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Effect of Segmental Expansion Exercises on Pulmonary Function in Patients with Upper Abdominal Surgery- A Randomized Controlled Trial

Pranali R. Gaikwad
MGM Institute of Physiotherapy, pranalig997@gmail.com

Manish P. Shukla
MGM Institute of Physiotherapy, manish.shukla20@gmail.com

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Abstract

Background: Following upper abdominal surgeries, restricted pulmonary function and limited chest expansion often occur due to incisions near the diaphragm. This study aimed to assess the influence of segmental expansion exercises on pulmonary function among individuals recovering from upper abdominal surgery. **Method:** The study involved 88 patients who underwent elective upper abdominal surgery, randomized into two groups. Over a five-day postoperative period, Group A received standard physiotherapy, including diaphragmatic exercises, splinted huffing/coughing, and ambulation. In contrast, Group B received routine physiotherapy along with segmental expansion exercises. The study evaluated pulmonary function through measurements of forced vital capacity, Forced Expiratory Volume in 1 second (FEV1), FEV1/FVC ratio, Peak Expiratory Flow, and chest expansion. **Results:** Following the five-day intervention period, significant differences in pulmonary function and chest expansion measurements were observed between the intervention group and the control group. Although no significant disparities were detected between the groups in terms of pulmonary function test results, a noteworthy statistical significance was found in chest expansion measurements (p=0.0001). **Conclusion:** Segmental expansion exercises administered as part of postoperative care for upper abdominal surgery patients have led to significant improvements in pulmonary function and chest expansion.

Author Bio(s)

1. PRANALI RAVINDRA GAIKWAD

Postgraduate, MGM Institute of Physiotherapy, Aurangabad, Maharashtra, India

Email: pranalig997@gmail.com

Phone number: 8652819243

ORCID ID- 0000-0002-1863-8825

2. MANISH PRANNATH SHUKLA

Associate Professor, MGM Institute of Physiotherapy, Aurangabad, Maharashtra, India

Email: manish.shukla20@gmail.com

Phone Number: 9960290614

ORCID ID- 0000-0001-7416-4663

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Pranali R. Gaikwad
Manish P. Shukla

MGM Institute of Physiotherapy

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ABSTRACT
Background: Following upper abdominal surgeries, restricted pulmonary function and limited chest expansion often occur due to incisions near the diaphragm. This study aimed to assess the influence of segmental expansion exercises on pulmonary function among individuals recovering from upper abdominal surgery. **Method:** The study involved 88 patients who underwent elective upper abdominal surgery, randomized into two groups. Over a five-day postoperative period, Group A received standard physiotherapy, including diaphragmatic exercises, splinted huffing/coughing, and ambulation. In contrast, Group B received routine physiotherapy along with segmental expansion exercises. The study evaluated pulmonary function through measurements of forced vital capacity, Forced Expiratory Volume in 1 second (FEV1), FEV1/FVC ratio, Peak Expiratory Flow, and chest expansion. **Results:** Following the five-day intervention period, significant differences in pulmonary function and chest expansion measurements were observed between the intervention group and the control group. Although no significant disparities were detected between the groups in terms of pulmonary function test results, a noteworthy statistical significance was found in chest expansion measurements (p=0.0001). **Conclusion:** Segmental expansion exercises administered as part of postoperative care for upper abdominal surgery patients have led to significant improvements in pulmonary function and chest expansion.

Keywords: Upper abdominal surgery, pulmonary function, chest expansion, postoperative pulmonary complications.

INTRODUCTION

Upper abdominal surgery stands as a predominant surgical procedure in developed countries, reflecting its clinical significance.[1,2,3] However, this procedure often brings about challenges, including hypoventilation in specific lung regions. The amalgamation of factors such as surgical pain, muscle guarding, atelectasis, and pneumonia instigates concerns, culminating in a severe outcome termed Postoperative Pulmonary Complications (PPC). These complications stem from diminished lung volumes, compromised respiratory muscle function, and impaired mucociliary clearance, resulting in postoperative physiological alterations. [4,5] The incidence of PPC varies significantly, spanning from less than 1% to 23%, across diverse major surgical scenarios. [1-3]

Numerous risk factors contribute to the development of PPC, including older age, smoking, malnutrition, anesthesia effects, intraoperative blood loss, emergency surgery, and upper abdominal or thoracic procedures.[5] Additionally, medical conditions such as arterial hypertension, heart disease, and diabetes mellitus elevate the susceptibility to PPC. Moreover, extended surgical durations exceeding three hours have been associated with an elevated risk of PPC. [6] Reduced forced expiratory volume (FEV1) and forced vital capacity (FVC), often around 65%-70% of predicted values, constitute the primary cause of postoperative pulmonary issues.[7] Notably, chest wall mobility, intertwined with lung capacity, wanes with age, declining by 50%-60% between ages 15 and 75, with males experiencing a 20% greater reduction.

