ORIGINAL RESEARCH　　　　　　　　　　　　　**INTENSIVE CARE**

Comparative study between noninvasive ventilation with continuous positive airway pressure mask versus stacked breathing on chest expansion and pulmonary function in patients with pneumonia

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Abstract

Background: Majority of patients with pneumonia fail the treatment by the noninvasive ventilation (NIV), not because of its low efficacy for maintaining upper airway patency but because of intolerance. The current study was designed to compare the effectiveness of stacked breathing exercise (SBE) versus continuous positive airway pressure (CPAP) mask on the chest expansion and pulmonary functions for patients with pneumonia.

Methodology: A randomized controlled experimental study was conducted in chest ICU in Assiut University Hospital in Egypt and registered at www.clinicaltrials.gov (NCT04576221 identifier). Sixty patients with pneumonia were selected by convenience sampling and randomly assigned into two groups (30 patients each), the patients in SB group received SBE and were instructed to perform the exercise 3 times per day for one week; and the CPAP group received NIV with using CPAP mask. Chest expansion and pulmonary functions were assessed before and after the exercise.

Results: There were significant differences in chest expansion and pulmonary functions between the SB and CPAP groups after exercise in the first day, after 3 days and on the last day of the study (p=0.018, < 0.001 and < 0.001) respectively. Chest expansion and pulmonary functions in the SB group was much improved than those in the CPAP group.

Conclusions: Implementing SB exercise had a significant effect on improving chest expansion and pulmonary functions in patients with pneumonia than NIV with CPAP mask.

Key words: Chest expansion; CPAP mask; Pneumonia; Pulmonary Function; Stacked breathing

1. Introduction

Pneumonia is a frequent complication in critical care patients, with a rate up to 56%.[1] Although oxygen therapy is the cornerstone for pneumonia treatment, its efficacy might be minimized because of shunt effects due to the presence of pulmonary exudate and atelectasis.[1] To improve oxygenation, alveolar

recruitment through the application of either invasive or non–invasive mechanical ventilation (NIV) might be necessary, especially in severe pneumonia.[1]

