hong Gu[4], Xue-Lian Wang[3], Yi Xin[5], Ying-Jun Quan[4*] and Yi Luo[4*]

Abstract

Background Intervention plans for frail older people patients with gastrointestinal tumors often involve three aspects: nutritional support, exercise, and psychological care. However, interventions are mostly concentrated before surgery, and there is less research focusing on postoperative frailty management. Therefore, this study proposes a hypothesis that a multimodal rehabilitation program, combining nutritional support, exercise, and psychological care, will be applied to the perioperative frailty management of patients to explore the impact of perioperative multimodal rehabilitation on the frailty status of older people gastrointestinal surgery patients.

Methods This study is a two-arm, single-blind, parallel clinical randomized controlled trial. It involves the selection of frail older people patients with gastrointestinal tumors admitted to Tongren Hospital affiliated with Shanghai Jiao Tong University from April to September 2024. Patients were randomly divided into an Intervention Group (IG) and a Control Group (CG). Participants in the IG received multimodal rehabilitation management during the perioperative period, while those in the CG received routine perioperative care. The patients' frailty status changes were assessed using the Fried Frailty Phenotype (FFP) at admission, on the first postoperative day, on the day of discharge, and one week after discharge.

Results This study ultimately included 96 participants, with 48 in each of the Intervention Group (IG) and Control Group (CG). Among them, 66 (68.75%) patients underwent colorectal surgery, and 30 (31.25%) underwent gastric surgery; there were no intergroup differences in the baseline characteristics of all variables ($P > 0.05$), indicating adequate randomization. The primary outcome measures showed no significant difference in frailty status between the IG and CG at admission and on the first postoperative day. On the day of discharge, the proportion of pre-frail patients in the IG (39.58%) was significantly higher than that in the CG (8.33%), and the proportion of frail patients (60.41%) was significantly lower than that in the CG (91.66%), with a meaningful difference ($P < 0.001$). One week after discharge, the proportion of pre-frail patients in the IG increased to 87.50%, and the proportion of frail patients

*Correspondence:
Ying-Jun Quan
qyj4347@shtrhospital.com
Yi Luo
ly1922@shtrhospital.com

Full list of author information is available at the end of the article

© The Author(s) 2025. **Open Access** This article is licensed under a Creative Commons Attribution-NonCommercial-NoDerivatives 4.0 International License, which permits any non-commercial use, sharing, distribution and reproduction in any medium or format, as long as you give appropriate credit to the original author(s) and the source, provide a link to the Creative Commons licence, and indicate if you modified the licensed material. You do not have permission under this licence to share adapted material derived from this article or parts of it. The images or other third party material in this article are included in the article's Creative Commons licence, unless indicated otherwise in a credit line to the material. If material is not included in the article's Creative Commons licence and your intended use is not permitted by statutory regulation or exceeds the permitted use, you will need to obtain permission directly from the copyright holder. To view a copy of this licence, visit http://creativecommons.org/licenses/by-nc-nd/4.0/.

decreased to 12.50%, with an even more significant difference compared to the CG ($P < 0.001$). The results indicate that the proportion of pre-frail patients in the IG increased over time, while the proportion of frail patients decreased, suggesting that the intervention measures may effectively slow the progression of frailty, with particularly noticeable effects one week after discharge. In terms of secondary outcome measures, the IG performed significantly better than the CG in the 6-minute walk Distance ($P = 0.004 < 0.05$). Additionally, the IG had significantly higher scores on the Barthel Index (BI) compared to the control group ($P < 0.001$), and on the Geriatric Depression Scale-15 (GDS-15), the IG scored lower than the CG ($P = 0.011 < 0.05$). The IG also had significantly higher EQ-5D scores than the CG ($P < 0.001$). There were no differences in the remaining secondary outcome measures.

Conclusions Perioperative multimodal rehabilitation can slow the progression of frailty in older people patients undergoing gastrointestinal surgery, thereby promoting postoperative recovery.

Trial registration This trial was registered in the Chinese Clinical Trials Registry (ChiCTR2500096968). The date of first registration, 02/10/2025.Retrospectively registered.

Keywords Frailty, Gastrointestinal cancer, Perioperative, Intervention, Surgery

Introduction

Colorectal cancer and gastric cancer are the third and fifth most common cancers worldwide, respectively, and are also the second and fourth leading causes of patient mortality [1]. The older people population is at high risk for gastrointestinal tumors; according to statistics, the proportion of patients over 60 years old with gastric cancer is as high as 70.8%; patients over 65 years old with colorectal cancer account for about 60% of all colorectal cancer patients [2]. In the older people population, the aging process is often accompanied by a decline in physiological reserves, increased vulnerability, and a decrease in stress resistance [3]. Therefore, frailty is considered an age-related syndrome in the older people. Fried et al. [3] defined five criteria for the frailty phenotype, namely weight loss, fatigue, low grip strength, slow walking speed, and low physical activity; meeting three or more of these criteria can lead to a diagnosis of frailty. For older people patients with gastrointestinal cancer, the internal complex biological changes caused by aging, immunosenescence, inflammation, age-related chronic diseases, as well as external environmental, psychosocial factors, in addition to cancer itself and cancer treatment, can all pose challenges to their physiological reserves, making them more susceptible to the development of frailty [4].

Surgery is considered one of the primary treatment methods for gastrointestinal cancers. In China, the prevalence of preoperative frailty in older people patients with gastrointestinal tumors is 43.8%, and it rises to as high as 59% postoperatively [5]. The presence of frailty can increase adverse outcomes in older people gastrointestinal surgery patients, such as impaired quality of life, increased mortality and readmission risk [6–8], as well as hospital stay and costs ranging from 15% to 60% [9, 10]; however, existing studies have confirmed that specific intervention measures can improve the prognosis of frail patients undergoing surgery [11–13].

In existing studies, intervention programs for frail older people patients with gastrointestinal tumors often involve three aspects: nutritional support, exercise, and psychological care [14]. However, interventions are often focused solely on the preoperative or postoperative phase [15, 16]. For example, in an RCT study by Carli et al. [16], two groups of patients received preoperative and postoperative rehabilitation models, respectively, which included the aforementioned three aspects of care. However, the study results indicated no observed differences in overall postoperative complication rates, hospital stay, and readmission rates between the preoperative and rehabilitation groups. There is also evidence suggesting that preoperative prehabilitation can improve patients' physical function and other postoperative outcomes [17]. However, few studies have focused on the comprehensive perioperative frailty management for these patients. Additionally, some studies have recommended combining preoperative and postoperative interventions in future trial assessments to address potential adverse effects throughout the entire perioperative trajectory [18]. Therefore, this study hypothesizes that a multimodal rehabilitation program, combining nutritional support, exercise, and psychological care, applied to the perioperative frailty management of patients, may improve to varying degrees the frailty status and physical function of such patients and enhance their postoperative quality of life. To this end, we conducted a clinical randomized controlled trial with frailty status as the primary outcome measure.

Methods

Ethics approval and consent to participate

The study was approved by the Ethics Committee of Shanghai Tongren Hospital. (Tongren Ethics Review 2024-019-01). All participating patients signed an informed consent form. The trial was first registered with the Chinese Clinical Trial Registry and followed

the Comprehensive Standards of Trial Reporting (CONSORT) reporting guidelines [19].

Sample size

To determine the minimum sample size, we selected 20 older people patients who underwent gastrointestinal tumor resection at our hospital, using the Fried Frailty Phenotype (FFP) score as the primary outcome measure. We collected data at four time points: admission, the first postoperative day, the day of discharge, and one week after discharge. We used repeated measures analysis of variance to calculate the required sample size for the study. The mean scores for the intervention group at each measurement were 3.2, 4.1, 2.5, and 1.5; for the control group, the mean scores were 3.4, 4, 3.4, and 3.1. The standard deviation was 1.0 for both groups, and the correlation coefficient was 0.65. Under the conditions of $\alpha = 0.05$ (two-sided) and a power of 90%, we used PASS 15 software to calculate that at least 38 samples were needed per group. Considering a 20% dropout rate, at least 48 samples per group would be required, totaling 96 samples.

Randomization

Eligible patients were randomly assigned to the multimodal rehabilitation group (IG) or the conventional treatment group (CG) in a 1:1 ratio. Random numbers were generated using Excel 2021, and these numbers were sequentially placed into sealed, opaque envelopes; it was stipulated that numbers 1–48 correspond to the control group and numbers 49–96 to the experimental group. The allocation was kept confidential until the baseline assessment was completed, at which point the envelopes were opened in numerical order. The randomization was managed by a researcher who did not participate in the assessment or intervention.

Baseline and outcome assessments were conducted by several trained researchers to ensure the reliability of the evaluations, but they were blinded to the randomization status.