Post-surgery, respiratory interventions such as chest physiotherapy, breathing exercises, incentive spirometry, and nebulizers (albuterol, DouNebs) Were utilized to encourage maximal inhalation. These interventions aimed to counteract overt atelectasis and facilitate the early re-expansion of collapsed alveoli.[8]These interventions encompass lung expansion exercises,[9] techniques for clearing secretions, limb exercises, progressive mobilization regimens, and other therapeutic measures. Among these, segmental breathing exercises focus on localized lung expansion by targeting specific segments of lung lobes.[10,11,12] This technique triggers various mechanisms, including the stretch reflex, which prompts a rapid stretch of the external intercostal muscles, leading to their contraction and subsequent expansion of the targeted lung segment.[13]

Despite the significance of these challenges, there remains a dearth of research investigating the impact of segmental expansion exercises on individuals undergoing upper abdominal surgery. This study seeks to bridge this gap by examining the influence of segmental expansion exercises on lung function, chest expansion, and the occurrence of postoperative complications such as atelectasis.

Research Question

How do segmental expansion exercises affect pulmonary function and chest expansion in patients undergoing upper abdominal surgery?

Objective

The aim of this study is to assess the impact of segmental expansion exercises on postoperative pulmonary outcomes in individuals who have undergone upper abdominal surgery.

Hypothesis

It is hypothesized that the incorporation of segmental expansion exercises into the postoperative care regimen will lead to improved pulmonary function, enhanced chest expansion, and a reduced incidence of atelectasis in patients recovering from upper abdominal surgery.

METHODOLOGY

Study Design and Participants

This study employed a prospective, randomized, open-label parallel trial design to analyze data from 88 participants who underwent elective upper abdominal surgery at a tertiary care hospital's surgery ward between March 2020 and July 2021. Participant selection was conducted using the convenience sampling method.

Inclusion and Exclusion Criteria

The study encompassed patients aged 18 to 60 who were undergoing elective upper abdominal surgery and possessed an ASA (American Society of Anesthesiologists) grade of 1 or 2. Exclusion criteria encompassed unwillingness to participate, duration of mechanical ventilation exceeding 24 hours, prior preoperative pulmonary complications such as pneumonia or atelectasis, prior lower abdominal procedures, uncontrolled hypertension, Chronic diabetes mellitus or Type I diabetes mellitus, neurological involvement, chronic respiratory diseases, kidney disease, cardiac abnormalities, and the presence of pacemakers. Ethical approval was obtained from the Institutional Ethics Committee (ECRHS/2020/18) on March 13, 2020, and also received approval from CTRI (Clinical Trials Registry - India) under registration number CTRI/2021/07/034620. Enrolled participants provided informed consent.

Randomization and Sample Size Calculation
Randomization was carried out using sealed envelopes, assigning participants to either the control or intervention group. Blinding was not implemented in this study. The sample size was calculated based on statistical power analysis, indicating that each group should consist of 44 patients to detect a significant between-group difference. The analysis employed a two-sided significance level of 0.05, a power of 80%, and an effect size (d) of 0.61, derived from a pilot study.

Outcome Measures
The primary outcome measures included pulmonary function tests and chest expansion evaluations. Spirometry, utilizing the MiniSpir Spirometer A23-C.06270, was employed to measure Forced Vital Capacity (FVC), Forced Expiratory Volume in 1 Second (FEV1), FEV1/FVC ratio, and Peak Expiratory Flow (PEF) in accordance with ATS/ERS standards.[14] Chest expansion measurements were recorded at the axillary, nipple, and xiphisternal levels using measuring tape. All outcome measures were assessed both preoperatively and postoperatively on days 3 and 5. In cases where pulmonary issues were identified, a chest X-ray was performed.

Intervention Procedure
The study enrolled 88 subjects undergoing upper abdominal surgery, dividing them into two groups. Group A (Control Group) received standard physiotherapy, including diaphragmatic breathing exercises, splinted huffing/coughing, and ambulation. In contrast, Group B (Experimental Group) received routine physiotherapy alongside segmental expansion exercises targeting apical, lateral costal, and posterior basal regions. This was administered from the first postoperative day to the fifth.