One method of NIV is continuous positive airway pressure (CPAP) which is to administer fresh oxygen at continuous high pressure to the spontaneously breathing patient. By opening up more alveolar spaces,
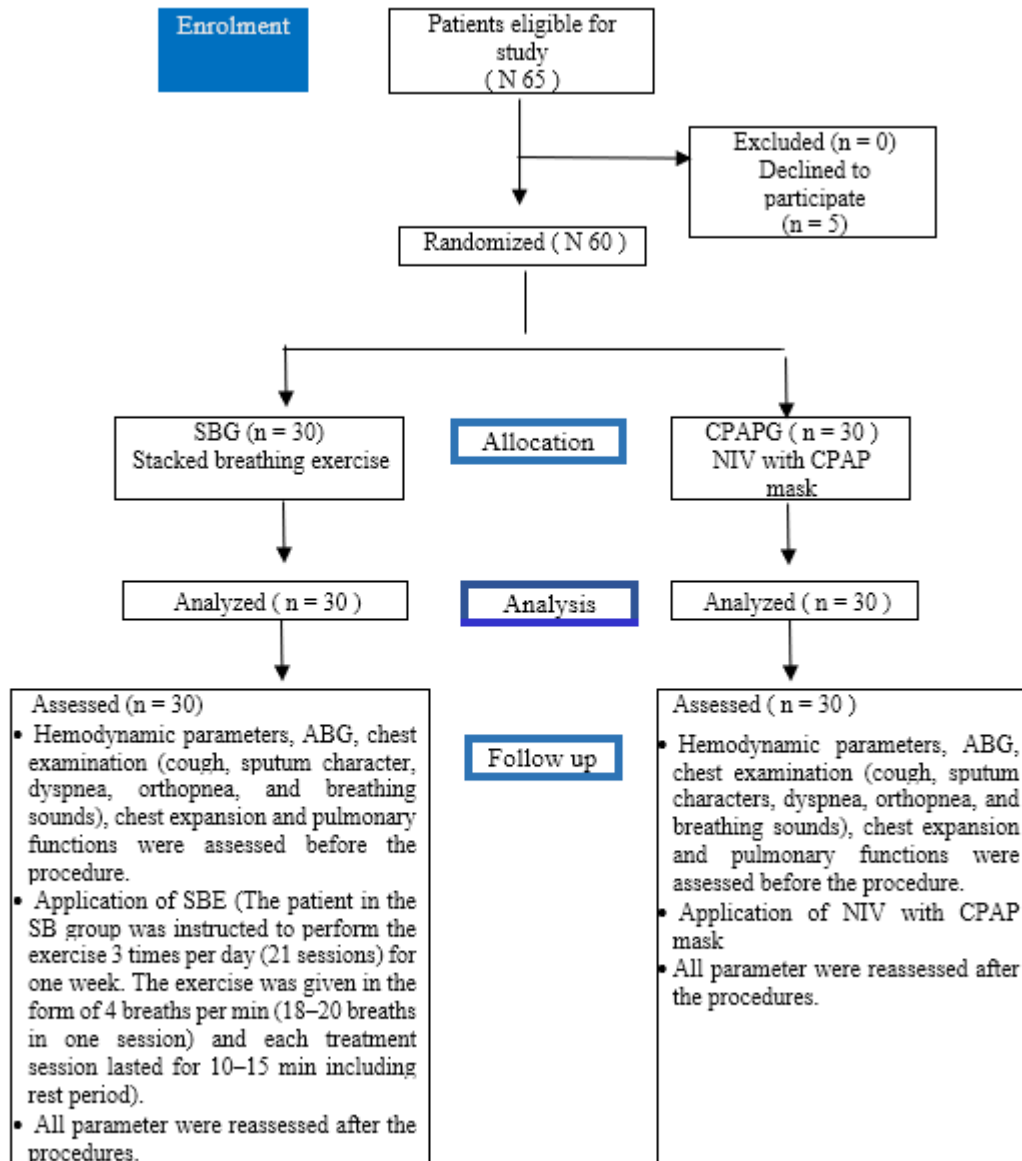

Figure 1: CONSORT flow diagram of randomized controlled trial

NIV treatment for pneumonia has been proven to be effective only in patients with COPD[2] and in immunocompromised patients with lung infiltrates.[3] Lack of strong evidence in literature led international experts to suggest only cautious trials of NIV in well–selected patients with pneumonia and in controlled settings with a clear objective to avoid endotracheal intubation.[4]

CPAP increases the number of functional airways, thereby reducing the total resistance. The success of CPAP therapy is influenced by patient compliance and the level of comfort provided by the CPAP mask and headgear. If the patient is able to tolerate CPAP and uses it correctly, its effectiveness is nearly 100%. The majority of patients fail the treatment not because of its low efficacy for maintaining upper airway patency but because of intolerance.[5]

There are different types of physiotherapy exercises which can benefit the patient with pneumonia and help lung recruitment as CPAP ventilation, but are more tolerable to the patient than CPAP mask. Stacked breathing (SB) is one of the exercises that helps in improving and maintaining the size of the breath that the patient is able to take and can be used regularly to help the patient clear secretions from his chest. It can also be used to help improve the force of the cough and voice.[6]

Objective of study: This study aimed to compare the effect of NIV with CPAP mask versus stack breathing exercise (SBE) on chest expansion and pulmonary function for patients with pneumonia. We hypothesized that chest expansion and pulmonary

Table 1: Comparative hemodynamic parameters in two groups [n = 60; data given as Mean ± SD)]