Study participant

This study was conducted from April to September 2024 at Tongren Hospital affiliated with Shanghai Jiao Tong University School of Medicine in China for patient recruitment and implementation of the research. Inclusion criteria were: (1)age ≥ 65 years; (2) gastrointestinal cancer diagnosed by endoscopic biopsy; (3) scheduled for elective laparoscopic gastrointestinal cancer resection; (4) a Fried Frailty Phenotype (FFP) score ≥ 3 upon admission [3]. Exclusion criteria were: (1) presence of other malignant tumors, severe infectious diseases; (2) presence of severe dysfunction of the heart, brain, lungs, etc.; (3) presence of mental illness, communication disorders, consciousness disorders; (4) use of medications that could cause symptoms similar to frailty (such as levodopa, donepezil hydrochloride, antidepressants); (5) inability to walk even with the assistance of auxiliary devices.

Research process

Trial interventions

Phase 1: Preoperative rehabilitation (Admission to the day before surgery) Nutritional Support: The nutritional status of participants was assessed by a dietitian. Patients with malnutrition or at risk of malnutrition, those who are expected to be unable to eat orally for more than 5 days during the perioperative period, or those who cannot intake 50% of the required energy or protein for more than 7 days, underwent perioperative nutritional assessment and management [20]. A provision of 1.2–1.5 g/(Kg·d) was made, with high-quality protein accounting for 50%, with whey protein being the best option; the preferred treatment method was oral intake and oral nutritional supplements (ONS). Other nutritional support included blood sugar control.

Exercise: Participants engaged in personalized aerobic and resistance exercises developed according to guidelines [21, 22]; and followed the principles of staging and gradual progression. Exercise duration lasted from the day of admission to the day before surgery. Aerobic exercise: mainly walking, with more than 20 min of activity per day. The intensity of exercise was based on the Borg 6–20 Subjective Fatigue Scale levels 12–14. Resistance exercise: resistance training with elastic bands targeting major muscle groups related to function and mobility in the upper and lower body, including multi-joint exercises (leg press, chest press) and single muscle group exercises (triceps, knee extensors, hip abductors). Start with 1–2 sets and gradually increase to 2–3 sets, with 8–12 repetitions per set. The intensity starts at level 15 on the Borg 6–20 scale and gradually increases to level 18.

Psychological Care: Participants were assessed and managed by a nurse trained in psychology. Participants received approximately 20 min of mindfulness meditation daily from the day of admission to the day before surgery, which included teaching patients how to relax and breathe deeply. In addition, patients could be educated about surgery-related knowledge such as preoperative preparation, surgical methods, disease prognosis, etc., and psychological interventions could be conducted through environmental management.

Phase 2: Postoperative rehabilitation (Postoperative to one week after discharge) Nutritional Support: For patients who are expected to be unable to eat or whose oral intake is less than 50% of their nutritional needs, early (within 24 h) enteral nutrition (EN) should be initiated

postoperatively. Patients undergoing gastric surgery may resume oral intake or ONS early (24–48 h) postoperatively; patients undergoing colorectal surgery may start with liquid or ONS on the day of surgery. Postoperative protein supplementation should be 1.5–2.0 g/(Kg·d), such as with ONS. The recommended total energy intake is 25-30Kcal/(Kg·d) [23]. Within one week after discharge, in addition to oral intake, nutritional treatment should primarily be ONS, with a dosage of at least 400-600Kcal/d.

Exercise: Patients can perform simple activities such as turning over in bed once they are conscious postoperatively, and can get out of bed on the first postoperative day. The postoperative exercise plan should be developed collaboratively by sports medicine physicians, gastrointestinal surgeons, nurses, and patients, taking into account the individual's condition and changes in their medical status; it should primarily consist of aerobic exercise, moderately combined with resistance exercise; and the daily exercise volume and time should be gradually increased. After discharge: aerobic exercise should be incorporated into daily life activities, with the time increased to 30 min per day; resistance exercises can also be performed through daily actions such as pushing, pulling, lifting, and pressing, such as squats and wall push-ups, 2–3 times a week. Breathing exercises: active deep breathing, cough exercises, etc. There should be a 5–10 min warm-up before each exercise session, and it is recommended that the warm-up activity be a simplified version of the exercise that will be performed, but at a lower intensity, such as slow walking. When performing resistance exercises, rest for 1–3 min between sets. There should be at least 5 min of relaxation activities after exercise.

Psychological Care: Mindfulness meditation is still conducted for 20 min daily postoperatively, and family members and caregivers are guided to increase their companionship time, encourage patients to persist in exercise, actively participate in social activities, and strengthen interest learning.

Conventional therapy

Preoperatively, participants undergo baseline assessments upon admission by researchers, which are the same as those for the multimodal rehabilitation group. Patients are guided to complete preoperative examinations and other related checks. Patients are encouraged not to stay in bed for extended periods during their hospital stay and are encouraged to move around the ward's corridor. If malnutrition is present, a dietitian assesses the situation and provides corresponding nutritional support, dietary education, and routine instructions on surgical precautions.

Postoperatively, patients are encouraged to be active early on. Once the patient is conscious after surgery, they are guided to turn over independently in bed; they are encouraged to get out of bed and be active on the first postoperative day. Patients can set daily activity goals based on their condition and gradually increase their activity levels. At the same time, the dietitian will conduct another nutritional assessment of the patient and provide appropriate nutritional support.

Adherence to the program

Patients in the multimodal rehabilitation group will receive a follow-up manual to record their daily activities, and a phone call will be made to the patients one week after surgery to determine their compliance at home.

Outcomes and measures

Primary outcome

The primary outcome is the assessment of frailty status: evaluated using the Fried Frailty Phenotype (FFP). This scale was first proposed by Fried et al. in 2001 [3]. A patient is considered frail if they exhibit at least three of the following five criteria: weight loss, fatigue, low grip strength, slow walking speed, and low physical activity; meeting one or two criteria indicates pre-frailty, and zero criteria indicate no frailty.

Minimal clinically important difference (MCID) in frailty status

When determining the MCID for the Fried Frailty Phenotype, it is necessary to systematically analyze the thresholds for the "smallest clinically meaningful change" and the "largest clinically meaningful change" obtained from distribution-based methods and anchor-based methods. In the study by Jang et al. [24], the "small change" calculated using the distribution-based method for the Fried Frailty Phenotype was 0.249, and the "large change" was 0.623. These values are based on the statistical distribution characteristics of the data and reflect only the variation pattern of the indicator itself. The anchor-based method yielded a "small change" of 0.097 and a "large change" of 0.607, which directly reveal the degree of change with actual clinical significance by associating it with clinical outcomes. Since the core definition of MCID is the "smallest meaningful change perceptible to patients or in clinical practice," the results from the anchor-based method are given higher priority because they directly relate to clinical significance. Therefore, we suggest using its "small change" of 0.097 as the core candidate value for MCID. At the same time, the "small change" of 0.249 from the distribution-based method is used to verify the statistical rationality of this candidate value. If the difference between the two is within an acceptable range (for example, if the anchor-based results do not exceed the reasonable fluctuation range of the distribution-based method), and considering the research

objectives and population characteristics, this study sets the MCID threshold range for the Fried Frailty Phenotype at 0.097–0.249.

Secondary outcomes

(1) 6-Minute Walk Distance (6MWD), a test previously recognized as an indicator of recovery after gastrointestinal surgery [25]; (2) Barthel Index (BI); (3) Geriatric Depression Scale (GDS-15); (4) Nutritional Assessment Scale (Nutritional Risk Screening-2002, NRS-2002); (5) serum biomarkers: albumin, albumin, and NRS-2002; and (6) Geriatric Depression Scale-15(GDS-15); (7) Healthy Quality of Life (EuroQol Five Dimensions Questionnaire, EQ-5D); (8) complication rate within 30 days after surgery.

Table 1 Fried Frailty Phenotype

Detection Items	Male	Female
Weight Loss	In the past year, unexpected weight loss >4.5kg or >5% of body weight	In the past year, unexpected weight loss >4.5kg or >5% of body weight
Walking Time (4.57m)	Height ≤ 173cm:； ≥ 7sHeight >173cm:； ≥ 6s	Height ≤ 159cm； ≥ 7sHeight >159cm； ≥ 6s
Grip Strength (Kg)	BMI ≤ 24.0Kg/m^2； ≤ 29BMI 24.1 - 26.0Kg/m^2； ≤ 30BMI 26.1 - 28.0Kg/m^2； ≤ 30BMI >28.0Kg/m^2； ≤ 32	BMI ≤ 23.0Kg/m^2:； ≤ 17BMI 23.1 - 26.0Kg/m^2； ≤ 17.3BMI 26.1 - 29.0Kg/m^2； ≤ 18BMI >29.0Kg/m^2； ≤ 21
Physical Activity Level	Meeting any one of the following three items indicates low physical activity level:(1) In the past week, have you been unable to complete light household chores (such as grocery shopping, sweeping the floor) due to lack of physical strength for 3 days?(2) Male < 393Kcal/week (about 2.5 hours of walking); Female < 270Kcal/week (about 2 hours of walking)(3) In the past week, have the activities you participated in mainly been sitting activities?	Meeting any one of the following three items indicates low physical activity level:(1) In the past week, have you been unable to complete light household chores (such as grocery shopping, sweeping the floor) due to lack of physical strength for 3 days?(2) Male < 393Kcal/week (about 2.5 hours of walking); Female < 270Kcal/week (about 2 hours of walking)(3) In the past week, have the activities you participated in mainly been sitting activities?
Fatigue	Have you experienced the following phenomena for more than 3 days in the past week?(1) I feel that everything is very difficult to do(2) I cannot walk forward	Have you experienced the following phenomena for more than 3 days in the past week?(1) I feel that everything is very difficult to do(2) I cannot walk forward
Conclusion	Normal: 0 point; Pre - frailty: 1 - 2 points; Frailty: 3 - 5 points	

