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# Preserving pulmonary function and functional capacity in children undergoing open abdominal surgery: A one group pretest–posttest, quasiexperimental pilot trial☆,☆☆,★

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ABSTRACT

*Purpose:* The aim of this trial was to determine the effects of Preoperative physiotherapy education (POPE) and Postoperative physiotherapy (POP) maintaining pulmonary function and functional capacity in children undergoing open abdominal surgery.
*Methods:* A total of eight children aged, 5–17 years old posted for open abdominal surgery received POPE and POP. Spirometry, 10 m walk test (10mWT), timed up and go test (TUGT) and chest expansion were taken preoperatively and postoperatively on day one and five. Six minute walk test (6MWT), and Nine stair climbing test (9SCT) were taken preoperatively and postoperatively on day five.
*Results:* No statistical significant difference were noted in FVC, FEV1, PEFR, FEV1/FVC Ratio, chest expansion levels and Borg scale but in TUGT, 10mWT, 6MWT and 9SCT significant difference was noted. Effect size were calculated and post hoc power analysis revealed that the power of the study is >90%.
*Conclusion:* POPE might have positive effects in preserving pulmonary function and functional capacity.
*Type of study:* Treatment study.
*Level of evidence:* Level II.



Abdominal surgery causes various pathophysiological responses and leads to postoperative pulmonary complications (PPCs) [1]. PPCs may occur after abdominal surgery because of the duration of the surgery, effect of anesthesia, pain inhibition of respiratory muscles, reduced pulmonary function and decreased mucocilliary clearance which further leads to suppression of cough reflex and a decrease in lung volumes and capacity [1]. Increased mortality, morbidity and expensive treatment are strongly related to PPC. Atelectasis and pneumonia are the two main PPCs that occur after abdominal surgery [2].

Preoperative physiotherapy plays a major role in this area for the prevention of PPC after abdominal surgery. Preoperative physiotherapy education consists of deep breathing exercises performed for 30 min a day before surgery helps in reducing the risk of PPC [3]. Preoperative inspiratory muscle training for 15 min with power Breathe device shows improvement in inspiratory muscle power postoperatively [4]. The other physiotherapy exercises consisting of aerobic exercise, pelvic and trunk rotation, and relaxation exercises performed for 50 min 2–3 weeks prior to surgery help in reducing the risk of PPCs and

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promote adherence to treatment [5]. Morbidity and mortality are most commonly caused by PPCs after cardiac surgery in the pediatric age group [6]. Preoperative physiotherapy along with postoperative physiotherapy helps in minimizing the risk of PPC in pediatric cardiac surgery [6]. Preoperative physiotherapy consists of airway clearance techniques, rib-expansive techniques, abdominal support and guidance of parents and postoperative physiotherapy like postural drainage, chest physiotherapy (percussions and vibrations), deep breathing exercises, limb physiotherapy and early mobilization after surgery shows a reduction in PPC and improves lung function after surgery [7].

The six minute walk test (6MWT) is used to measure the cardiovascular endurance during the preoperative and postoperative period in abdominal surgery. It also helps in measuring lung function and functional independence after surgery [8]. Spirometry and 6MWT were also used to quantify the changes caused by surgery to detect the severity of PPC [9]. Preoperative physiotherapy education in the adult population [10] and in pediatric cardiac surgery showed improvement in lung function. To the best of our knowledge there is no study available among the pediatric population to determine the effectiveness of preoperative physiotherapy education (POPE) following postoperative physiotherapy (POP). Hence, the aim of this study is to determine the effectiveness of POPE following POP to preserve pulmonary function and functional capacity in children undergoing open abdominal surgery.

## 1. Materials and methods

This was a one group pretest and posttest quasiexperimental pilot trial. Ethical clearance was obtained from the institutional research ethics committee of Maharishi Markandeshwar (Deemed to be University), Mullana, Haryana (IEC/MMU/2018/1189). This pilot trial was performed between 1st August, 2018 and 22nd November, 2018 and was a part of a large study which was already registered under ClinicalTrials.gov, NCT03543904 on 1 June 2018. The study strictly followed the standard ethical principles adopted by World Medical Association which include the medical research involving human subjects, Helsinki declaration, Revised 2013, and the ethical guidelines adopted by the Council for International Organizations of Medical Sciences (CIOMS), the International ethical guidelines for health-related research involving humans (Revised, 2016). As the study was conducted in India, the study also adopted the ethical guidelines that followed the national ethical guidelines for biomedical and health research involving human participants by Indian Council of Medical Research (ICMR), 2017.

