Original Article

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Prehabilitation as a Prophylactic Measure to Mitigate the Postoperative Pulmonary Complications among Patients Undergoing Abdominal Surgeries – A Randomized Controlled Trial

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Abstract:

Objective: Abdominal surgeries are performed extensively worldwide, and the prevalence of post-operative pulmonary complications (PPC) following upper abdominal procedures remains high. Despite emerging interest, the impact of prehabilitation on functional capacity and postoperative outcomes remains unclear. The study evaluated the effectiveness of prehabilitation in preventing postoperative pulmonary complications, enhancing functional capacity, and reducing the length of hospital stay.

Material and Methods: A total of 80 participants, planned for abdominal surgeries, were randomized into the experimental group (n=40) and control group (n=40) based on the inclusion criteria: participants aged 18–60, willing to participate, and with an adequate preoperative period to attend the prehabilitation sessions. The experimental group underwent eight prehabilitation sessions, while the control group received a single education session. Both groups received the standard postoperative care. PPCs were assessed within the first 24 hours postoperatively using the Melbourne Group Scale, and functional capacity was assessed both preoperatively and postoperatively before discharge. Length of stay was monitored.

Results: Prehabilitation significantly reduced the incidence of postoperative pulmonary complications in the experimental group compared to the control group (p-value<0.001), and there were significant improvements in functional capacity (p-value<0.001). However, no significant difference was found between groups in length of stay (p-value>0.068).

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Conclusion: Prehabilitation before abdominal surgery effectively reduces postoperative pulmonary complications and enhances functional capacity, highlighting it as an effective preventive strategy in perioperative care. Further research is warranted to explore its long-term clinical and functional outcomes.

Keywords: abdominal surgery, functional capacity, length of stay, prehabilitation, postoperative pulmonary complication

Introduction

Postoperative pulmonary complications (PPCs) remain common after abdominal surgery, with reported incidences ranging widely from 1% to 40%[1]. The incidence of postoperative pneumonia has been comparatively low but remains clinically relevant, with reported rates ranging from 1% to 9.9%[2]. These markers show an overall postoperative morbidity of approximately 24.5%, indicating a higher respiratory risk associated with upper abdominal surgeries[1,2]. General anaesthesia contributes substantially to perioperative respiratory impairment by reducing lung volumes, altering respiratory drive and respiratory muscle performance, and promoting atelectasis in more than 75% of patients[3]. Additionally, the surgical stress response induces a hypermetabolic state that elevates oxygen requirements; insufficient oxygen delivery may compromise immune function and delay wound healing[4]. Frequently observed PPCs, such as respiratory infections and secretion retention, pleural effusion, atelectasis, and pulmonary embolism, are primarily linked to reductions in lung volumes, impaired mucociliary clearance, and pain-related inhibition of respiratory muscle activity[5].

Abdominal surgeries can significantly impact patients' functional capacity, reducing it by 40-50% immediately after the surgery due to compromised respiratory muscle function and core stability[6,7]. This, combined with high rates of PPCs, delays recovery and prolongs hospital stays, resulting in a substantial financial burden, particularly in low- and middle-income countries. The economic impact varies depending on factors like surgery type, incision method, suture site infections, and postoperative recovery. PPCs have severe implications, including increased morbidity and mortality, extended intensive care unit (ICU) stays, and added healthcare costs[8].

Implementing safe prehabilitation would be a proactive approach that prepares patients' lung compliance, cardiovascular fitness, and muscle strength for the procedure and postoperative recovery. The aim would be to increase functional capacity before the physiological stress brought on by the procedure[9,10]. To lessen the stress associated with abdominal surgeries, patients may benefit from prehabilitation to raise their cardiorespiratory fitness and exercise capacity to withstand the elevated postoperative oxygen demands[11,12]. Physiological reserve and inflammatory response after the surgery would improve with prehabilitation by enhancing the oxygen delivery to the tissues[3,13]. Prehabilitation aims to reduce postoperative complications and healthcare utilization, including length of stay and financial burden. Prehabilitation encourages patients to lead healthy lifestyles and speeds up healing by facilitating the return to regular activities[13]. Functional capacity is the common outcome measure in prehabilitation, as it encompasses and recognizes the interrelation of physical and metabolic status[14].