Research tools

1. FFP: The five assessment dimensions and specific criteria of this scale are shown in Table 1.
2. 6-Minute Walk Distance: Before the test, fatigue is assessed using the Borg scale and medication intake is inquired about. Then, patients are asked to walk as far as possible in the corridor, noting any stops during the walk, and wearing a fitness tracker (HUAWEI Band 4) to record data throughout the test. After the test, fatigue is assessed again using the Borg scale, and the walking distance (in meters) is recorded.
3. Measurement of body weight and limb muscle mass: Bioelectrical Impedance Analysis (BIA) method is used; the measurement is conducted with a HUAWEI Smart Scale 3 Pro-323.
4. EQ-5D: This questionnaire includes five dimensions: mobility, self-care, usual activities, pain/discomfort, and anxiety/depression; each dimension consists of five levels: no problems, slight problems, moderate problems, severe problems, and unable to do/extreme problems. Health utility values are calculated according to the Chinese EQ-5D scoring system formula [26], with a maximum score of 1, and the higher the score, the better the health-related quality of life.

Measures

The FFP will be assessed at admission, on the first postoperative day, on the day of discharge, and one week after discharge. The secondary outcome measures, including 6MWD, GDS-15, NRS-2002, albumin, prealbumin, hemoglobin count, and limb muscle mass, will be collected at admission and on the day of discharge. The EQ-5D will be collected on the day of discharge and 30 days after discharge.

Statistical analysis

Statistical analysis was performed using SPSS 26.0 software. For normally distributed continuous data, the mean ± standard deviation was used for description, paired t-tests were used for within-group differences, and two independent sample t-tests were used for between-group differences. For skewed continuous data, the median and interquartile range were used for description, the Wilcoxon signed-rank test was used for within-group differences, and the Mann-Whitney U test was used for between-group differences. Categorical data were described using frequencies or percentages, within-group differences were tested using the McNemar test, and between-group differences were tested using the chi-square test or Fisher's exact test.

Our primary analysis followed the intention-to-treat (ITT) principle, including all study subjects who met the inclusion criteria and participated in at least one intervention for analysis. Missing data were imputed using the last observation carried forward. All tests were two-sided, and a P-value of less than 0.05 was considered statistically significant.

Result

Participant flow

A total of 112 patients underwent initial screening with the FFP. Among them, 16 did not meet the inclusion criteria; there were 6 with contraindications to surgery and 10 who were planned to receive neoadjuvant therapy first. Ninety-six older people patients with gastrointestinal tumors and frailty were randomly assigned to the IG or the CG. During the follow-up process, one patient in the IG switched to palliative treatment, and three patients in the CG switched to palliative treatment. Therefore, a total of 96 patients were included in the intention-to-treat analysis (48 in the IG and 48 in the CG), and the recruitment flowchart of the study subjects is shown in Figure 1.

Baseline characteristics

This study included 96 patients with gastrointestinal cancer, with 48 in each the IG and the CG. The median age was 72.00, and the median BMI was 22.40; among them, 24 (25.00%) had ≥ 2 comorbidities, and 72 (75.00%) had fewer than 2 comorbidities. The proportion of smokers was 3.12%, and the proportion of drinkers was 4.16%. In terms of self-rated health, most considered themselves to be in average health (38.54%). Additionally, a high number of individuals, 43 (44.79%), never exercised within a week; the majority had an education level of junior high school (40.62%). There were 66 (68.75%) patients undergoing colorectal surgery, with 33 in each intervention and control group, and 30 (31.25%) patients undergoing gastric surgery, with 15 in each group. The distribution of surgical types among the two groups showed no statistically significant difference (P = 0.382 > 0.05). All baseline characteristics of the variables in this study showed no intergroup differences (P > 0.05), indicating adequate randomization. For details, see Table 2

Baseline characteristics of frailty-related features, body composition, health-related features, and nutritional biochemical indicators

In the frailty-related characteristics, the median 6MWD was 368.00 m, with no difference between the two groups at baseline ($P = 0.496 > 0.05$); the SD of the FFP score was 3.28 ± 0.51, and there was also no difference between the groups ($P = 0.845 > 0.05$). In health-related characteristics, the SD of the BI was 99.42 ± 3.15, and the median