Segmental Expansion Exercise. The patient was instructed to breathe out and feel the rib cage shift downward and inwards. Using the palms of the hands, pressure was applied to the ribcage as the patient exhaled. A short downward and inward stretch of the chest was administered just before the inspiration to assist the contraction of the intercostal muscles. While the patient breaths in deeply to expand the chest, a light manual resistance to the lower ribs was applied to promote sensory awareness. The patient was next aided with mild rib cage squeezing in a downward and inward motion while he breathed out. Before and after the procedure, all vital indicators such as heart rate, respiratory rate, blood pressure, and oxygen saturation were measured.[15]

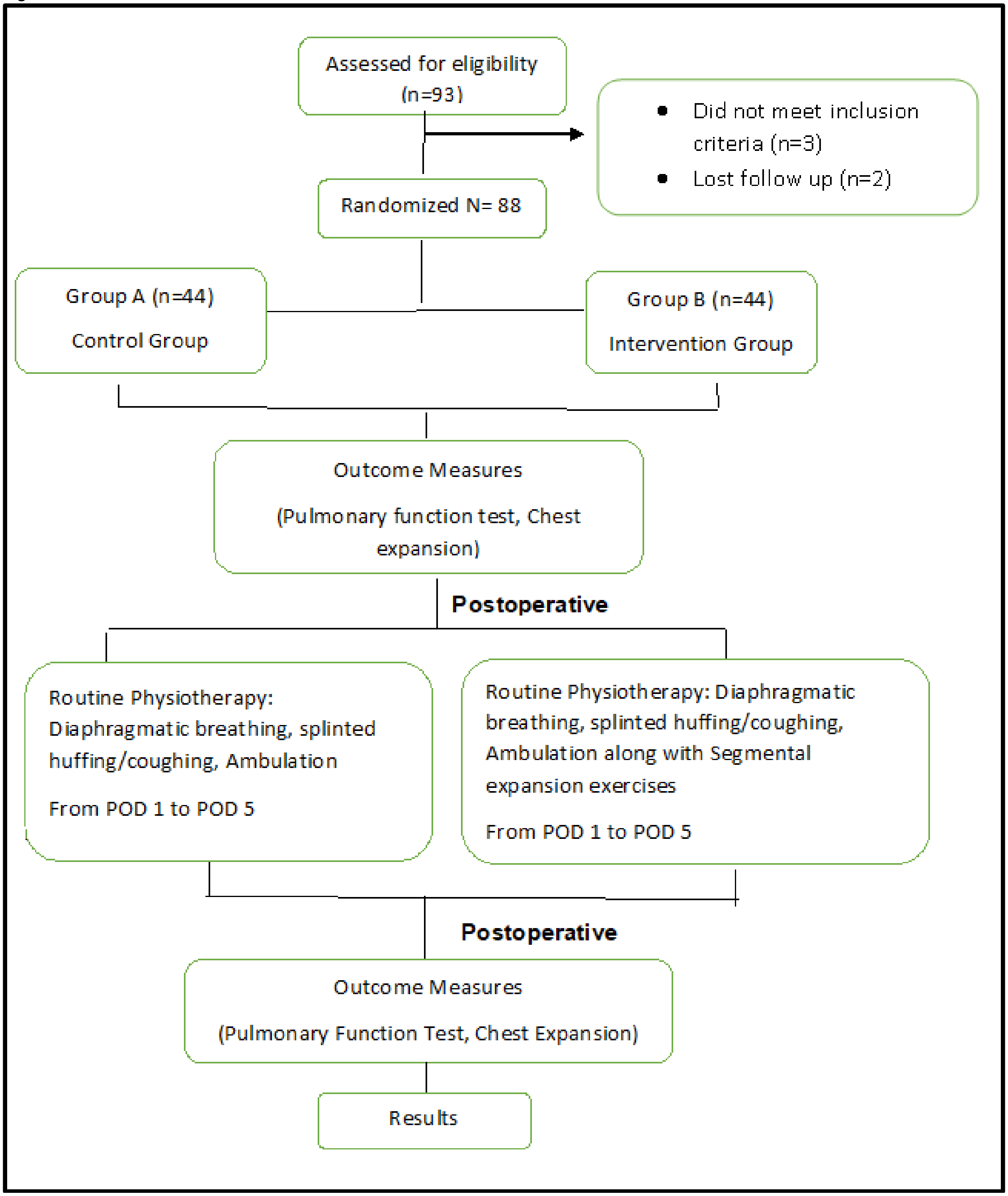
The treatment regimen involves a structured approach to improve lung function. During each session, patients perform a total of 54-60 breaths, with a breathing rate of 6 breaths per minute. After every 6 breaths, there is a brief 6-breath rest interval. Patients undergo this regimen three times a day. Each session focuses on specific lung areas: the apical (upper), lateral costal (side), and posterior basal (lower back) regions. These areas are individually targeted for 6-8 minutes during each session. In total, the daily treatment duration ranges from 20 to 25 minutes.