Many studies have stated that the impact of prehabilitation on postoperative pulmonary complications, functional capacity, and length of stay is uncertain. Furthermore, given the heterogeneous design's lack of power, prehabilitation may result in clinically significant changes in the patient's preoperative status and surgical outcome[6,15]. There are currently few guidelines for integrating prehabilitation into routine care. Poor surgical outcomes are associated with any preexisting condition that makes it difficult for the patient to tolerate the physiological stress of an operation, compromises the stress response, or increases the catabolic stress response[7]. Therefore, we aimed to determine how prehabilitation affects the likelihood of postoperative problems, enhances functional ability, and shortens hospital stays following abdominal surgery.

Material and Methods

This study was a single-centre, assessor-blinded clinical trial conducted in SRIHER (DU) (Chennai, India). This study was approved by the Institutional Ethical Committee of the Sri Ramachandra Institute of Higher Education and Research (DU), IEC: CSP/23/NOV/139/896. Participants scheduled for abdominal surgery were screened for inclusion and recruited for the study. The inclusion criteria were participants aged 18 to 60 years, those undergoing planned abdominal surgery, and individuals with sufficient time for prehabilitation sessions. The exclusion criteria were oncological conditions, existing cardiopulmonary conditions, and cognitive impairment.

Sample size was calculated to detect the minimal, clinically important difference (MCID) of 25m in the 6-minute walk test distance with two-sided α=0.05 and at a power 90% with a pooled S.D. $\approx$ of 51.95 meters. The required sample size determined was 70 per group; however, due to feasibility, we recruited 40 participants[16]. Following an explanation of the study's goals and the acquisition of informed consent, participants were blinded and randomized using block randomization with a block size of 4 into experimental and control groups, 40 in each group.

Procedure

The preoperative exercise protocol was designed based on the FITT principle (Frequency, Intensity, Time, Type). Participants underwent 8 supervised exercise sessions, which were continued daily until the participants were kept nil per os. The exercise intensity was maintained at 30-40% of the maximum heart rate (HRmax) and monitored using the Rating of Perceived Exertion (RPE) scale between 12 and 13 on the 6-20 Borg scale, indicating moderate intensity. The type of exercises included a combination of aerobic exercises and breathing exercises aimed at improving cardiopulmonary function. Each session lasted 10-15 minutes, with an adequate rest period provided after every 3 minutes to prevent fatigue and ensure patient safety, (Table 1) and the control group received a single session of prehabilitation education and a booklet (Figure 1). The participants were educated about pulmonary complications following the surgery, the effect of abdominal surgery on bronchial hygiene, and lung volumes.

Outcomes measures

The Melbourne Group scale: The eight-item Melbourne Group Score assessment was utilized; if a patient tests positive for four or more of the criteria in 24 hours, they are diagnosed with PPC[17,18]. Six-minute walk test: Participants' functional capacity was assessed in accordance with the guidelines of the American Thoracic Society.

Data acquisition

The baseline data, such as age, gender, body mass index, comorbidities, and type of procedure, were collected

Table 1 Prehabilitation exercise FITT principle

Frequency	8 Sessions followed all days till NPO for the participants
Intensity	30–40% of HRmax and RPE 12–13 (6–20)
Type	Aerobic Exercises and Breathing Exercises.
Time	10–15minutes with rest after every 3minutes

RPE=rating of perceived exertion, NPO=nil per os (nothing by mouth), HRmax=heart rate maximum, FITT=frequency, intensity, time, type
During the preoperative phase, hospitalized participants were introduced to the aforementioned (Table 1) FITT–based exercise regimen. During the intervention, every participant was observed, and no dropouts were noted.