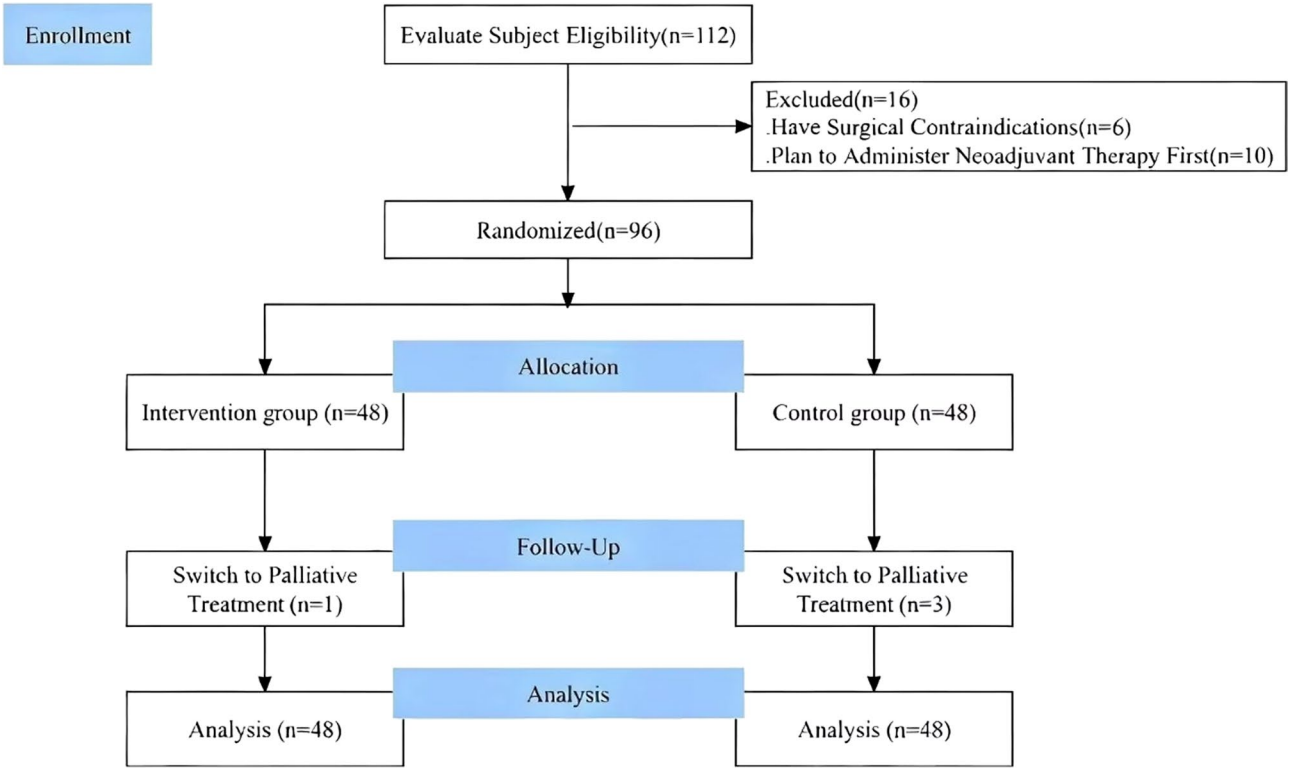


Fig. 1 Flow chart of the Frailty Intervention Trial

Table 2 Baseline data of the two groups of patients

Sports event	Variance	Total(n=96)	Intervention group (n=48)	Control group (n=48)	*t/Z/X²*	*P*
	age	72.00(68.00,75.00)	72.00(68.00,75.00)	70.50(67.50,75.00)	1.621	0.105[a]
	Height(m)	1.63(1.56,1.70)	1.65(1.56,1.73)	1.63(1.55,1.68)	1.270	0.204[a]
	weight(Kg)	59.22(54.07,66.55)	59.22(54.77,66.55)	59.40(52.50,66.35)	0.180	0.858[a]
	BMI(kg/m^2)	22.40(20.65,24.70)	22.40(20.90,24.45)	22.40(20.40,25.05)	−0.443	0.658[a]
Type of surgery					7.471	0.429[b]
	right hemicolectomy (%)	12(12.50)	7(14.58)	5(10.41)		
	left hemicolectomy (%)	13(13.54)	6(12.50)	7(14.58)		
	transverse colectomy (%)	3(3.12)	0(0.00)	3(6.25)		
	sigmoid resection (%)	16(16.66)	10(20.83)	6(12.50)		
	Low anterior resection (%)	10(10.41)	5(10.41)	5(10.41)		
	radical operation for rectal cancer (%)	12(12.50)	5(10.41)	7(14.58)		
	Gastric lesion resection (%)	8(8.33)	2(4.16)	6(12.50)		
	radical operation for gastric cancer (%)	22(22.91)	13(27.08)	9(18.75)		
Comorbidities					0.222	0.637[c]
	≥2(%)	24(25.00)	13(27.08)	11(22.91)		
	<2(%)	72(75.00)	35(72.91)	37(77.08)		
Smoker					0.344	1.000[b]
	Yes (%)	3(3.12)	2(4.16)	1(2.08)		
	No(%)	93(96.87)	46(95.83)	47(97.91)		
Alcohol use					1.044	0.617[b]
	Yes (%)	4(4.16)	3(6.25)	1(2.08)		
	No(%)	92(95.83)	45(93.75)	47(97.91)		
Self-health					2.289	0.515[c]
	mediocre(%)	11(11.45)	4(8.33)	7(14.58)		
	poorly (%)	27(28.12)	14(29.16)	13(27.08)		
	Fair(%)	37(38.54)	17(35.41)	20(41.66)		
	good(%)	21(21.87)	13(27.08)	8(16.66)		
Exercise					6.667	0.083[b]
	never exercise(%)	43(44.79)	18(37.50)	25(52.08)		
	1–2 times/week (%)	26(27.08)	17(35.41)	9(18.75)		
	3–4 times/week (%)	14(14.58)	9(18.75)	5(10.41)		
	daily exercise (%)	13(13.54)	4(8.33)	9(18.75)		
education					2.141	0.544[c]
	Primary education (%)	21(32.29)	12(25.00)	9(18.75)		
	junior high school education (%)	39(40.62)	17(35.41)	22(45.83)		
	Bachelor's degree (%)	28(29.16)	16(33.33)	12(25.00)		
	university degree(%)	8(8.33)	3(6.25)	5(10.41)		

score of the EQ-5D was 0.71; the SD of the NRS2002 score was 2.69 ± 0.95, and the SD of the GDS-15 score was 3.33 ± 2.07. In nutritional biochemical indicators, the median counts for albumin, prealbumin, and hemoglobin were 40.00, 192.00, and 126.50, respectively. In this study, all baseline characteristics of the variables in frailty-related features, health-related features, and biochemical indicators showed no intergroup differences ($P > 0.05$), indicating that the two groups of patients were comparable. For details, see Table 3.

Changes in frailty status of two groups of patients at different time points

This study conducted comparative analyses of the distribution of frailty status and the effectiveness of interventions between the IG and the CG at different time points. The results showed that at the time points of admission and the first postoperative day, the proportion of pre-frail individuals in both groups was 0.00%, and the proportion of frail individuals was 100.00%, with no difference in the distribution of frailty status between the groups. On the day of discharge, the proportion of pre-frail individuals in the IG was 39.58% (19 cases), and the proportion of frail individuals was 60.41% (29 cases), while in the CG, the proportion of pre-frail individuals was 8.33% (4 cases), and the proportion of frail individuals was 91.66% (44 cases), The chi-square value (χ^2) was 12.865, the odds ratio (OR) was 0.139, indicating a statistically significant difference ($P < 0.001$), and a statistically significant difference in the distribution of frailty status

Table 3 Baseline characteristics of frailty-related features, body composition, health-related features, and nutritional biochemical indicators

Variance		Total(n=96)	Intervention group (n=48)	Control group (n=48)	*T/Z*	*P*
frailty-related features	6MWD(m)	368.00(305.00,430.00)	378.50(305.50,431.00)	350.00(305.00,417.00)	0.682	0.496[a]
	FFP	3.28±0.51	3.29±0.50	3.27±0.53	0.196	0.845[b]
body composition	Left upper limb muscle(Kg)	2.45(1.95,2.95)	2.45(2.10,2.90)	2.45(1.80,3.00)	0.440	0.660[a]
	Left lower limb muscle(Kg)	6.35(5.05,7.60)	6.30(5.40,7.75)	6.60(4.80,7.55)	0.601	0.548[a]
	Right upper limb muscle(Kg)	2.55(2.00,3.00)	2.55(2.10,3.00)	2.55(1.90,3.05)	0.407	0.684[a]
	Right lower limb muscle(Kg)	6.55(5.25,7.50)	6.50(5.45,7.40)	6.60(4.95,7.55)	0.363	0.717[a]
health-related features	NRS2002	2.69±0.95	2.81±0.15	2.58±0.12	1.181	0.241[b]
	BI	99.42±3.15	99.58±2.26	99.27±3.85	0.484	0.630[b]
	GDS-15	3.33±2.07	3.27±0.31	3.39±0.29	−0.294	0.770[b]
	EQ-5D	0.71(0.57,0.78)	0.73(0.65,0.78)	0.66(0.52,0.78)	1.540	0.124[a]
Nutritional Biochemical Indicators	Albumin (g/L)	40.00(38.00,42.90)	39.00(37.35,42.10)	40.50(39.00,43.30)	−1.679	0.093[a]
	Prealbumin (mg/L)	192.00(156.50,235.00)	182.00(142.00,222.00)	211.00(169.50,253.00)	−1.913	0.056[a]
	Hemoglobin (g/L)	126.50(107.00,136.00)	123.50(108.50,135.00)	128.00(101.45,137.00)	0.399	0.690[a]

[a] Wilcoxon signed rank sum test

[b] independent samples t test

Table 4 Changes in Frailty Status of Two Groups of Patients at Different Time Points

	frailty status	Group		X^2	OR (95CI)	*P*
		Intervention group(N=48)	Control group(N=48)			
Admission Day	Pre-frailty(%)	0(0.00)	0(0.00)			
	frailty(%)	48(100.00)	48(100.00)			
1 st Postoperative Day	Pre-frailty(%)	0(0.00)	0(0.00)			
	frailty(%)	48(100.00)	48(100.00)			
Discharge Day	Pre-frailty(%)	19(39.58)	4(8.33)	12.865	0.139(0.040，0.421)	<0.001
	frailty(%)	29(60.41)	44(91.66)			
1 st Week Post-Discharge	Pre-frailty(%)	42(87.50)	14(29.16)	33.600	0.059(0.121，0.172)	<0.001
	frailty(%)	6(12.50)	34(70.83)			

between the groups. At the time point of one week after discharge, the proportion of pre-frail individuals in the IG was 87.50% (42 cases), and the proportion of frail individuals was 12.50% (6 cases), while in the CG, the proportion of pre-frail individuals was 29.16% (14 cases), and the proportion of frail individuals was 70.83% (34 cases), The chi-square value (χ^2) was 33.600, the odds ratio (OR) was 0.06, indicating a significant difference between the groups ($P < 0.001$). In summary, as time progressed, the proportion of pre-frail individuals in the IG increased while the proportion of frail individuals decreased, showing a significant difference compared to the CG. This suggests that the intervention measures may effectively slow the progression of frailty, with the intervention effects being more pronounced one week after discharge. For details, see Table 4 and Figure 2.

Results of the minimal clinically important difference in frailty status

The data on reaching the Minimal Clinically Important Difference (MCID) showed that 42 people (87.50%) in the IG and 14 people (29.20%) in the CG achieved the MCID. Statistically, the OR was 17, indicating that the number of people in the IG who reached the MCID was 17 times that of the CG; the 95% CI was (5.90, 48.96), which does not include 0, confirming that the difference is genuinely present; the χ^2 value was 33.600, and the difference was statistically significant ($P < 0.001$), indicating that the proportion of individuals reaching the MCID between the groups was not due to chance. In summary, the intervention had a significant effect and a clear advantage. For details, see Table 5 and Figure 3.