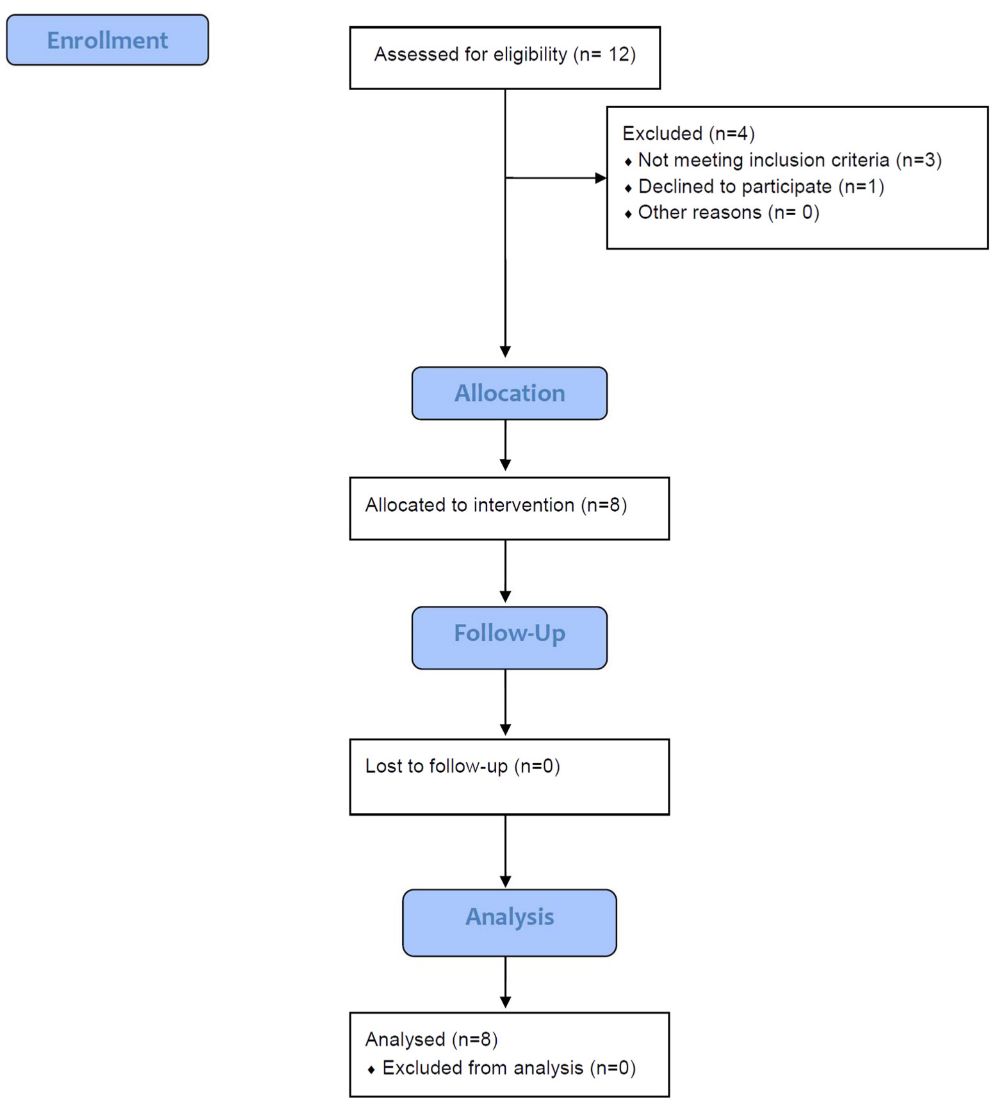


**Fig. 1.** Flowchart of the pilot study plan.

### 1.1. Inclusion criteria and exclusion criteria

Twelve children who were aged between 5 and 17 years scheduled for open abdominal surgery were assessed for the eligibility to the study. Among them 8 children were found to be eligible for trial enrolment; 4 children were excluded owing to not meeting the inclusion criteria ($n = 3$) and declining to participate ($n = 1$). Children with open abdominal incisions such as inguinal incision, left subcostal incision, right subcostal incision, Kehr incision, McBurney incision, transverse incision, thoracoabdominal incision, median and paramedian incision were included in the trial while the children with mental retardation and physical disability, children/families that refused enrolment, children who did not follow and obey the command, those who require organ transplant, and those who had mental retardation and physical disability were excluded from this trial. Written informed consent was taken from the participants' caregiver/parents and assent from the children prior to the study. The detailed study plan was displayed in Fig. 1.