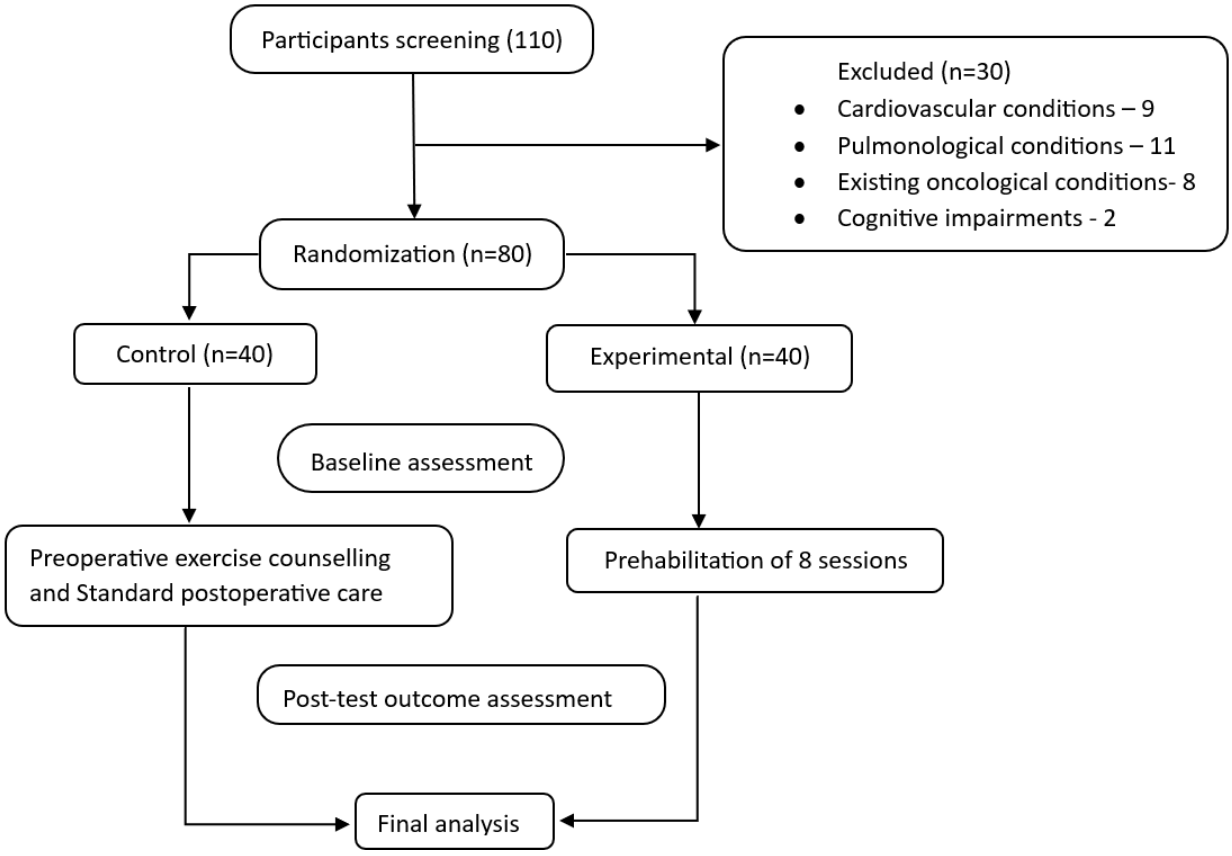


Figure 1 Consort participants flow

in the preoperative period, within 24 hours after surgery, and at discharge. All participants were monitored regularly and received the intervention throughout the study period, resulting in 100% adherence. The risk assessment, including chest assessment (wheezing, crackles, rhonchi), palpation, percussion, and chest radiograph (basal atelectasis, pleural effusions, pulmonary congestion, linear opacities, post-procedural pneumonic changes), was done in the preoperative period, and the pulmonary complications were assessed within 24 hours after surgery. The chest radiograph was diagnosed by the anesthetists or intensivists based on the standard diagnostic criteria, which include the presence of volume loss, opacities, air bronchograms, pleural signs, diaphragm positions, and vascular markings. Functional capacity (6-minute walk test distance) was assessed at the initial preoperative session and the last postoperative session before discharge. The length of stay was recorded at the time of discharge.

Statistical analysis

Data were analyzed using appropriate descriptive and inferential statistics. Continuous variables were expressed as mean±standard deviation. Normality of data was assessed using the Shapiro-Wilk test. For normally distributed variables, independent sample t-tests were used for between-group comparisons; otherwise, the Mann-Whitney U test was applied.

Analysis of covariance (ANCOVA) was performed to evaluate the effect of the intervention on postoperative pulmonary complications (PPCs) using the continuous Melbourne Group Score while adjusting for potential confounders. The study group was entered as the fixed factor, and age, body mass index (BMI), and type of surgery were included as covariates. The assumptions were examined before performing the ANCOVA. The normality of residuals was assessed using the Shapiro-Wilk test and Q-Q plots, and the homogeneity of regression slopes was evaluated by testing the interaction between covariates and the group variables.

Results

Among the experimental and control groups, the baseline characteristics were broadly similar, and with 70% of individuals in the control group and 65% in the experimental group being obese, the average BMIs for the experimental group and the control group were 27.48 (4.05) and 28.13 (3.82), respectively. The study indicates that the majority of participants underwent open abdominal surgery (65%) rather than laparoscopic surgery (35%) (Table 2).