Hemodynamics	SB Group	CPAP Group	Z	p
Temperature (°C)				
1st day	37.61 ± 0.57	37.65 ± 0.65	−0.195	0.845
3rd day	37.31 ± 0.35	37.32 ± 0.52	−0.398	0.691
7th day	37.22 ± 0.32	37.37 ± 0.48	−1.334	0.182
Heart rate (beats / min)				
1st day	112.5 ± 21.85	109.47 ± 21.91	−0.793	0.428
3rd day	97.1 ± 16.65	103.87 ± 20.91	−1.067	0.286
7th day	95.67 ± 18.29	104.89 ± 18.63	−1.878	0.060
Mean arterial pressure (mmHg)				
1st day	94.73 ± 15.37	85.33 ± 14.22	−2.282	0.022*
3rd day	90.17 ± 13.34	83.9 ± 11.75	−1.816	0.069
7th day	83.37 ± 12.91	83.53 ± 12.12	−0.312	0.755
Respiratory rate (Breaths / min)				
1st day	25.93 ± 6.79	24.23 ± 6.23	−1.309	0.190
3rd day	18.83 ± 4.19	23.47 ± 8.05	−2.478	0.013*
7th day	15.8 ± 3.16	21.63 ± 5.98	−4.178	< 0.001**

*Mann–Whitney Test *Significant difference at $p < 0.05$, **Significant difference at $p < 0.01$*

function in critically ill patients with pneumonia will be significantly improved after implementing SBE.

1. Research methodology

The current study was a prospective single–center randomized parallel group trial registered at www.clinicaltrials.gov (NCT04576221 identifier) carried out in Assiut University Hospital, Chest Intensive Care Unit, between July 2019 and July 2020. The study protocol was approved by Ethics Committee of the faculty of medicine (No.17300332). Ethics of the World Medical Association (Declaration of Helsinki) and written consent was obtained from patients or guidance that participated in the study after explaining the nature and purpose of the study.

1.1.   Patient selection:

All patients, 18–60 years old, diagnosed with pneumonia and have asymmetrical chest expansion were included. Patients with orthopedic condition or a malignant condition or with cognitive impairment were excluded.

To detect an effect size of 0.29 difference in the mean of pulmonary function between the two studied groups, with a p–value < 0.05 and 80% power, confidence level 0.95, a sample size of 20 patients for each group was needed. However, 60 patients were included in this study to avoid drop–outs (30 in each group). This was calculated using G Power 3.1.[7]

Patients were allocated in 1:1 ratio into the two study groups using a web–based randomizer (https://www.randomizer.org/) to generate codes placed within sealed, opaque, sequentially numbered envelopes to assign patients into SB group (SB group) or CPAP group.

1.2.   Data collection:

The data were collected from the first day of admission after stabilization of the patient's condition and extended up to 7 days, every day and in every shift then the data were recorded in the developed tools.

Table 2: Comparative chest examination data on the first day of the study [n = 60; data given as n (%)]

Chest examination	Before exercise			After exercise		
	SB Group	CPAP Group	p– value	SB Group	CPAP Group	p–value
Cough						
Nil	9(30.0)	16(53.3)	0.047*	8(26.7)	16(53.3)	0.105
Dry	6(20.0)	8(26.7)		7(23.3)	5(16.7)	
Productive	15(50.0)	6(20.0)		15(50.0)	9(30.0)	
Cough force						
Forceful	0(0.0)	0(0.0)	0.067	19(63.3)	2(6.7)	< 0.001**
Weak	21(70.0)	14(46.7)		3(10.0)	12(40.0)	
Sputum color						
Nil	18(60.0)	19(63.3)		13(43.3)	21(70.0)	
Yellowish	5(16.7)	5(16.7)	0.842	8(26.7)	5(16.7)	0.106
Whitish	7(23.3)	5(16.7)		9(30.0)	4(13.3)	
Dyspnea	29(96.7)	21(70.0)	0.006**	7(23.3)	24(80.0)	0.001** >
Orthopnea	22(73.3)	18(60.0)	0.273	6(20.0)	20(66.7)	0.001** >
Pain with breathing	16(53.3)	14(46.7)	0.606	9(30.0)	12(40.0)	0.417
Wheezing	18(60.0)	10(33.3)	0.038*	8(26.7)	10(33.3)	0.573
Crepitation	8(26.7)	4(13.3)	0.197	1(3.3)	6(20.0)	0.044*
Bronchospasm	5(16.7)	6(20.0)	0.739	0(0.0)	3(10.0)	0.076

Chi–square test, * Significant difference at p. value < 0.05, **Significant difference at p. value < 0.01.