Intergroup comparison of secondary outcome measures

Regarding secondary outcomes, we assessed the impact of perioperative multimodal rehabilitation on limb muscle mass in patients. The results showed that the IG had slightly higher muscle mass in the left upper limb compared to the CG, but this difference was not statistically significant ($P = 0.080 > 0.05$). Similarly, the muscle mass in the left lower limb, right upper limb, and right lower limb also showed similar trends, with no statistically significant differences ($P = 0.143$, $P = 0.087$, $P = 0.114$, all > 0.05). The IG performed significantly better than the CG in the 6MWD ($P = 0.007 < 0.05$). Additionally, the IG had significantly higher BI scores compared to

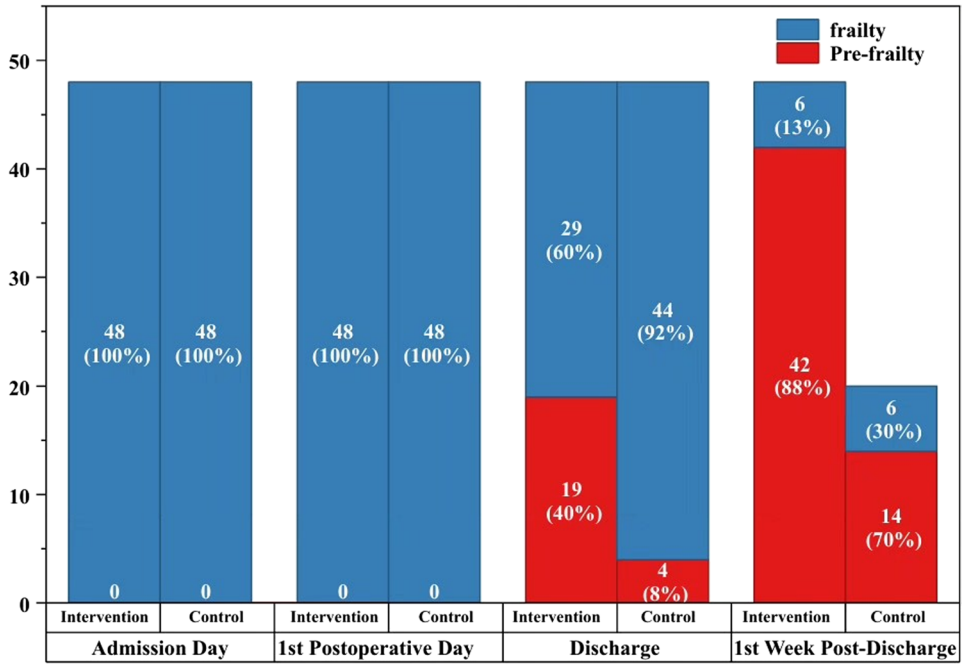


Fig. 2 Changes in Frailty Status of Two Groups of Patients at Different Time Points

Table 5 Results of the Minimal Clinically Important Difference in Frailty Status

	Intervention group(N=48)	Control group(N=48)	X^2	OR (95CI)	*P*
Number of People Reaching the MCID(%)	42(87.50)	14(29.20)	33.600	17(5.90 , 48.96)	<0.001
Number of People Not Reaching the MCID(%)	6(12.50)	34(70.80)			

the CG (P < 0.001), indicating that multimodal rehabilitation can improve the ability to perform activities of daily living. On the GDS-15 scores, the IG scored lower than the CG (P = 0.005 < 0.05). There was no significant difference in NRS2002 scores between the two groups (P = 0.684 > 0.05). However, the IG had significantly higher EQ-5D scores than the CG (P < 0.001). In terms of nutritional biochemical indicators, no significant differences were observed in albumin count, prealbumin count, and hemoglobin count between the two groups (P = 0.689, P = 0.555, P = 0.371). For more details on these results, see Table 6.

Intragroup comparison of secondary outcome measures

Regarding the secondary outcome measures, the within-group comparisons before and after the intervention revealed that there were no statistical differences in limb muscle mass for the IG both before and after the intervention. However, for the CG, there were statistical differences in limb muscle mass before and after the intervention, with the muscle mass being lower after the intervention compared to before. For both groups, there were differences in the 6MWD before and after the intervention, and the distances were shorter after the intervention than before. Similar patterns were observed in health-related scales and nutritional biochemical indicators. As for the EQ-5D scores, an upward trend was found in the scores for both groups 30 days after discharge. For more details on these results, see Table 7.

Discussion

The main findings of this study indicate that on the day of discharge, the proportion of pre-frail patients in the IG (39.58%) was significantly higher than that in the CG (8.33%), and the proportion of frail patients (60.41%) was significantly lower than that in the CG (91.66%), with a meaningful difference ($P < 0.001$). One week after discharge, the proportion of pre-frail patients in the IG increased to 87.50%, and the proportion of frail patients decreased to 12.50%, showing an even more significant difference compared to the CG ($P < 0.001$), with particularly noticeable effects one week after discharge. This suggests that as the duration of the intervention extends, perioperative multimodal rehabilitation may better

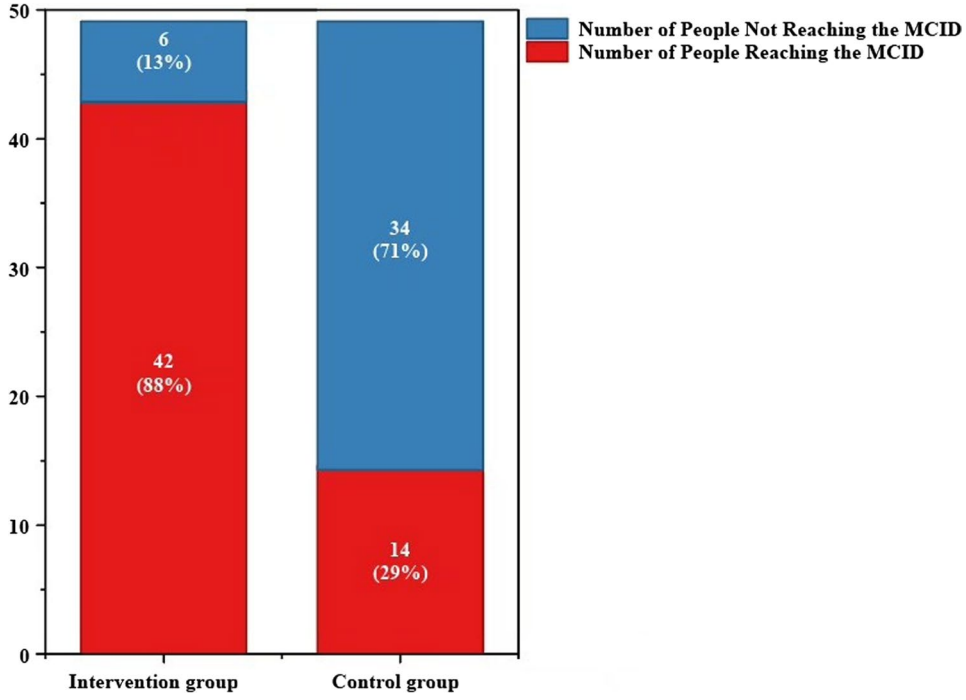


Fig. 3 Results of the Minimal Clinically Important Difference in Frailty Status

Table 6 Between-group comparison of secondary outcomes in the two groups of patients

Variance	Intervention group (n=48)	Control group (n=48)	Z/t	*P*
Left upper limb muscle(Kg)	2.45(2.10,3.10)	2.30(1.70,2.80)	1.750	0.080[a]
Left lower limb muscle(Kg)	6.30(5.65,7.50)	6.10(4.35,7.15)	1.466	0.143[a]
Right upper limb muscle(Kg)	2.60(2.15,3.30)	2.35(1.80,2.85)	1.710	0.087[a]
Right lower limb muscle(Kg)	6.50(5.80,7.45)	5.85(4.35,7.15)	1.580	0.114[a]
6MWD (m)	330.00(276.50,412.00)	292.50(235.00,351.50)	2.701	0.007[a]
BI	97.39±3.71	90.10±8.21	5.601	<0.001[b]
GDS-15	2.10±0.20	3.06±0.26	−2.860	0.005[b]
NRS2002	3.20±0.14	3.29±0.14	−0.409	0.684[b]
EQ-5D	1.00(0.95,1.00)	0.90(0.83,0.95)	4.857	<0.001[a]
Albumin (g/L)	36.00(33.00,39.55)	36.00(34.00,37.60)	0.400	0.689[a]
Prealbumin (mg/L)	149.00(123.50,191.00)	154.50(129.50,195.00)	−0.590	0.555[a]
Hemoglobin (g/L)	118.50(104.00,129.00)	110.50(101.50,122.50)	0.894	0.371[a]
Complication Rate	7(14.58%)	7(14.58%)	0.000	1.000[c]

[a] Mann-Whitney U test

[b] t test

[c] chi-square test

improve or delay the progression of their frailty status. Improvement in frailty during the perioperative period will be key for gastrointestinal cancer patients to achieve good long-term outcomes [27]. However, there is limited evidence regarding the perioperative management of frail older people patients undergoing gastrointestinal cancer surgery, but this study provides new evidence and ideas for the perioperative frailty management of older people gastrointestinal surgery patients. In this study, it may be due to the fact that both groups experienced an increase in frailty levels on the first postoperative day after undergoing major surgery stress [28], but one week after discharge, the number of people in the IG who reached the pre-frail state was significantly better than that in the CG ($P < 0.001$), indicating that adhering to perioperative multimodal rehabilitation has a positive effect on the patient's body. This is similar to the results of a study by Chow et al. [29] on short-term multimodal rehabilitation in older people patients aged 65 and over undergoing abdominal surgery.