Data Analysis
Data analysis was conducted using SPSS version 27.0. The continuous variables, including age, gender, BMI, presence of diabetes mellitus (DM), hypertension (HT), duration of surgery, and duration of anesthesia, underwent a normality assessment using the Kolmogorov-Smirnov test. Within each group, all data exhibited a normal distribution. Consequently, continuous variables were summarized using means and standard deviations.

The impact of the intervention on Pulmonary Function test parameters (Forced Vital Capacity - FVC, Forced Expiratory Volume in 1 Second - FEV1, FEV1/FVC ratio, Peak Expiratory Flow - PEF) and chest expansion measurements was estimated and analyzed. Changes from baseline to postoperative day 3 (POD-3) and postoperative day 5 (POD-5) within each group were examined utilizing the paired t-test. Additionally, differences between the two groups were assessed using the unpaired t-test.

RESULTS
A total of 93 patients were initially assessed for participation in the study, from which 5 were excluded - 2 due to lack of follow-up and 3 for not meeting the inclusion criteria. Consequently, the study ultimately included 88 participants, with 44 individuals assigned to the experimental group and 44 to the control group.

Figure 1. Patient Flow Chart



Routine Physiotherapy

The flow of patients through the study is visually depicted in Figure 1. The enrolled patients ranged in age from 18 to 60 years. The baseline characteristics of the two groups, including patient age, gender distribution, body mass index (BMI), duration of surgery, duration of anesthesia, and the presence of co-morbidities and addictions, were comparable and are detailed in Table 1.

Table 1 summarizes the demographic and clinical characteristics of the study's participants in the control and experimental groups. The mean age in both groups was similar, with no significant difference observed. The gender distribution showed a slightly higher number of males in both groups, and again, there was no significant difference. The BMI, duration of surgery, and duration of anesthesia also demonstrated no significant group differences. Comorbidities and addictions, including diabetes, hypertension, and smoking, did not significantly differ between the two groups. Overall, baseline characteristics were well-balanced between the control and experimental groups, suggesting a similar patient profile for the study.

Table 1. Demographic Characteristics of Patients

Variables	Control Group	Experimental Group	p-value
Age (Years) Mean±SD	42±14.05	36.29±12.07	0.4
Male	29	25	0.38
Female	15	19	
BMI	23.61±2.34	23.22±2.11	0.42
Duration of surgery	98.86±22.01	100.56±19.28	0.70
Duration of anaesthesia	130.45±19.28	132.66±18.77	0.58
Comorbidities			
None	32(72.7%)	27(61.4%)	χ2-value 3.77 p=0.28
DM	3(6.8%)	5(11.4%)	
HT	6(13.7%)	7(15.9%)	
Both	3(6.8%)	5(11.4%)	
Addictions			
None	32(72.7%)	24(54.5%)	χ2-value 6.32 p=0.09
Smoking	10(22.7%)	14(31.8%)	
Alcohol	1(2.2%)	3(6.8%)	
Both	1(2.2%)	3(6.8%)	

*DM-Diabetes Mellitus, HT- Hypertension

Table 2 provides information on the type of incision and type of surgery performed in both the control and experimental groups. The choice of incision type was significantly different between the groups, with the midline incision being more common in the control group and subcostal incisions more frequent in the experimental group. However, there were no significant differences in the distribution of various types of surgery between the two groups.

Table 2: Distribution of Surgical Procedures in the Control and Experimental Groups

Type of incision			
Incision	**Control Group**	**Experimental Group**	**χ2-value**
Midline	28(63.64%)	26(59.09%)	7.72 p=0.0211, **Sig**
Subcostal	4(9.09%)	13(29.55%)	
Upper Midline	12(27.27%)	5(11.36%)	
Type of Surgery			
Surgery	**Control Group**	**Experimental Group**	**χ2-value**
Acute Pancreatitis	2(4.55%)	1(2.27%)	16.84 p=0.26, **N Sig**
Appendectomy	0(0%)	3(6.82%)	
Cholecystectomy	12(27.27%)	13(29.55%)	
Gastric outlet obstruction	1(2.27%)	0(0%)	
Hemicolectomy	1(2.27%)	1(2.27%)	
Intestinal obstruction	3(6.82%)	3(6.82%)	
Jejunal Stricture Enteritis	1(2.27%)	3(6.82%)	
Periampullary Ca	3(6.82%)	2(4.55%)	
SMA thrombosis	3(6.82%)	2(4.55%)	
Small Bowel Obstruction	6(13.64%)	4(9.09%)	
Spleenectomy	2(4.55%)	0(0%)	
Umbilical Hernia	10((22.73%)	5(11.36%)	
Duodenal Peritonitis	0(0%)	1(2.27%)	
Sigmoid Diverticulum	0(0%)	2(4.55%)	
Whipples	0(0%)	4(9.09%)	
Total	44(100%)	44(100%)	