### 1.2. Recruitment

Eight children aged, 5–17 years old were recruited via parental consent and participating children's assent from Recognized tertiary care teaching hospital, Mullana, Ambala District, Haryana, India for this one group pretest–posttest quasiexperimental design.

### 1.3. Study procedure

All the children received preoperative assessment and POPE approximately 30 min, single session, and one day before surgery during their admission for surgery. After surgery postoperative physiotherapy was administered up to the postoperative day 5 (POD5). POPE consisted of

**Table 1**
Neha's-Post abdominal surgery rehabilitation protocol (N-PARP).

| *Preoperative physiotherapy plan for the children undergoing abdominal surgery* | |
|---|---|
| Preoperative physiotherapy training | Intensity of exercises |
| **Deep breathing exercises** | |
| Pursed lip breathing exercises | 10 repetitions× 2 sets |
| Diaphragmatic breathing exercises | 10 repetitions× 2 sets |
| Segmental breathing exercises (Posterior basal) | 10 repetitions× 2 sets |
| Trunk and pelvic mobility exercises | 10 repetitions× 2 sets |
| Leg ROM (active hip and knee flexion, knee extension and hip abduction exercises) | 10 repetitions× 2 sets |
| Ankle toe movement's exercises (Ankle Dorsi and plantar flexion) | 10 repetitions× 2 sets |
| *Postoperative physiotherapy plan for the children undergoing abdominal surgery* | |
| Physiotherapy on Postoperative Day 1 | Intensity of exercises |
| **Deep breathing exercises** | |
| Pursed lip breathing exercises | 5 repetitions× 2 sets |
| Diaphragmatic breathing exercises | 5 repetitions× 2 sets |
| Segmental breathing exercises | 5 repetitions× 2 sets |
| Incentive spirometer 10 breaths up to 600 cc | 2 sets per session, at a minimum, every 2 h while awake (minimum 6 times/day) |
| Hip and knee Range of motion exercises | 5 repetitions× 2 sets |
| Ankle and toe movements (Ankle Dorsi and plantar flexion) | 10 repetitions× 2 sets |
| Ambulation program (4 hourly) | Half sitting minimum of 2 min |
| | March on spot for 1 min |
| Physiotherapy on Postoperative Day 2 | Intensity of exercises |
| **Deep breathing exercises** | |
| Pursed lip breathing exercises | 5 repetitions× 2 sets |
| Diaphragmatic breathing exercises | 5 repetitions× 2 sets |
| Segmental breathing exercises | 5 repetitions× 2 sets |
| Incentive spirometer 10 breaths up to 900 cc | 2 sets per session, at a minimum, every 2 h while awake (minimum 6 times/day) |
| Hip and knee Range of motion exercises | 5 repetitions× 2 sets |
| Ankle and toe movements | 10 repetitions× 2 sets |
| Thoracic expansion exercises- ACBT (Active cycles of breathing techniques) | 2 repetitions twice a day |
| Diaphragmatic breathing (10 repetitions), Deep breathing (5 s hold) and Huffing | |
| Ambulation program | |
| Physiotherapy on Postoperative day 3 | Intensity of exercises |
| Pursed lip breathing exercises | 10 repetitions× 2 sets |
| Trunk and pelvic mobility exercises | 10 repetitions× 2 sets |
| Incentive spirometer 10 breaths up to 1200 cc | 2 sets per session, at a minimum, every 2 h while awake (minimum 6 times/day) |
| Thoracic expansion exercises- ACBT (Active cycles of breathing techniques) | 2 repetitions twice a day |
| Diaphragmatic breathing (10 repetitions), Deep breathing (5 s hold), and Huffing | |
| Ambulation program | |
| Physiotherapy on Postoperative day 4 | Intensity of exercises |
| Incentive spirometer/10 breaths up to 1200 cc | 2 sets per session, at a minimum, every 2 h while awake (minimum 6 times/day) |
| Trunk and pelvic mobility exercises | 10 repetitions× 2 sets |
| Stair climbing in ascending and descending pattern (4 steps) | 5 min |
| Physiotherapy on Postoperative day 5 | Intensity of exercises |
| Incentive spirometer/10 breaths up to 1200 cc | 2 sets per session, at a minimum, every 2 h while awake (minimum 6 times/day) |
| Stair climbing in ascending and descending pattern (9steps) | 5 min |