1.3. Instruments and measurements

Three tools were used in this study:

The first tool was patient assessment sheet which was developed by the researcher and used to monitor hemodynamic parameters, assessment of respiratory system, assessment of laboratory findings, and fluid balance in addition to socio–demographic and medical data.

Assessments of hemodynamic parameters system included (Mean arterial pressure (MAP), heart rate (HR), temperature and CVP readings) and laboratory findings every day.

Assessment of chest condition included assessment of respiratory rate, cough (dry or productive, forceful or weak), and sputum characteristics: (amount, viscosity and color), dyspnea, orthopnea, pain with breathing and also assessment of sputum and blood culture. Auscultation of the chest for breath sounds and determines if there is abnormal breathing e.g.

wheezing, bronchospasm, crepitation etc. in every shift.

The first tool also included assessment of chest expansion originated from Kakizaki et al, 1999[8] by using a measuring tape (marked in mm). Basal expansions were determined by using a tape measure. Each measurement was obtained after maximal expiration followed by maximum inspiration and another maximal expiration. Measurements were taken three times and the mean of the three values was recorded.

The first tool also included assessment of pulmonary functions with Sabrasez breath holding test; patient was asked to take a full but not too deep breath and hold it as long as possible and cardiopulmonary reserve and volume capacity were evaluated.

The second tool was pneumonia treatment sheet which was developed by researcher and used to assess procedures done like NIV with CPAP mask or SBE.[11]

Table 3: Comparative chest examination data after 3 days of the study [n = 60; data given as n (%)]

Chest examination	Before exercise			After exercise		
	SB Group	CPAP Group	p– value	SB Group	CPAP Group	p–value
Cough						
No	14(46.7)	16(53.3)		14(46.7)	17(56.7)	
Dry	5(16.7)	4(13.3)	0.864	4(13.3)	1(3.3)	0.352
Productive	11(36.7)	10(33.3)		12(40.0)	12(40.0)	
Cough strength						
Forceful	9(30.0)	4(13.3)	0.274	15(50.0)	5(16.7)	0.005**
Weak	7(23.3)	10(33.3)		1(3.3)	8(26.7)	
Sputum color						
Yellowish	3(10.0)	4(13.3)	0.919	2(6.7)	4(13.3)	0.686
Whitish	8(26.7)	8(26.7)		9(30.0)	8(26.7)	
Dyspnea	8(26.7)	24(80.0)	< 0.001**	1(3.3)	23(76.7)	< 0.001**
Orthopnea	4(13.3)	18(60.0)	< 0.001**	0(0.0)	19(63.3)	< 0.001**
Pain with breathing	4(13.3)	11(36.7)	0.037*	1(3.3)	9(30.0)	0.006**
Wheezing	5(16.7)	15(50.0)	0.006**	0(0.0)	12(40.0)	< 0.001**
Crepitation	2(6.7)	5(16.7)	0.228	0(0.0)	5(16.7)	0.020*
Bronchospasm	2(6.7)	5(16.7)	0.228	1(3.3)	2(6.7)	0.554

Chi–square test, * Significant difference at p < 0.05, **Significant difference at p < 0.01.

The third tool was patients' outcomes evaluation sheet which was developed by the researcher and used to assess the effect of SBE and NIV with CPAP mask on chest expansion, pulmonary functions and complications e.g., pulmonary complications as pulmonary edema, bronchitis, pulmonary embolism, respiratory failure ...etc. and general complications such as acute renal failure, liver failure, and multi–organ failure etc.