Table 3 presents the changes in pulmonary function parameters (FVC, FEV1, FEV1/FVC, PEF) from baseline to postoperative days 3 (POD-3) and 5 (POD-5) in both the control group (CG) and experimental group (EG). The results show that for all parameters, there was a significant improvement in both groups from baseline to POD-5. The changes were statistically significant for FEV1, FEV1/FVC, and PEF in the EG, and for FVC, FEV1, and PEF in the CG.

Table: 3 Pulmonary Function Test

Parameter	**Group**	**Baseline**	**POD-3**	**POD-5**	**B Vs POD3**	**B Vs POD3**	**CG Vs EG**	**B Vs POD5**	**B Vs POD5**	**CG Vs EG**
FVC	CG	1.50 ±0.66	1.55± 0.60	1.76± 0.61	1.55± 0.60	0.56	0.92	1.76± 0.61	0.02	0.64
	EG	2.99± 0.62	2.32± 0.62	2.58± 0.62	2.32± 0.62	0.6		2.58± 0.51	0.0001	
FEV1	CG	1.13± 0.52	1.08± 0.43	1.36± 0.5	1.08±0.43	0.36	0.7	1.36± 0.50	0.001	0.13
	EG	1.89± 0.47	1.9± 0.57	2.23± 0.43	1.90± 0.57	0.82		2.23± 0.43	0.0001	
FE1/FVC	CG	73.52± 25.46	72.65±25.87	77.66± 25.87	72.65± 25.87	0.51	0.88	77.66± 20.45	0.047	0.58
	EG	80.08± 14.96	78.47±14.04	85.66± 11.42	78.47± 14.04	0.32		85.66± 11.42	0.002	
PEF	CG	1.88± 1.42	1.95± 1.24	2.29± 1.36	1.95± 1.24	0.61	0.91	2.29± 1.36	0.46	0.2
	EG	3.04± 1.13	3.13± 1.37	3.68± 1.26	3.13± 1.37	0.46		3.68± 1.26	0.0001	

*FVC-Forced Vital Capacity, FEV1-Forced Expiratory Volume in one second, PEF- Peak Expiratory Flow, POD-Post-operative Day, B-Baseline, CG-Control Group, EG- Experimental Group

Figure 2. Comparison of Pulmonary Function Test (A-FVC, B-FEV1, in Two Groups at Post-Operative Day 3 and 5 with Baseline