Abnormal breath sounds were observed in 48% (19/40) in the experimental group, including wheezing (6), crackles (11), and rhonchi (2). Whereas 77% (31/40) of participants in the control group exhibited abnormal breath sounds, including wheezing (6), crackles (21), and rhonchi (4). Hypoxia following extubation was present in 5% (2/40) of the experimental group compared with 44.5% (18/40) in the control group. Elevated body temperature occurred in 20% (8/40) of the participants in the experimental group and 42.5% (17/40) in the control group. Chest radiographic abnormalities were identified in 37.5% (15/40) of the experimental group, including basal atelectasis (2), pleural effusion (2), pulmonary congestion (5), and linear opacities (6). In the control group, chest radiographic abnormalities were observed in 65% (26/40) of participants, including basal atelectasis (3), pleural effusion (2), pulmonary congestion (12), linear opacities (8), and post-procedural pneumonic changes (1).

Figure 2 shows that the 6-MWD (Six-Minute Walk Test Distance) improved in the experimental group compared to the control group. Both groups do not have any variations in the colour of the sputum (Figure 3). Figure 3 describes the postoperative pulmonary complications in

the experimental and control groups using the Melbourne group scale. ANCOVA revealed a significant effect of group on the Melbourne Group Score after adjusting for age, BMI, and type of surgery (F=21.8, p-value<0.001, partial η^2=0.22). Surgery type showed a significant association with the outcome (F=4.3, p-value=0.041), whereas age and BMI were not significant covariates.

The postoperative pulmonary complications showed a substantial variation (p-value<0.001) between the experimental group, which received prehabilitation sessions, and the control group. Furthermore, there was a significant improvement in functional capacity (p-value<0.001) in the experimental group, but no statistically significant changes in length of stay (p-value>0.068) (Table 3). After adjustment, the experimental group demonstrated significantly lower PPC scores compared to the control group (adjusted mean difference=-1.4, 95% CI – 2.0 to 0.8, p-value<0.001) (Table 4).

This investigation demonstrated that administering prehabilitation before abdominal surgeries reduced postoperative pulmonary complications more effectively in the experimental group than in the control group. Noticeably, there seemed to be no change in the duration of stay between the control and experimental groups.

Discussion

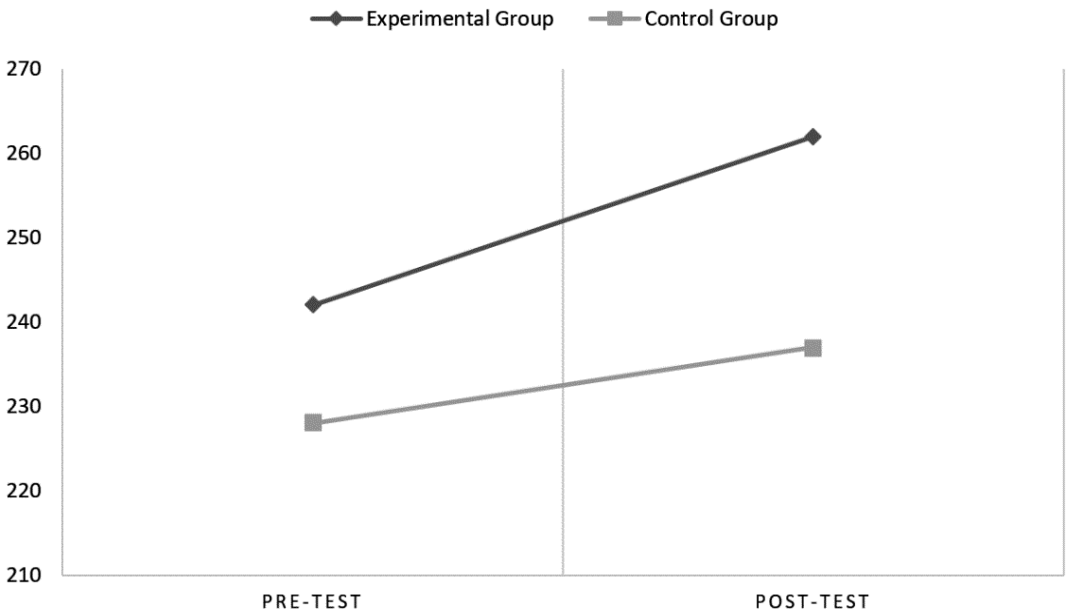
Impact of obesity on PPCs

The current study demonstrates that both the experimental and control groups have a high prevalence of obesity (65% vs. 70%) with similar mean BMIs (27.48+/-4.05 vs. 28.13+/-3.82). Obesity was a notable risk factor for PPCs, also suggesting that BMI alone did not account for the observed difference in clinical outcomes, due to similar baseline characteristics. These findings indicate that prehabilitation may mitigate the adverse respiratory effects of obesity during the perioperative period. The reduction in PPCs among overweight and obese patients highlights prehabilitation as an effective strategy to improve postoperative respiratory outcomes in this vulnerable population.