This study conducted a frailty assessment for all patients upon admission to understand their preoperative

Table 7 Intragroup comparison of secondary outcome measures

Variance	Group	Pre-Intervention	Post-Intervention	*Z*/t	*P*
Left upper limb muscle(Kg)	IG	2.45(2.10,2.90)	2.45(2.10,3.10)	−1.089	0.206[a]
	CG	2.45(1.80,3.00)	2.30(1.70,2.80)	4.819	<0.001[a]
Left lower limb muscle(Kg)	IG	6.30(5.40,7.75)	6.30(5.65,7.50)	−0.272	0.786[a]
	CG	6.60(4.80,7.55)	6.10(4.35,7.15)	4.392	<0.001[a]
Right upper limb muscle(Kg)	IG	2.55(2.10,3.00)	2.60(2.15,3.30)	−0.952	0.341[a]
	CG	2.55(1.90,3.05)	2.35(1.80,2.85)	4.463	<0.001[a]
Right lower limb muscle(Kg)	IG	6.50(5.45,7.40)	6.50(5.80,7.45)	−0.628	0.530[a]
	CG	6.60(4.95,7.55)	5.85(4.35,7.15)	4.991	<0.001[a]
6MWD (m)	IG	378.50(305.50,431.00)	330.00(276.50,412.00)	3.257	0.001[a]
	CG	350.00(305.00,417.00)	292.50(235.00,351.50)	5.149	<0.001[a]
NRS2002	IG	2.81±0.15	3.20±0.14	−3.725	0.001[b]
	CG	2.58±0.12	3.29±0.14	−7.186	<0.001[b]
BI	IG	99.58±2.26	97.39±3.71	0.484	0.630[b]
	CG	99.27±3.85	90.10±8.21	5.601	<0.001[b]
GDS-15	IG	3.27±0.31	2.10±0.20	6.170	<0.001[b]
	CG	3.39±0.29	3.06±0.26	2.369	0.022[b]
EQ-5D	IG	0.73(0.65,0.78)	1.00(0.95,1.00)	−6.216	<0.001[a]
	CG	0.66(0.52,0.78)	0.83(0.84,0.95)	−5.867	<0.001[a]

[a] Wilcoxon signed rank sum test

[b] t test

health status and functional reserves, and to identify potential risks, thereby initiating intervention plans in a timely manner. Additionally, this study found that the degree of frailty in both groups was increased on the first postoperative day compared to admission, which may be related to the stress response caused by surgery, including inflammatory responses, endocrine disorders, and metabolic changes. On the first postoperative day, patients often experience symptoms such as pain, fatigue, sleep disturbances, and anxiety. Surgery triggers an inflammatory response, releasing inflammatory mediators (such as interleukin-6, growth differentiation factor-15, etc.), which not only affect wound healing but also interfere with muscle metabolism and neural function, further exacerbating frailty. Fatigue and sleep disturbances lead to increased adrenocorticosteroid hormones and abnormal release of cytokines, triggering an inflammatory response through neuroendocrine pathways, disrupting immune system balance, weakening disease resistance, and thus exacerbating frailty. The degree of pain is a risk factor for postoperative frailty, and frailty may be a risk factor for pain regulation acting on the descending inhibitory pathway; the two may share some common molecular mechanisms, such as inflammation and neuroinflammation, thereby strengthening their interaction [30, 31]. During the postoperative recovery period, as patients experience reduced pain, gastrointestinal function recovery, and general improvement in physical condition, the number of frail patients in both groups decreased on the day of discharge. However, the IG had significantly fewer frail patients than the CG, indicating that perioperative multimodal rehabilitation may more effectively improve outcomes for frail patients, consistent with the findings of Muscedere et al. [32]. One week after discharge is a critical transition period for patients moving from the hospital to the home environment, and frailty status may fluctuate due to the lack of continuous medical support. A study by Shi et al. [33] showed that interventions for high-risk frail populations after discharge can further prevent health decline. Such interventions can improve patients' frailty status, quality of life, and prognosis. Similar conclusions were reached in this study, with the IG showing a significant improvement in the number of patients with frailty, further indicating that perioperative multimodal rehabilitation may more effectively improve outcomes for frail patients.

The dynamic changes in patients' frailty status during hospitalization and recovery recorded in this study may reflect the combined impact of underlying chronic health issues and new or residual acute health problems. These dynamic changes further clarify that frailty is a multifactorial, multidimensional process whose trajectory varies among individuals and is heterogeneous. Therefore, future research should provide targeted interventions based on the trajectory of frailty development in such patients to improve their frailty status and reduce postoperative adverse outcomes.

In recent years, with the shortening of postoperative hospital stays for patients undergoing laparoscopic gastrointestinal surgery, there has been an increasing focus on changes in physical function over a short period after surgery (i.e., within one week after surgery) [34]. Previous studies have reported [25, 35] that the 6MWD of gastrointestinal cancer patients significantly decreases

compared to preoperative levels before discharge. A similar conclusion was reached in our study. However, the 6MWD of patients in the IG who received multimodal rehabilitation training was significantly better than that of patients in the CG before discharge. This may be because patients who lack activity before surgery may need more time to engage in postoperative activities, potentially delaying the improvement of postoperative physical function [25]. Both surgical trauma and frailty can lead to a decline in physical function, and the BI can not only be used to assess the functional status of patients before surgery but also to monitor postoperative recovery [36]. In this study, the BI scores of the CG at discharge were lower than those of the IG, which may be because perioperative multimodal rehabilitation can effectively improve patients' ability to perform activities of daily living to some extent, benefiting patients in returning to normal life as soon as possible after discharge.

Studies have shown that the incidence of nutritional risk in older people patients with gastrointestinal malignancies is as high as 40%–80% [37]. This is due to the fact that most patients with gastrointestinal cancer are already in the advanced stages of the disease at the time of presentation, with factors such as poor absorption, malignant tumor consumption, inadequate nutritional intake, and weakened gastrointestinal function all contributing to the problem. Despite significant advancements in nutritional support therapy, surgical techniques, and postoperative recovery, patients still face a high risk of malnutrition after surgery due to gastrointestinal complications, reduced dietary intake after surgery, chronic comorbidities, and involuntary weight loss before surgery [38]. In this study, both groups of patients exhibited signs of postoperative malnutrition (NRS2002 scores were both ≥ 3 points). However, early and continuous nutritional assessment and intervention can help to avoid negative outcomes during the perioperative period, including rapid muscle loss [39].

Hospitalized frail older people individuals are characterized by low body weight, high waist circumference, high body fat, and low bone and muscle mass [40]. The relationship between body composition and frailty is complex and not well understood. It has been reported that surgery not only affects metabolic status but also leads to loss of skeletal muscle and a decline in muscle function [41]. During surgical stress, immune cells produce cytokines as mediators of the immune and systemic response to injury. Cytokines produced during and after surgery accelerate muscle cachexia, which results in reduced muscle mass after surgery [42]. In this study, both groups of patients also experienced loss of limb muscle mass. In frail older people patients, postoperative loss of muscle mass and body weight adversely affects daily activities and quality of life [43]. Therefore, it is crucial to prevent the loss of muscle mass in the short term after surgery in older people gastrointestinal patients. The present study found that implementing multimodal rehabilitation training during the perioperative period can slow down the rate of muscle loss in older people gastrointestinal surgery patients, and this loss is slower compared to the CG. Additionally, another study showed that a personalized multi-component exercise program, including progressive strength training for three days or more, can significantly improve muscle strength in hospitalized older people patients [44].

In recent years, there has been increasing attention to the mental and psychological states of older people patients with gastrointestinal tumors [45]. Some studies [46] have indicated that depression can increase the risk of frailty by disrupting neurohumoral regulation, reducing patients' adherence to treatment, and impairing gastrointestinal function. Therefore, it is important to pay attention to the psychological state of older people patients undergoing gastrointestinal tumor surgery in clinical practice. In this study, the mean GDS-15 scores for both groups were around 3 points at admission, which, although not diagnostic of depression, indicated a risk of depression and required attention. Moreover, there was a difference in GDS-15 scores between the two groups at discharge ($P = 0.005 < 0.05$), suggesting that perioperative multimodal rehabilitation can alleviate depressive symptoms in frail older people patients undergoing gastrointestinal surgery.

Research [47] has proposed that assessing potential serum biomarkers can better diagnose and monitor frailty. One hypothesis suggests that systemic dysregulation of protein synthesis and metabolism is one of the underlying processes leading to the pathogenesis of frailty; among these, nutritional markers such as hemoglobin and albumin levels, which are potential indicators of frailty, are particularly noteworthy [48, 49]. However, due to the multitude of confounding factors during the perioperative period, comparing data indicators is challenging. For instance, the inflammatory response caused by surgical trauma and potential complications can reduce iron deposition, leading to decreases in albumin and hemoglobin levels [50]. Similar conclusions were reached in this study. Additionally, guidelines [51] also recommend that patients should engage in exercise and receive nutritional support during the perioperative period.