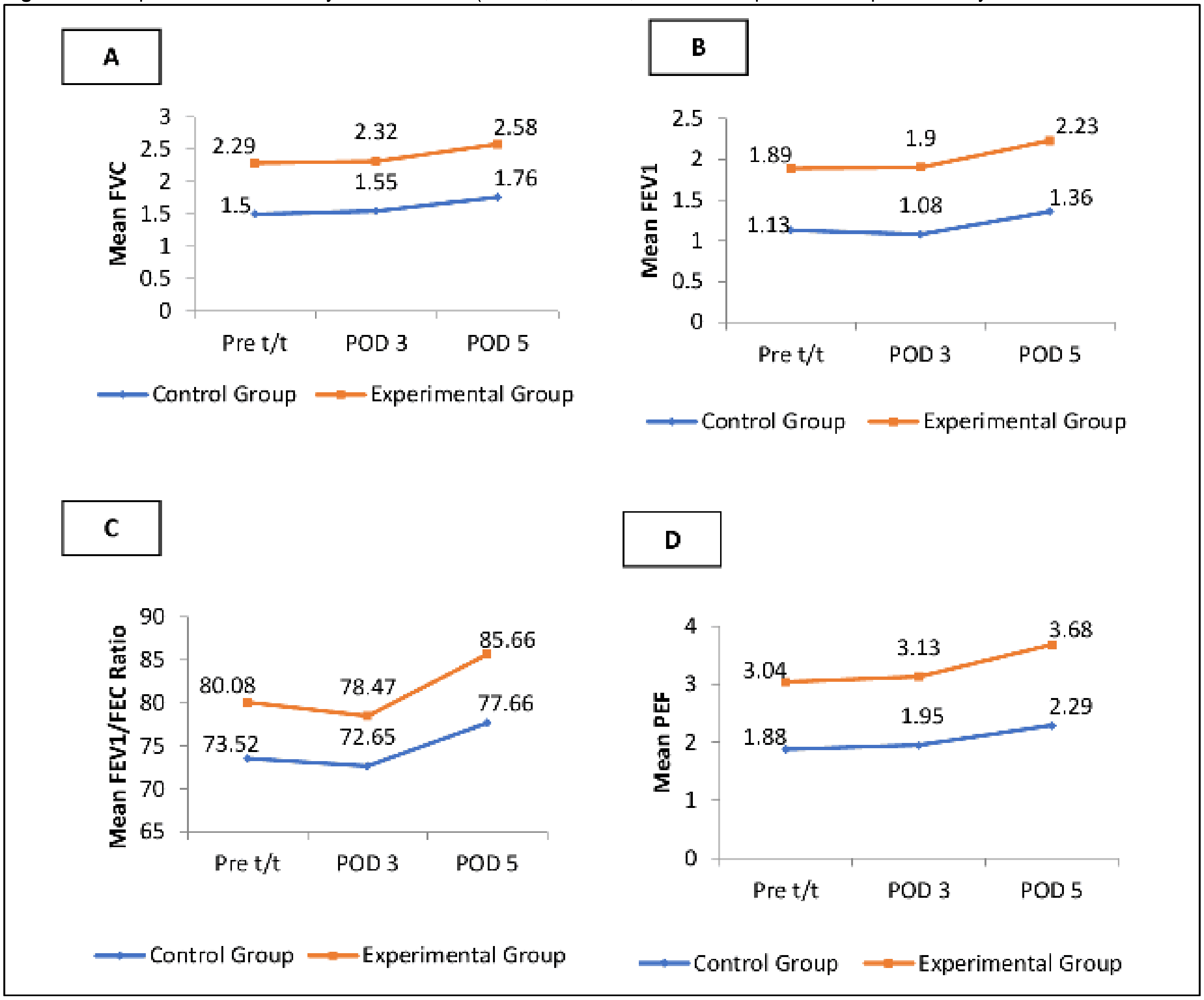
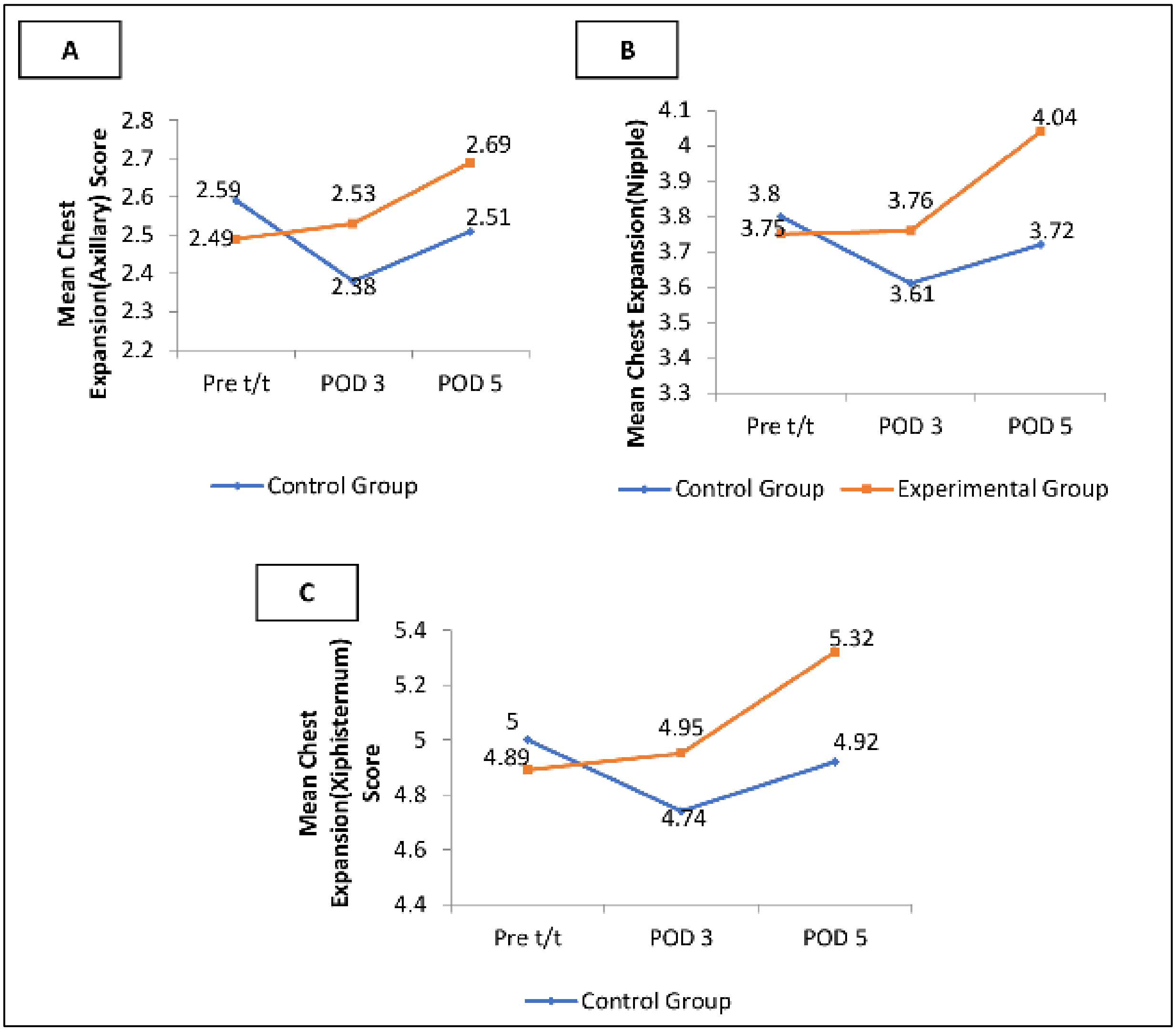