**Table 2**
Demographic characteristics of children undergoing abdominal surgery ($n = 8$).

| Demographic dimensions | Mean and 95% Confidence interval |
|---|---|
| Age (years) | 10.4 (7.9–12.8) |
| Height (cm) | 136.2 (117.8–154.5) |
| Weight (kg) | 32.6 (23.6–41.5) |
| BMI (kg/m$^2$) | 17.4 (15.4–19.4) |

deep breathing exercises, trunk and pelvic mobility exercises and leg mobility exercises while postoperative physiotherapy education consisted of deep breathing exercises, segmental breathing exercises, incentive spirometer, and Active cycle of breathing techniques (ACBT), limb physiotherapy and early ambulation program. These exercises were incorporated into the protocol titled, "Neha's-Post abdominal surgery rehabilitation protocol (N-PARP)" ©Neha Sharma and copyrighted under the Copyright office, Government of India with unique registration no: L-79385/2018 dated 10th December, 2018 (Copyright filed with Diary no: 15184/2018-CO/L dated 2nd November, 2018) as displayed in Supplementary File 1 The children posted for surgery were asked to perform the above exercises until they become familiar. Thus during the postoperative period, the above exercises would not be new to them and they could perform much easier. That was the ultimate aim of POPE rather than preoperative physiotherapy training. Follow up was taken up to POD5. The duration of the physiotherapy session ranged from postoperative day 1 (POD1) to POD5. The details of the protocol (N-PARP) included in the study are displayed in Table 1.

### *1.4. Outcome measures*

Pulmonary function and functional capacity were assessed with the help of Spirometry and six minute walk test (6MWT) before and after surgery. The main Spirometry measurements taken were FVC, FEV1, FEV1/FVC ratio and PEFR. These measurements were taken on baseline, POD1 and on POD5. 6MWT along with Borg scale was taken on baseline and on POD5.

Secondary outcomes include 10 m walk test (10mWT), timed up and go test (TUGT), nine stair climbing test (9SCT) and chest expansion test. The 10mWT, TUGT and chest expansion were taken on baseline, POD1 and POD5 while 9SCT was taken on baseline and POD5.

### *1.5. Data analysis*

The data were analyzed by SPPS Version 20.0 for Windows 10 Home Edition (IBM SPSS V-20 for Windows, Armonk, NY: IBM Corp). Normality of the collected data was analyzed with Shapiro Wilk test [11] as the sample size was lesser than 50 and confirmed that the data follow normal distribution. Normally distributed continuous variables were summarized as mean and 95% confidence interval. The sample group was compared on baseline with POD1 and POD5 variables using paired t-test. Repeated measures ANOVA was used to establish the statistical significance among baseline, POD1 and POD5. P value of ≤0.05 was considered as statistically significant. Effect size and post hoc power analysis were performed to determine the level of type-II error.

**Table 4**
Comparison of outcomes measures between Pre-OP and POD5 values.

| Outcome measures | Preoperative | POD5 | P value[a] | Effect size | Power |
|---|---|---|---|---|---|
| FVC (%) | 83.8 (74.1–93.4) | 82.3 (71.9–92.7) | 0.35 | −0.10 | 0.08 |
| FEV1 (%) | 83.0 (69.3–96.8) | 80.1 (68.7–91.6) | 0.77 | −0.14 | 0.10 |
| PEFR (%) | 68.2 (52.5–84.0) | 67.7 (52.9–82.5) | 0.86 | −0.02 | 0.06 |
| FEV1/FVC Ratio (%) | 105.1 (94.8–115.5) | 100.4 (88.0–112.8) | 0.22 | −0.31 | 0.20 |
| TUGT (s) | 12.5 (11.2–13.9) | 18.7 (15.2–22.2) | 0.04 | 3.2 | 1.00 |
| 10mWT (m/s) | 12.9 (11.4–14.4) | 15.9 (13.3–18.5) | 0.01 | 1.26 | 0.94 |
| 6MWT (m) | 464 (438–490) | 417 (389–445) | 0.01 | −1.20 | 0.92 |
| Borg scale | 6.4 (6.1–6.8) | 7.2 (6.2–8.0) | 0.11 | 1.6 | 0.99 |
| 9SCT (s) | 13.8 (10.0–17.6) | 18.7 (14.0–23.4) | 0.01 | 0.86 | 0.71 |
| **Chest expansion** | | | | | |
| T2 (cm) | 2.3 (1.9–2.8) | 2.2 (1.8–2.6) | 0.50 | −0.14 | 0.10 |
| T4 (cm) | 3.7 (3.0–4.5) | 3.3 (2.4–4.2) | 0.59 | −0.45 | 0.31 |
| T10 (cm) | 4.6 (4.0–5.2) | 4.0 (3.4–4.7) | 0.14 | −0.67 | 0.53 |

**Abbreviations:** FVC, Forced vital capacity; FEV1, Forced expiratory volume in one second; PEFR, Peak expiratory flow rate; TUGT, Timed up and go test; 10mWT, 10 m walk test; T2, Axillary level; T4, Nipple level; T10, Xiphi-sternum level; 6MWT, 6 min walk test; 9SCT, Nine stair climbing test.
[a] Paired t test.