The treatment goal for older people gastrointestinal surgery patients should be to treat malignant tumors while maintaining the patients' quality of life and independence [52]. In a study by Han et al. [53]on the changes in health-related quality of life in older people gastric cancer patients one year after surgery, it was pointed out that the quality of life of older people patients was

significantly compromised one month after surgery and did not fully recover until one year postoperatively. However, in our study, the quality of life scores for both groups were significantly higher one month after surgery compared to the scores at discharge; and the IG's scores were notably better than the CG's. This may be because at discharge, patients were still in the recovery period from surgical trauma, and pain, discomfort, and temporary decline in physical function could all contribute to lower quality of life scores. As time passed, patients gradually adapted and recovered from the surgery, with reduced pain and gradual improvement in physical function, thereby increasing the quality of life scores.

Limitations

The highlight of this study is that it uses the FFP as the primary outcome measure, which is relatively rare in previous studies. Additionally, while it has been established that multimodal interventions can prevent the progression of illness to a frail state, the effectiveness of such interventions for patients who are already frail is unclear, and this study is an attempt to explore this area. However, this study has some limitations: First, it is based on data from a single center, and both the intervention and follow-up periods are relatively short; second, complications were not included as a primary outcome measure in the study, which may be crucial for assessing postoperative recovery in older people gastrointestinal surgery patients; furthermore, the study observed changes in limb muscle mass, but this is not sufficient to comprehensively evaluate the body composition of the older people. Future research should focus on overall muscle mass and use more accurate tools to assess muscle mass to enhance its effectiveness in older people frail patients. Lastly, due to the nature of the intervention, this study could not blind the patients or those administering the intervention.

Conclusion

In summary, this study intervened in frail older people patients undergoing gastrointestinal surgery, and the results showed that compared to routine care, perioperative multimodal rehabilitation can effectively suppress or delay the progression of frailty in older people patients undergoing gastrointestinal surgery. To further optimize the perioperative management of older people gastrointestinal surgery patients and reduce the postoperative adverse outcomes associated with frailty, more high-quality RCT studies with long-term interventions and follow-ups are needed in the future to explore the best timing, duration, and specific content of interventions, with the aim of providing more precise and effective frailty management strategies for older people gastrointestinal surgery patients.

Abbreviations

FFP	Fried frailty phenotype
IG	Intervention group
CG	Control group
ONS	Oral nutritional supplements
EN	Enteral nutrition
6MWD	6-Minute Walk Distance
BI	Barthel Index
GDS-15	Geriatric Depression Scale-15
NRS-2002	Nutritional Risk Screening-2002
BIA	Bioelectrical Impedance Analysis
EQ-5D	EuroQol Five Dimensions Questionnaire
ITT	Intention-To-Treat
PPA	Perprotocol analysis
MCID	Minimal Clinically Important Difference

Acknowledgements

The authors would like to thank Tongren Hospital of Shanghai Jiao Tong University and all participants who contributed to this study.

Authors' contributions

YJQ and YL Conceptualized and designed the study. YLY and TQY analyzed the data and drafted the initial manuscript. Data collection was undertaken by XLW and YX. YLY and TQY analyzed the data and drafted the initial manuscript.

Funding

Grant Disclosures.
The following grant information was disclosed by the authors:
Initial Scientific Research Fund of Shanghai Tongren Hospital: TR2020rc01.
Research Fund of Key laboratory for translational research and innovative therapeutics of gastrointestinal oncology: ZDSYS-2023-03.
Scientific research project of Changning District Science and Technology Commission: CNKW2022Y11.

Data availability

The datasets analyzed during the current study are available from the corresponding author on reasonable request.

Declarations

Ethics approval and consent to participate

This study adheres to the Declaration of Helsinki.The study was approved by the Ethics Committee of Shanghai Tongren Hospital (Tongren LunShen 2024-019-01).Written informed consent to participate in this study was obtained from all subjects participating in the study.

Consent for publication

Not Applicable.

Competing interests

The authors declare no competing interests.

Author details

[1]Division of Vascular Surgery, Department of General Surgery, West China Hospital, Sichuan University, Chengdu, Sichuan 610041, China
[2]West China School of Nursing, Sichuan University, Chengdu, China
[3]Wuxi Medical College, Jiangnan University, Wuxi 214122, Jiangsu Province, China
[4]Department of General Surgery, Tongren Hospital, Shanghai Jiao Tong University School of Medicine, Shanghai 200335, China
[5]Department of Anesthesiology, Fudan University Shanghai Cancer Cencer, Shanghai 200032, China

Received: 29 October 2024 / Accepted: 23 October 2025
Published online: 26 December 2025

References

1. Sung H, Ferlay J, Siegel RL, Laversanne M, Soerjomataram I, Jemal A, et al. Global cancer statistics 2020: GLOBOCAN estimates of incidence and