Figure 3. Comparison of Chest Expansion (A-Axillary, B-Nipple, C-Xiphisternum) in Two Groups at Postoperative Days 3 and 5 with Baseline.



*FVC-Forced Vital Capacity, FEV1-Forced Expiratory Volume in one second, PEF- Peak Expiratory Flow, POD-Post-operative Day, Pre t/t- Pretreatment

Table 4 illustrates changes in chest expansion measurements at different levels (axillary, nipple, xiphisternum) from baseline to postoperative days 3 (POD-3) and 5 (POD-5) in the control group (CG) and experimental group (EG). In both groups, there were significant improvements in chest expansion at all three levels from baseline to POD-5. The improvements were statistically significant for all levels in both groups.

Table 4. Table:4 Chest Expansion Measurements

Level of measurements	Group	Baseline	POD-3	POD-5	B Vs POD3	B Vs POD3	CG Vs EG	B Vs POD5	B Vs POD5	CG Vs EG
Axiliary	CG	2.59± 0.313	2.38± 0.17	2.51± 0.14	2.38± 0.17	0.0001	0.0001	2.51±0.14	0.0001	0.0001
	EG	2.49± 0.12	2.53± 0.16	2.69± 0.12	2.53± 0.16	0.0001		2.69±0.12	0.0001	
Nipple	CG	3.80± 0.363	3.61± 0.33	3.72± 0.27	3.61± 0.33	0.0001	0.0023	2.59±0.13	0.017	0.0001
	EG	3.75± 0.16	3.76± 0.24	4.04± 0.21	3.76± 0.24	0.85		2.59±0.13	0.0001	
Xiphisterm	CG	5.00± 0.49	4.74± 0.39	4.92± 0.34	4.74± 0.39	0.0001	0.0004	4.92±0.34	0.16	0.0001
	EG	4.89± 0.26	4.95± 0.29	5.32± 0.26	4.95± 0.29	0.17		5.32±0.26	0.0001	

* POD-Post-operative Day, B-Baseline, CG-Control Group, EG- Experimental Group

DISCUSSION

Our research hypothesis was supported by the results, indicating that segmental expansion exercises had a significant impact on pulmonary function in patients undergoing upper abdominal surgery. Previous studies have already demonstrated that pulmonary function tends to be compromised following such surgical procedures. This deterioration can be attributed to various factors, including prolonged effects of anesthesia, surgical duration, and diverse comorbidities, all contributing to the occurrence of postoperative pulmonary complications. In this context, the integration of segmental expansion exercises appears to have led to improvements in both pulmonary function and chest expansion measurements in our study (as evidenced in Table 3). Notably, this study is unique in being the first to examine the effects of segmental expansion exercises on pulmonary function and chest expansion in the context of upper abdominal surgery.