Table 2 Baseline characteristics

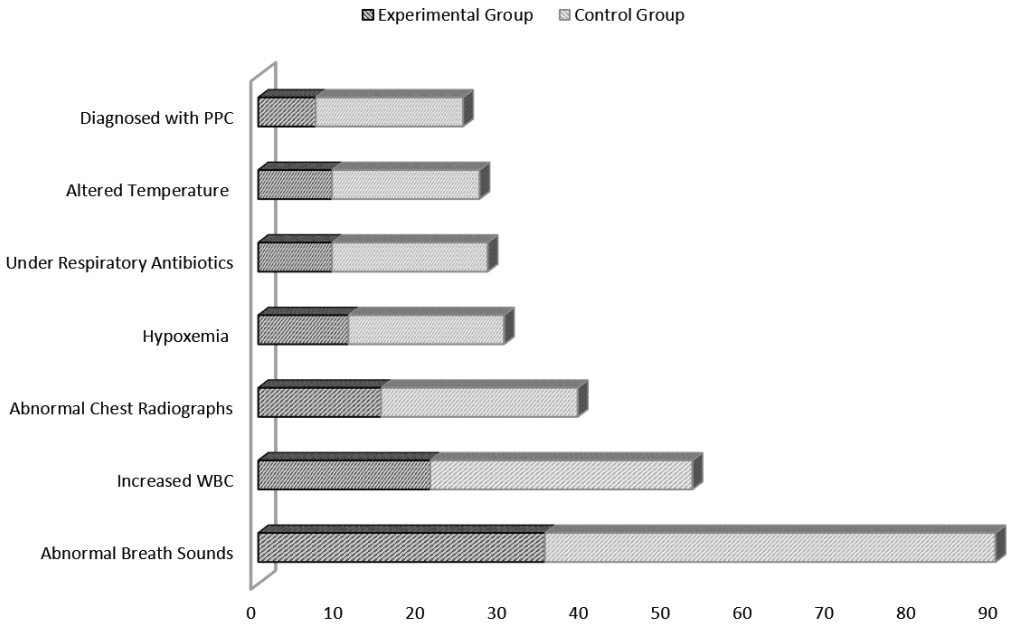
Demographic data	Experimental group (n=40)	Control group (n=40)
Age, mean (S.D.), y	43.1 (10.2)	43.8 (9.5)
BMI, mean (S.D.)	27.4 (4.0)	28.1 (3.8)
Abdominal girth, mean (S.D.)	103.9 (15.8)	107.2 (13.9)
Gender, n (%)		
Male, n (%)	15 (37.5)	14 (35.0)
Female, n (%)	25 (62.5)	26 (65.0)
T_2DM, (%)	42.5	46.2
SHTN, (%)	45.0	43.7
Smoker, (%)	6.2	9.0
Alcoholic, (%)	3.7	5.5
Laparoscopic abdominal surgeries, (%)	37.5	35.0
Open abdominal surgeries, (%)	62.5	65.0

Table 2 describes the age, BMI, abdominal girth in Mean (S.D.), and the other variables, gender. T_2DM, SHTN, smoker, alcoholic, laparoscopic abdominal surgeries, and open abdominal surgeries are expressed in percentage (%). (BMI=body mass index, T_2DM=type 2 diabetes mellitus, SHTN=systemic hypertension)



X-axis=time of measure, Y-axis=6-minute walk distance in meters

Figure 2 Functional capacity in the preoperative and postoperative period of the experimental and control groups



X-axis=number of participants, Y-axis=symptoms

Figure 3 Comparison of complications following the postoperative period

Heterogeneity of prehabilitation and clinical outcomes

Existing studies on prehabilitation programs for individuals undergoing planned abdominal surgery demonstrate varied designs, length of the program, post-pulmonary complications, and functional capacity. Also, studies incorporated various exercise training methods, such as endurance exercises, resistance training, inspiratory muscle training, or a combination of everything. However, the influence of improved aerobic capacity on unfavourable postoperative clinical outcomes has been studied little in general abdominal surgeries. These reports show a heterogeneous design of prehabilitation regarding how long the intervention lasts, the type of intervention, which depends on the time available before the surgery, and organizational standards.Bottom of Form In the current study, individuals who receive prehabilitation before abdominal surgery have a lower risk of developing pulmonary complications after the procedure[19,20].