mortality worldwide for 36 cancers in 185 countries. CA Cancer J Clin. 2021;71(3):209–49.
2. Fagard K, Leonard S, Deschodt M, Devriendt E, Wolthuis A, Prenen H, et al. The impact of frailty on postoperative outcomes in individuals aged 65 and over undergoing elective surgery for colorectal cancer: a systematic review. J Geriatr Oncol. 2016;7(6):479–91.
3. Fried LP, Tangen CM, Walston J, Newman AB, Hirsch C, Gottdiener J, Seeman T, Tracy R, Kop WJ, Burke G, et al. Frailty in older adults: evidence for a phenotype. J Gerontol Biol Sci Med Sci. 2001;56(3):M146–156.
4. Zhang X, Meng X, Chen Y, Leng SX, Zhang H. The biology of aging and cancer: frailty, inflammation, and immunity. Cancer J. 2017;23(4):201–5.
5. Zhang Q, Zhang M, Hu S, Meng L, Xi J, Xu A, et al. Prevalence and risk factors of preoperative frailty in Chinese elderly inpatients with gastric and colorectal cancer undergoing surgery: a single-center cross-sectional study using the Groningen frailty indicator. Support Care Cancer. 2022;30(1):677–86.
6. Lin HS, Watts JN, Peel NM, Hubbard RE. Frailty and post-operative outcomes in older surgical patients: a systematic review. BMC Geriatr. 2016;16(1):157.
7. Miao X, Guo Y, Ding L, Xu X, Zhao K, Zhu H, et al. A dynamic online nomogram for predicting the heterogeneity trajectories of frailty among elderly gastric cancer survivors. Int J Nurs Stud. 2024;153:104716.
8. Dammavalam V, Murphy J, Johnkutty M, Elias M, Corn R, Bergese S. Perioperative cognition in association with malnutrition and frailty: a narrative review. Front Neurosci. 2023;17:1275201.
9. McIsaac DI, Beaulé PE, Bryson GL, Van Walraven C. The impact of frailty on outcomes and healthcare resource usage after total joint arthroplasty: a population-based cohort study. Bone Joint J 2016, 98–b(6):799–805.
10. Thillainadesan J, Yumol MF, Suen M, Hilmer S, Naganathan V. Enhanced recovery after surgery in older adults undergoing colorectal surgery: a systematic review and meta-analysis of randomized controlled trials. Dis Colon Rectum. 2021;64(8):1020–8.
11. Dominguez LJ, Donat-Vargas C, Sayon-Orea C, Barberia-Latasa M, Veronese N, Rey-Garcia J, et al. Rationale of the association between Mediterranean diet and the risk of frailty in older adults and systematic review and meta-analysis. Exp Gerontol. 2023;177:112180.
12. Renna ME, Shrout MR, Madison AA, Alfano CM, Povoski SP, Lipari AM, et al. Depression and anxiety in colorectal cancer patients: ties to pain, fatigue, and inflammation. Psychooncology. 2022;31(9):1536–44.
13. Normann M, Ekerstad N, Angenete E, Prytz M. Effect of comprehensive geriatric assessment for frail elderly patients operated for colorectal cancer-the colorectal cancer frailty study: study protocol for a randomized, controlled, multicentre trial. Trials. 2022;23(1):948.
14. Adeleke I, Blitz J. Perioperative frailty: lessons learned and future directions. Curr Opin Anaesthesiol. 2021;34(3):373–80.
15. Hanna K, Ditillo M, Joseph B. The role of frailty and prehabilitation in surgery. Curr Opin Crit Care. 2019;25(6):717–22.
16. Carli F, Bousquet-Dion G, Awasthi R, Elsherbini N, Liberman S, Boutros M, et al. Effect of multimodal prehabilitation vs postoperative rehabilitation on 30-day postoperative complications for frail patients undergoing resection of colorectal cancer: a randomized clinical trial. JAMA Surg. 2020;155(3):233–42.
17. Malot C, Durand-Bouteau A, Barizien N, Bizard A, Kennel T, Fischler M, et al. Prehabilitation program in elderly patients: a prospective cohort study of patients followed up postoperatively for up to 6 months. J Clin Med. 2021. https://doi.org/10.3390/jcm10194500.
18. Thomsen SN, Mørup ST, Mau-Sørensen M, Sillesen M, Lahart I, Christensen JF. Perioperative exercise training for patients with gastrointestinal cancer undergoing surgery: a systematic review and meta-analysis. Eur J Surg Oncol. 2021;47(12):3028–39.
19. Moher D, Hopewell S, Schulz KF, Montori V, Gøtzsche PC, Devereaux PJ, et al. CONSORT 2010 explanation and elaboration: updated guidelines for reporting parallel group randomised trials. Int J Surg. 2012;10(1):28–55.
20. McClave SA, DiBaise JK, Mullin GE, Martindale RG. ACG clinical guideline: nutrition therapy in the adult hospitalized patient. Am J Gastroenterol. 2016;111(3):315–34. quiz 335.
21. Izquierdo M, Merchant RA, Morley JE, Anker SD, Aprahamian I, Arai H, et al. International exercise recommendations in older adults (ICFSR): expert consensus guidelines. J Nutr Health Aging. 2021;25(7):824–53.
22. Dent E, Morley JE, Cruz-Jentoft AJ, Woodhouse L, Rodríguez-Mañas L, Fried LP, et al. Physical frailty: ICFSR international clinical practice guidelines for identification and management. J Nutr Health Aging. 2019;23(9):771–87.
23. Weimann A, Braga M, Carli F, Higashiguchi T, Hübner M, Klek S, et al. Espen practical guideline: clinical nutrition in surgery. Clin Nutr. 2021;40(7):4745–61.
24. Jang IY, Jung HW, Lee HY, Park H, Lee E, Kim DH. Evaluation of clinically meaningful changes in measures of frailty. J Gerontol A Biol Sci Med Sci. 2020;75(6):1143–7.
25. Yanagisawa T, Tatematsu N, Horiuchi M, Migitaka S, Yasuda S, Itatsu K, et al. Preoperative physical activity predicts postoperative functional recovery in gastrointestinal cancer patients. Disabil Rehabil. 2022;44(19):5557–62.
26. Luo N, Liu G, Li M, Guan H, Jin X, Rand-Hendriksen K. Estimating an EQ-5D-5L value set for China. Value Health. 2017;20(4):662–9.
27. Mima K, Nakagawa S, Miyata T, Yamashita YI, Baba H. Frailty and surgical outcomes in gastrointestinal cancer: integration of geriatric assessment and prehabilitation into surgical practice for vulnerable patients. Ann Gastroenterol Surg. 2023;7(1):27–41.
28. Alvarez-Nebreda ML, Bentov N, Urman RD, Setia S, Huang JC, Pfeifer K, Bennett K, Ong TD, Richman D, Gollapudi D, et al. Recommendations for preoperative management of frailty from the society for perioperative assessment and quality improvement (SPAQI). J Clin Anesth. 2018;47:33–42.
29. Chow JJL, Teo ZHT, Acharyya S, Natesan S, Cheong SK, Tony S, et al. Recovery of surgery in the elderly (ROSE) program: the efficacy of a multi-modal prehabilitation program implemented in frail and pre-frail elderly undergoing major abdominal surgery. World J Surg. 2024;48(1):48–58.
30. Gong Z, Su F, Kang X, Zhong Y, Xie Y. The influencing factors of frailty and quality of life in elderly patients after spinal surgery. Clin Interv Aging. 2024;19:769–78.
31. D'Agnelli S, Amodeo G, Franchi S, Verduci B, Baciarello M, Panerai AE, Bignami EG, Sacerdote P. Frailty and pain, human studies and animal models. Ageing Res Rev. 2022;73:101515.
32. Muscedere J, Bagshaw SM, Kho M, Mehta S, Cook DJ, Boyd JG, et al. Frailty, outcomes, recovery and care steps of critically ill patients (FORECAST): a prospective, multi-centre, cohort study. Intensive Care Med. 2024;50(7):1064–74.
33. Shi SM, Olivieri-Mui B, Oh G, McCarthy E, Bean JF, Kim DH. Frailty and time at home after post-acute care in skilled nursing facilities. J Am Med Dir Assoc. 2023;24(7):997-e10011002.
34. Yanagisawa T, Tatematsu N, Horiuchi M, Migitaka S, Yasuda S, Itatsu K, et al. Responsiveness and minimal clinically important difference of the 6-minute walk distance in patients undergoing colorectal cancer surgery. Support Care Cancer. 2024;32(6):382.
35. Hara T, Kogure E, Iijima S, Fukawa Y, Kubo A, Kakuda W. Minimal clinically important difference in postoperative recovery among patients with gastrointestinal cancer. Support Care Cancer. 2022;30(3):2197–205.
36. Yang T, Liu DQ, Qiu W, Fan ZQ, Sun LY, Wang NY, et al. The Barthel index predicts surgical textbook outcomes following hepatectomy for elderly patients with hepatocellular carcinoma: a multicenter cohort study. Am J Surg. 2024;237:115761.
37. Su H, Luo Q, Wang X, Yan W. Frailty combined with nutritional risk score in predicting postoperative complications of elderly patients with gastrointestinal malignancies. Asian J Surg. 2023;46(10):4240–4.
38. Tan S, Meng Q, Jiang Y, Zhuang Q, Xi Q, Xu J, et al. Impact of oral nutritional supplements in post-discharge patients at nutritional risk following colorectal cancer surgery: a randomised clinical trial. Clin Nutr. 2021;40(1):47–53.
39. Prado CM, Anker SD, Coats AJS, Laviano A, von Haehling S. Nutrition in the spotlight in cachexia, sarcopenia and muscle: avoiding the wildfire. J Cachexia Sarcopenia Muscle. 2021;12(1):3–8.
40. Xu L, Zhang J, Shen S, Hong X, Zeng X, Yang Y, et al. Association between body composition and frailty in elder inpatients. Clin Interv Aging. 2020;15:313–20.
41. Prado CM, Ford KL, Gonzalez MC, Murnane LC, Gillis C, Wischmeyer PE, et al. Nascent to novel methods to evaluate malnutrition and frailty in the surgical patient. JPEN J Parenter Enteral Nutr. 2023;47(Suppl 1Suppl 1):S54-68.
42. Aoyama T, Maezawa Y, Yoshikawa T, Segami K, Kano K, Hayashi T, et al. Comparison of weight and body composition after gastrectomy between elderly and non-elderly patients with gastric cancer. In Vivo. 2019;33(1):221–7.
43. Nishida Y, Tokunaga M, Kameyama A, Miyamoto M, Yoshifuku S, Sasahara K, et al. A prospective clinical study evaluating short-term changes in body composition and quality of life after gastrectomy in elderly patients receiving postoperative exercise and nutritional therapies. BMC Surg. 2023;23(1):181.
44. Cadore EL, Izquierdo M, Teodoro JL, Martínez-Velilla N, Zambom-Ferraresi F, Moriguchi EH, Sáez de Asteasu ML. Effects of short-term multicomponent exercise intervention on muscle power in hospitalized older patients: A secondary analysis of a randomized clinical trial. J Cachexia Sarcopenia Muscle. 2023;14(6):2959–68.

45. Tsai HF, Liu CY, Yang SH, Chiou AF. Factors related to frailty in older cancer patients undergoing colorectal surgery: a longitudinal study. Cancer Nurs. 2022;45(6):E865-73.
46. Ding L, Miao X, Jiang X, Chen L, Lu J, Zhu H, et al. Adverse outcomes and health-ecological influencing factors of preoperative frailty among elderly patients with gastric cancer. J Cancer Res Clin Oncol. 2023;149(10):7043–51.
47. Sioutas G, Tsoulfas G. Frailty assessment and postoperative outcomes among patients undergoing general surgery. Surgeon. 2020;18(6):e55-66.
48. Saedi AA, Feehan J, Phu S, Duque G. Current and emerging biomarkers of frailty in the elderly. Clin Interv Aging. 2019;14:389–98.
49. Xu L, Zhang J, Shen S, Liu Z, Zeng X, Yang Y, et al. Clinical frailty scale and biomarkers for assessing frailty in elder inpatients in China. J Nutr Health Aging. 2021;25(1):77–83.
50. Egenvall M, Karlsson E, Nygren-Bonnier M, Franzén E, Rydwik E. Associations between a composite score of hemoglobin, CRP and albumin and physical performance in older patients undergoing gastrointestinal cancer surgery. Clin Nutr ESPEN. 2021;46:330–5.
51. Gustafsson UO, Scott MJ, Hubner M, Nygren J, Demartines N, Francis N, et al. Guidelines for perioperative care in elective colorectal surgery: enhanced recovery after surgery (ERAS(®)) society recommendations: 2018. World J Surg. 2019;43(3):659–95.
52. Montroni I, Ugolini G, Saur NM, Rostoft S, Spinelli A, Van Leeuwen BL, et al. Predicting functional recovery and quality of life in older patients undergoing colorectal cancer surgery: real-world data from the international GOSAFE study. J Clin Oncol. 2023;41(34):5247–62.
53. Han DS, Ahn J, Ahn HS. Are the elderly patient's changes in the health-related quality of life one year after gastrectomy for stomach cancer different from those in young patients? Ann Surg Treat Res. 2021;100(1):8–17.

Publisher's Note

Springer Nature remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.