Circumferential measurements were performed with a tape measure, and anteroposterior and transverse measurements using caliper. Measurements were performed three times by the same researcher and mean recorded. At circumferential measurement by tape measure; the difference between deep inspiration and deep expiration was determined by measuring chest circumferences at the level of the fourth intercostal space. For anteroposterior measurement, the front tip of the caliper was placed on the xiphisternal junction. For transverse measurement, the calipers were placed on either side of the virtual line passing through the same junction.[8] Before and

after the intervention, bed–side pulmonary function tests were done by using a spirometer.[9]

SB group received breath stacking technique explained by (Providence Care, 2008)[6] as it was done in a sitting position or semi–sitting position. If sitting: rest against the back of a chair and keep the patient's shoulders, arms and hands relaxed. By using the mouthpiece of the ambo bag, the lips were placed tightly around the mouthpiece to create a tight seal and the patient was instructed to take a deep breath and hold that breath and attention was paid to possible leaks between the mouthpiece and the mouth then the bag was squeezed gently, stacking another breath on top of the first and taking more air in.

Taking in even more air as the bag was squeezed again. The bag was squeezed 2–5 times until the patient felt that the lungs are full of air, the patient should feel a stretch across the front of his/her chest and the patient was instructed to hold the air in as long as he was comfortable then the mouthpiece was removed and the patient was instructed to hold the breath for 3–5 sec

Table 4: Comparative chest examination data on the last day of the study [n = 60; data given as n (%)]

Chest examination	Before exercise			After exercise		
	SB Group	CPAP Group	p–value	SB Group	CPAP Group	p–value
Cough						
No	25(83.3)	18(60.0)	0.126	25(83.3))	18(60.0)	0.134
Dry	3(10.0)	6(20.0)		2(6.7)	5(16.7)	
Productive	2(6.7)	6(20.0)		3(10.0)	7(23.3)	
Cough strength						
Forceful	4(13.3)	6(20.0)	0.078	5(16.7)	6(20.0)	0.027*
Weak	1(3.3)	6(20.0)		0(0.0)	6(20.0)	
Sputum color						
Yellowish	0(0.0)	2(6.7)	0.226	0(0.0)	3(10.0)	0.125
Whitish	2(6.7)	4(13.3)		2(6.7)	4(13.3)	
Dyspnea	1(3.30	18(60.0)	< 0.001**	0(0.0)	17(56.7)	< 0.001**
Orthopnea	0(0.0)	10(33.3)	0.001**	0(0.0)	9(30.0)	0.001**
Pain with breathing	0(0.0)	4(13.3)	0.038*	0(0.0)	3(10.0)	0.076
Wheezing	1(3.3)	9(30.0)	0.006**	0(0.0)	8(26.7)	0.002**
Crepitation	0(0.0)	2(6.7)	0.206	0(0.0)	2(6.7)	0.150
Bronchospasm	1(3.3)	5(16.7)	0.126	0(0.0)	2(6.7)	0.150

Chi–square test, *Significant difference at $p < 0.05$, **Significant difference at $p < 0.01$.

Table 5: Comparative chest expansion in two groups (n = 60; Data given as Mean ± SD)

Chest expansion	SB Group)	CPAP Group	Z	p–value
1st day of the study				
Before Exercise	0.88 ± 0.4	0.92 ± 0.4	−0.379	0.705
After Exercise	1.3 ± 0.43	1.01 ± 0.43	−2.361	0.018*
After 3 days of the study				
Before Exercise	1.49 ± 0.42	1.22 ± 0.4	−2.451	0.014*
After Exercise	1.89 ± 0.32	1.24 ± 0.38	−5.275	< 0.001**
on the last day of the study				
Before Exercise	2.03 ± 0.29	1.46 ± 0.41	−4.744	< 0.001**
After Exercise	2.35 ± 0.26	1.57 ± 0.39	−5.951	< 0.001**

Mann–Whitney test *significant difference at $p < 0.05$, **significant difference at $p < 0.01$

before gently exhaling. If phlegm was present, the patient was instructed to try to produce a forceful cough.

The patients in the SB group were instructed to perform the exercise 3 times per day (21 sessions) for one week. The exercise was given in the form of 4 breaths per min (18–20 breaths in one session) and each treatment session lasted for 10–15 min including a rest period.