Prehabilitation, including deep breathing exercises and incentive spirometry, has been an effective intervention in reducing postoperative pulmonary complications by optimizing lung function, preventing atelectasis, clearing secretions, and enhancing oxygenation, with effects similar to those of previous studies[19–22]. In the existing literature, all high-risk patients scheduled for elective abdominal surgery received supervised high-intensity interval training for 3 weeks, whereas the participants in our study received an incentive spirometer, deep breathing exercises, and aerobic exercise with a Rating of Perceived Exertion[22–24].

Table 3 Between-group comparison of postoperative pulmonary complications, functional capacity, and length of stay

Variables	Experimental group	Control group	p-value
Postoperative pulmonary complication, mean (S.D.)	3.2(1.3)	4.7(1.2)	<0.001
Functional capacity (Median)	263.5	229	<0.001
Length of stay, mean (S.D.)	4.1(1.1)	5.2(3.3)	>0.068

Table 3 describes the comparison of the postoperative pulmonary complications, functional capacity, and length of stay. The results show a significant difference in the p-value (<0.05) for postoperative pulmonary complications and functional capacity, but there is no significant difference in the length of stay.

Table 4 ANCOVA for PPC scores

Source	F	p-value	Partial η^2	95% CI (Adjusted mean difference)
Group	21.8	<0.001	0.22	−2.0 to −0.8
Age	1.2	0.28	0.02	–
BMI	0.9	0.34	0.01	–
Surgery type	4.3	0.041	0.06	–

CI=confidence interval, BMI=body mass index, PPC=postoperative pulmonary complication

Prehabilitation and surgical stress

Surgical stress promotes the inflammatory response, which increases the demand for oxygen consumption. Several other studies have demonstrated that prehabilitation improves cardiorespiratory fitness and oxygen delivery to the tissue, which is associated with an anti-inflammatory mechanism, as it enhances the physiological reserve and improves the functional capacity[21-24].

Functional capacity versus PPCs

High cardiorespiratory fitness before the surgery was believed to increase the patient's resilience to withstand any stress related to surgery, and high functional capacity before surgery was connected to a decreased rate of surgical complications after abdominal surgery. The current study warrants that, comparing the two groups, the experimental group had higher functional capacity, which could be attributed to the preoperative endurance training for the lower limb[23,24].

Length of stay versus PPCs: This study shows that there is no detectable variation in the length of stay between the experimental group and the control group. Many studies stated that the length of stay was affected by numerous factors, like age, comorbidities, type of surgical techniques, the type of incision, removal of surgical drains, cardiorespiratory fitness of the patients before the surgeries, the body's mechanism to withstand the impact of surgical stress, and physiological stress for the abdominal surgeries[25,26].

Limitations

Prehabilitation exercise prescription is not a standard protocol, and the functional capacity in the postoperative period was assessed within a week following the surgery. The scope of the study was to develop a prehabilitation protocol and examine the effects of prehabilitation on a population with specific modifiable comorbidities. Some of the other limitations in our study include a single-center design, a smaller sample size, a limited follow-up period, a lack of subject blinding, and a limited scope of outcome measures. These parameters might limit the generalizability and risk of type II errors and some areas of bias. Future study recommendations should include multicentric trials with long-term follow-up periods and broader outcomes, as well as the blinding of subjects.

Conclusion

The optimization of postoperative outcomes remains a paramount concern in abdominal surgeries. The current study underscores the vital role of prehabilitation in mitigating postoperative pulmonary complications and augmenting functional capacity, thereby facilitating a smoother recovery trajectory. Our findings affirm the efficacy of prehabilitation in enhancing postoperative outcomes. But the length of stay was insignificant between groups, which underscores the need for future studies. These results have profound implications for clinical practice, highlighting the importance of incorporating prehabilitation as one of the approaches to preoperative care.

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Conflict of interest

There are no conflicts of interest to declare.

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