The diverse anthropometric parameters we considered in our study, such as age, BMI, surgical duration, and smoking history, are important due to their established links to pulmonary function. Our findings revealed a substantial proportion of middle-aged individuals (40-60 years old), which correspondingly resulted in a more pronounced compromise in pulmonary function and chest expansion. Moreover, a majority of patients had no pre-existing comorbidities or addictions, except for smoking. Since these factors were comparatively low in our study, they did not significantly contribute to the development of postoperative pulmonary complications. However, prior research has indicated that variables like BMI, comorbidities, and smoking can elevate the risk of such complications. Similarly, current smokers have been identified as having twice the odds of developing postoperative pulmonary complications compared to non-smokers.[16]

When analyzing the results in more detail, we observed that while pulmonary function parameters (FVC, FEV1, FEV1/FVC, PEF) did not exhibit statistical significance on postoperative day 3 compared to preoperative measurements, they did demonstrate significant improvement by postoperative day 5 in both groups. Conversely, chest expansion measures at the axillary level displayed significant differences between the two groups on postoperative days 3 and 5 ($p=0.0001$ for both), with similar trends observed for the nipple and xiphisternum chest expansion measures. Notably, chest expansion measures improved across both groups, with the intervention group demonstrating a statistically significant advantage. Due to the fact that there is shallow, repetitive breathing without frequent sighs throughout the postoperative period, previous investigations have revealed a considerable decline in pulmonary function in the first few postoperative days. Moreover, postoperative incision pain, surgical trauma, and postoperative circumstances (drains, catheters) all affect the respiratory system's mechanics and lower lung airflow.[17,18] This improvement in pulmonary function, as indicated by the significant changes in lung function parameters, suggests that the use of segmental expansion exercises immediately after surgery likely played a crucial role in enhancing chest expansion. These exercises may have contributed to the positive outcomes observed in our study.

The observed improvements in pulmonary function and chest expansion can be attributed to several factors. Diaphragmatic breathing exercises, a component of the physiotherapy regimen, facilitate the descent and ascent of the diaphragm during inhalation and exhalation, promoting deep, even air distribution throughout the lungs. This technique enhances respiratory mechanics, thereby benefiting parameters like Forced Vital Capacity (FVC) and alleviating the strain on accessory muscles. Moreover, the rapid stretching of intercostal muscles during segmental expansion exercises triggers their contraction, aiding in inhalation and thereby improving pulmonary function and chest expansion.[19] The manual resistance applied by the physiotherapist during inhalation, followed by a quick release, initiates a "rib spring" motion that rapidly expands the thoracic cage, enabling increased air intake.[20]

These findings align with a previous study conducted by Frances Blaney et al., which supports the notion that segmental expansion exercises can lead to increased sensory input and re-education of normal movement through the reflex inhibition of the diaphragm. Manual contact over the intercostal region, as performed in the segmental expansion exercises, directly influences the diaphragm through the lower intercostal nerves. These nerves supply sensory fibers to the diaphragm margin and motor supply to the abdominal muscles. The tactile input obtained during these exercises also has the potential to alter abdominal muscle tone, thereby influencing the mechanical interaction of the diaphragm with the abdominal wall muscles.

In contrast, research has been conducted on lung expansion treatments like incentive spirometry following major operations such as upper abdominal surgery. However, the existing data is insufficient to fully justify the use of incentive spirometry in postoperative patient care.[22] Therefore, our study provides valuable insight by indicating that lung expansion treatments, specifically segmental expansion exercises, not only enhance lung function but also lead to improved chest expansion measurements.

In the present study, we also examined the utility of chest X-rays for identifying postoperative pulmonary complications, including atelectasis. Interestingly, none of the patients in either study group developed any such complications in the aftermath of their surgeries. This positive outcome can likely be attributed to the early implementation of standard physiotherapy exercises and segmental expansion exercises, which effectively decreased the occurrence of postoperative pulmonary complications. Furthermore, our research involved the continuous monitoring of vital parameters both before and after surgery to detect any potential changes in blood pressure or oxygen saturation levels during pulmonary function testing. It's worth mentioning that we observed no adverse events or complications in this regard.

Limitations

The main limitation of the study was that the in-patient setting limited our ability to analyze the long-term effects of segmental expansion exercises. The study's inclusion criteria were restricted to ASA grades 1 and 2, aiming to minimize the influence of additional respiratory or organ dysfunction variables on the outcomes. Furthermore, the single-center nature of the study might somewhat limit its generalizability.

Moving forward, while our study focused on in-patients, future research could expand its scope to investigate the longer-term impact of segmental expansion exercises. Additional outcome measures, such as lung volumes, respiratory pressure measures (MIP, MEP), and functional capacity tests, could contribute to a more comprehensive understanding of the intervention's effects. Moreover, investigations targeting individuals over the age of 60 would be valuable, as this demographic tends to exhibit greater reductions in these parameters due to age-related changes in the respiratory system.

CONCLUSION

Segmental expansion exercises administered as part of postoperative care for upper abdominal surgery patients have led to significant improvements in pulmonary function and chest expansion. By integrating these exercises into the standard physiotherapy protocol, we not only witnessed enhanced patient outcomes but also the potential reduction in the occurrence of postoperative pulmonary complications

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CONFLICT OF INTEREST: There are no conflicts of interest.

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