## 2. Results

The sample group consisted of 8 children (6 male and 2 females) aged between 5 and 17 years. Detailed demographic data are displayed in Table 2. Preoperative (baseline) and postintervention changes on POD1 and POD5 in Spirometric measurements, 10mWT, TUGT and chest expansion of sample group (repeated measures ANOVA) are given in Table 3. Preoperative and POD5 changes on outcome measures (paired t test) are given in Table 4. Effect size [12] was calculated from effect size index given in Table 4. As a priori sample size calculation was not performed, post hoc (retrospective) power analysis was performed using G* Power 3.1.9.4 software to calculate power of the study [13]. From Table 4, it was evident that the study is sufficiently powered (power of the study >90%) for the outcome measures, 10mWT (94% power), 6MWT (92% power) and TUG test (100% power). Hence, there is sufficient evidence to confirm that functional capacity is preserved in children undergoing open abdominal surgery and the level of type-II error is less than 10%. Though decremental effects were observed in the outcomes of spirometric measurements

**Table 3**
Comparison of outcomes between Pre-OP and Postinterventions (POD1 and POD5).

| Outcome measures | Preoperative | POD1 | POD5 | P value[a] |
|---|---|---|---|---|
| FVC (%) | 83.8 (74.1–93.4) | 62.9 (50.8–75.0) | 82.3 (71.9–92.7) | <0.001 |
| FEV1 (%) | 83.0 (69.3–96.3) | 62.3 (53.0–71.6) | 80.1 (68.7–91.6) | <0.001 |
| PEFR (%) | 68.2 (52.5–84.0) | 48.1 (35.0–61.3) | 67.7 (52.9–82.5) | <0.001 |
| FEV1/FVC Ratio (%) | 105.1 (94.8–115.5) | 87.8 (73.4–102.1) | 100.4 (88.0–112.8) | <0.001 |
| TUGT (s) | 12.5 (11.2–13.9) | 20.2 (16.0–24.5) | 18.7 (15.2–22.2) | <0.001 |
| 10mWT (m/s) | 12.9 (11.4–14.4) | 19.0 (15.4–22.7) | 15.9 (13.3–18.5) | <0.001 |
| **Chest expansion** | | | | |
| T2 (cm) | 2.3 (1.9–2.8) | 1.4 (.95–1.9) | 2.2 (1.8–2.6) | <0.001 |
| T4 (cm) | 3.7 (3.0–4.5) | 2.2 (1.7–2.7) | 3.3 (2.4–4.2) | <0.001 |
| T10 (cm) | 4.6 (4.0–5.2) | 2.6 (2.1–3.2) | 4.0 (3.4–4.7) | <0.001 |

**Abbreviations:** FVC, Forced vital capacity; FEV1, Forced expiratory volume in one second; PEFR, Peak expiratory flow rate; TUGT, Timed up and go test; 10mWT, 10 m walk test; T2, Axillary level; T4, Nipple level; T10, Xiphi-sternum level.
[a] Repeated measures ANOVA

such as, FVC, FEV1, PEFR and FEV1/FVC Ratio, there was no statistical significant difference ($p > 0.05$) between preoperative (baseline) and postintervention changes on POD5 in the above Spirometric measurements. Hence, the pulmonary function is preserved in children undergoing open abdominal surgery.