The patients in the CPAP mask group received NIV with the CPAP mask for a week. A full–face mask was tried first. The CPAP was started at 4 cmH$_2$O and gradually increased to reduce hypoxia, by approximately 5 cmH$_2$O every 10 min, until a therapeutic response was achieved and was not exceeded above 25 cmH$_2$O at any point and achieved a good seal with the NIV mask.

2. Results

2.1. Hemodynamic monitoring

There was no statistically significant difference between the two groups regarding the parameters of hemodynamic monitoring except MAP on the first day

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Table 6: Comparative pulmonary functions in two groups [n = 60; data given as n (%)]

Pulmonary functions	Before Exercise			After Exercise		
	SB Group	CPAP Group	p–value	SB Group	CPAP Group	p–value
1st day of the study						
Limited CPR (L)	17(56.7)	16(57.1)	0.908	19(63.3)	16(57.1)	0.007**
Very poor CPR (L)	13(43.3)	13(46.4)		5(16.7)	13(46.4)	
Normal	0(0.0)	0(0.0)		6(20.0)	0(0.0)	
Volume capacity[®]	2066.67 ± 430.18	1913.79 ± 329.2	0.157	2366.67 ± 413.84	1982.76 ± 365.54	0.001**
MBC > 60 L/min & FEV1 > 1.6 L	16(53.3)	16(57.1)	0.771	26(86.7)	20(71.4)	0.101
After 3 days of the study						
Limited CPR (L)	19(63.3)	18(64.3)	0.006**	8(26.7)	21(75.0)	< 0.001**
Very poor CPR (L)	4(13.3)	11(39.3)		0(0.0)	6(21.4)	
Normal	7(23.3)	0(0.0)		22(73.3)	2(7.1)	
Volume capacity[®]	2533.33 ± 472.22	2155.17 ± 403.19	0.002**	2933.33 ± 388.04	2310.34 ± 410	< 0.001**
MBC > 60 L/min & FEV1 > 1.6 L	29(96.7)	21(75.0)	0.010*	28(93.3)	22(78.6)	0.062
On the last day of the study						
Limited CPR (L)	6(20.0)	15(53.6)	< 0.001**	0(0.0)	15(53.6)	< 0.001**
Very poor CPR (L)	0(0.0)	5(17.9)		0(0.0)	0(0.0)	
Normal	24(80.0)	7(25.0)			12(42.9)	
Volume capacity[®]	3000 ± 371.39	2518.52 ± 489.93	< 0.001**	3383.33 ± 252	2703.7 ± 541.71	< 0.001**
MBC > 60 L/min & FEV1 > 1.6 L	30(100.0)	24(85.7)	0.061	29(96.7)	24(85.7)	0.251

*Mann–Whitney test; *significant difference at p < 0.05, **significant difference at p < 0.01, [®] Mean ± SD*
CPR: Cardiopulmonary reserve FEV1: Forced expiratory volume in the first second.
MBC: Maximum breathing capacity

of the study and respiratory rate on the third day and on the last day of the study. Regarding MAP, there was statistically significant difference between SB and CPAP groups (p=0.022). As regard to respiratory rate, there was statistically significant difference between SB and CPAP groups after three days and on the last day of the study (p=0.013 and 0.001) respectively (Table 1).

2.2. Comparison of chest examination

There was statistically significant difference between SB and CPAP groups regarding dry cough, dyspnea and wheezing as results show that p=0.047, p=0.006 and p=0.038 respectively Table 2. After the exercise on the first day of the study, it was noticed that there was statistically significant difference between the two

studied groups regarding cough strength, dyspnea, orthopnea and crepitations as results show that p ≤ 0.001, p ≤ 0.001, p ≤ 0.001 and p=0.044 respectively (Table 2).