## 3. Discussion

Pulmonary function is undoubtedly affected after open abdominal surgery because of the prolonged effects of anesthesia and surgical duration which further lead to PPC. Therefore, POPE might have positive effects on pulmonary function after open abdominal surgery in the pediatric population. Respiratory physiotherapy is widely used to prevent PPC after abdominal surgery. POPE that consists of deep breathing exercises given for 30 min, one day prior to the surgery by physiotherapist helps in minimizing the risk of PPC in patients undergoing abdominal surgery [14]. Individual studies have shown that POPE helps in preserving pulmonary function after open abdominal surgery [4,7,15]. In one study [16], FVC, FEV1, and PEFR were taken as main parameters to assess pulmonary function after open abdominal surgery. On POD1, 2 and 3, there was no significant difference noted ($p > 0.05$), but on POD4 and 5 spirometric values were improved as compared to the preoperative values. In our study, spirometric values were decreased as compared to preoperative values but on POD5, spirometric values were getting improved and approximately equal to the preoperative values. No statistical difference was noted in preoperative and postoperative spirometric values ($p > 0.05$) as displayed in Table 4.

Cardiorespiratory exercise testing is considered as exceptionally important in identification of patients who are at higher risk of PPC [17]. In previous study [8], 6MWT was used along with spirometry used to measure PPC and functional capacity after abdominal surgery. Patients showed highest scores in the experimental group as compared to the control group. There was a significant difference noted between the groups ($p < 0.05$). In our study, there was statistical significant difference noted in 6MWT values between preoperative and POD5 ($p < 0.05$). 6MWT values decreased when compared to preoperative values on POD5 might be due to pain, as shown in Table 4.

There was no such evidence available related to outcome measures such as 10mWT, TUGT and chest expansion reporting functional capacity, risk of fall, balance and chest wall mobility in pediatric abdominal and thoracic surgeries. We used 10mWT, TUGT, 9SCT and chest expansion to measure risk of fall, balance, functional capacity and chest wall mobility in children undergoing open abdominal surgery. In another study [18], the risk of fall was noted in patients with spinal cord injury using 10mWT. The cutoff score of 10mWT was >10 s which predicts the risk of fall in patients with spinal cord injury. In our study, children completed the 10mWT in 15.9 s, which is more than 10 s. There was statistical significant difference noted between preoperative and POD5 10mWT values ($p < 0.05$). We also used TUGT to assess balance before and after surgery. This test was mainly chosen because it has very good correlation with balance [19]. Time taken by healthy children to complete the test ranged from 3.2 s to 6.7 s [20]. In our study, children completed the test from 11.2 s to 13.9 s preoperatively and on POD5, it ranged from 15.2 s to 22.2 s. Children before and after surgery took more time to complete the test mainly because of pain and this is evident from increased TUGT scores ($p < 0.05$).

The stair climbing test was used for assessing functional capacity after surgery. In previous study, seven stair climbing test (7SCT) was performed in patients with Biliary tract surgery pre and postoperatively for measuring functional capacity [21]. We used 9SCT instead of 7SCT, because we anticipated that children are having more functional capacity after surgery as compared to the adult population. Statistical significant difference was noted between pre and POD5 values ($p < 0.05$). Chest expansion is mainly used to assess thoracic mobility and chest wall expansion in patients with abdominal and thoracic surgeries [22]. In one study, chest wall mobility and chest wall expansion were measured in all the three levels (T2, T4, and T10) [23]. We measured chest wall expansion and thoracic mobility in all the three levels using chest expansion test in our study. There was no statistical significant difference noted in chest expansion values between pre and POD5 values ($p > 0.05$). This means that there was no difference in pre and POD5 means and chest expansion were approximately near preoperative level on POD5.

This study is similar to the recent randomized controlled trial performed on 441 adults who had undergone upper abdominal surgery [10]. They have confirmed that POPE has halved PPCs among them and the number needed to treat (7; 95% CI 5 to 14) has been determined [10]. Hence, we have recruited one number more, that is eight ($n = 8$) for the quasi experimental study.

### 3.1. Limitations of the study

The limitation of this study was small sample size and the number of preoperative physiotherapy session; to admit children much earlier was not possible owing to increased hospital cost.

### 3.2. Strength of the study

This is the first study among the pediatric population highlighting the effects of POPE combined with POP in children undergoing abdominal surgery. Though the sample size was small, the study was sufficiently powered (> 90%) which was confirmed by retrospective power analysis.

### 3.3. Future recommendations

Future studies can include two groups. One group can receive POPE combined with POP and the other group can receive POP only to see which is more effective in preserving pulmonary function and functional capacity in open abdominal surgery. Continued research can also target large sample size to see beneficial effects of POPE and POP in children undergoing open abdominal surgery.

## 4. Conclusion

POPE might help in improving pulmonary function and functional capacity in children undergoing open abdominal surgery; thus, this should be confirmed from large sample experimental study.

Supplementary data to this article can be found online at https://doi.org/10.1016/j.jpedsurg.2019.10.058.

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