Before the exercise after three days of the study. It was noticed that there was statistically significant difference between the two studied groups in relation to dyspnea, orthopnea, pain with breathing and wheezing (p ≤ 0.001, p ≤ 0.001, p=0.037 and p=0.006 respectively) (Table 3). After exercise after three days of the study, there was statistically significant difference between SB and CPAP groups regarding cough strength, dyspnea, orthopnea, pain with breathing, wheezing and crepitations (p = 0.005, p ≤ 0.001, p ≤ 0.001, p ≤ 0.001 and p=0.020) respectively (Table 3).

Before the exercise on the last day of the study, there was statistically significant difference between SB and CPAP groups regarding dyspnea, orthopnea, pain with breathing and wheezing (p= < 0.001 & p=0.001 & p=0.038 & p=0.006) respectively (Table 4). After the exercise on the last day of the study, there was statistically significant difference between SB and CPAP groups regarding cough strength, dyspnea, orthopnea and wheezing (p=0.027 & p=< 0.001 & p=0.001 & p=0.002) (Table 4).

2.3.   Comparison in chest expansion

Results show that there was a high statistically significant difference between the two groups in relation to chest Comparison of pulmonary functions

Results show that there was a significant statistical difference between the two groups regarding the majority parameters of pulmonary function (CPR & VC) after exercise on the first day of the study (p=0.007 & p=0.001) respectively (Table 6). Also results show that there was a high statistically significant difference between the two groups before and after exercise after three days of the study and on the last day of the study (Table 6).

3. Discussion

The results obtained in this study indicated that there was a significant increase in chest expansion and pulmonary function in the SB group than the CPAP group. It means that SBE was more effective than NIV with using a CPAP mask.

3.1.   Chest Expansion:

There was a significant improvement of chest expansion in the SB group than CPAP group after exercise as results showed that there was statistically significant difference between SB and CPAP groups on the first day of the study and there was highly statistically significant difference between SB and CPAP groups regarding chest expansion after exercise after three days of the study and on the last day of the study. This in line with study done by Komal and Subin et al. (2016) [11]concluded that patients with pneumonia undergoing chest mobility exercises with incentive spirometer had shown statistically significant increase in chest expansion.

The physiological mechanism for the increase in chest expansion in SB group is probably due to effect on the stretch reflex mechanism. Quick stretch on the external intercostal muscles leads to facilitation of their contraction that assists in inspiration which leads to chest expansion.[11] It helped in increasing inspiratory capacity; and during expiration it helped in full expiration there by helping the patient to relax comfortably.

3.2.   Bedside pulmonary function tests:

There was a significant improvement of pulmonary function in the SB group than the CPAP group after exercise as results showed that there was a high statistically significant difference between the groups on the first day, after three days and on the last day of the study regarding Cardiopulmonary Reserve (CPR) and Volume capacity (VC).

3.3.   Volume Capacity (VC):

Pneumonia is a restrictive respiratory disease characterized by difficulty in inspiration which may be because of abnormality in the lungs or the pleural cavity or the patient may be unable to inhale due to a collapsed lung or restricted lung expansion. So in this condition the volume capacity is reduced.[12]

In the SB group there was a significant increase in volume capacity because the lungs are expanded appropriately and the walls of alveoli are stretched to the maximum. Vikram and Kamaria (June 2012)[13] conducted a study on the effect of intercostal stretch on pulmonary function parameters and they stated that the use of manual stretching procedures has become more established in cardiorespiratory physiotherapy to improve pulmonary functions. The results of the study showed that FEV1 in the SB group significantly improved than in the CPAP group, which means intercostal stretch increased lung volume and leads to lung function improvement. This is in line with the results of the current study which showed that there was a statistical significant difference between both groups after three days of the study and on the last day of the study regarding CPR, which reflects that there was more improvement in pulmonary function in SB group than CPAP group.

4. Conclusions

Based on the results of this study, we conclude that implementing stacked breathing exercise has significant effect on improving chest expansion and pulmonary functions for patients with pneumonia as compared to non-invasive ventilation with the CPAP mask.

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6. Conflict of interest:

The authors declare that they have no conflict of interest.

7. Authors' contributions:

AT: Study design and concept
AM: Conducted the study, Literature review and writing the draft
AA: Data collection
GS: Statistical analysis

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