Effect of breath stacking on respiratory efficiency, airway clearance and cough intensity in mechanically ventilated patients

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Abstract:

Background: The efficiency of physiotherapy maneuvers for respiratory disorders has not been proven because it depends on the proper performance of therapists and the patients' collaboration. Bag squeezing which is done with manual breathing unit (MBU) is a technique that is often studied. **Aim of the study:** to assess the effect of breath stacking technique on respiratory efficiency, airway clearance and cough intensity in mechanically ventilated patients. **Materials and Method: Research design:** A research design based on a quasi-experimental approach. **Settings:** This study was carried out at 2 ICUs at Alexandria Main University hospital. **Subjects:** A convenience sample of 80 critically ill patients was selected. **Tools of the study:** two tools were used in this study. **Tool I: Patient respiratory efficiency assessment:** it was used to assess patients' respiratory efficiency; it consisted of four parts. *Part I:* Patient characteristics and clinical data. *Part II:* Respiratory clinical parameters assessment. *Part III:* physiological parameters**.** *Part IV:* assessment of airway clearance. **Tool II: Cough reflex intensity scale:** to assess cough strength. **Methods:** Two groups (group A and group B) were used to divide the subjects of the study. The patients in group A were subjected to breath stacking technique and chest physiotherapy (CPT), while those in group B were received CPT. The researcher assessed patient respiratory efficiency and cough reflex intensity before, immediately after and after 60 mins of performing interventions. **Results:** it was found that the number of patients in the BS group who had no cough increased from more than half to seven patients after intervention. Simultaneously, the number of patients who had weak audible cough increased from 11 to 20, those with clear audible cough increased from 1 to 8, and others with strong cough increased to 5 with significant difference between groups in relation to cough strength. **Conclusion:** Stacked breathing technique is notably effective in enhancing cough intensity and airway clearance, thereby promoting respiratory efficiency.

Key words: breath stacking, respiratory efficiency, airway clearance, cough intensity, mechanically ventilated patients

Introduction:

Respiratory muscle weakness is a potentially fatal condition that affects critically ill patients (**Vanhorebeek et al., 2020)**. According to **Bissett et al., 2020** respiratory muscle weakness affects approximately 63% of patients in intensive care units. Not only does atrophy and subsequent diaphragm dysfunction contribute to weakening of the respiratory muscles, which is linked to significant morbidity in the ICU, but the extra-diaphragmatic both the inspiratory and expiratory muscles have a significant impact **(Bureau et al., 2023)**.

The efficiency of coughing, which clears the airways from secretion and shields patients from respiratory complications is regulated by the strength or weakness of the respiratory muscles. **(Sykes & Morice 2021)**. Breathing becomes harder, the respiratory pump fails, and gas exchange is hampered by respiratory muscle weakness, decreased lung volume, and increases in respiratory elastance and resistance. When lung or chest wall dysfunction impairs ventilation, gas exchange and respiratory failure results however, extended the use of mechanical ventilation, and respiratory muscle weakness are connected to a higher chance of extubation failure and an extended period of ventilator dependence **(Patel 2022 et al., Bissett et al., 2020)**.

Chest physiotherapy (CPT), a technique aimed to clear airway secretions that facilitates lung expansion, fortifies respiratory musculature, and mitigates airway obstruction along with its associated complications, such as atelectasis and hyperinflation. Components of chest physical therapy encompass vibration, suctioning, postural drainage, percussion, deep breathing exercises, and mobilization. Currently, a paramount approach within the realm of chest physical therapy is the breath stacking technique **(Belli et al., 2021).**

The technique of bag squeezing and manual hyperinflation utilizing an AMBU, commonly referred to as the breath stacking technique, involves the generation of an increase in inspiratory volume, thereby facilitating the expansion of collapsed pulmonary units; in addition, it enhances expiratory flow through the elastic recoil of the thoracic cage, thus aiding in the mobilization of secretions **(Valer et al., 2022)**. This technique, known as breath stacking, is also referred to as lung volume recruitment (LVR), manual or mechanical insufflation/exsufflation, and cough augmentation techniques **(Cleary et al., 2021)**.

The breath stacking (BS) plays an important role in increasing lung capacity, treating and preventing atelectasis, improving cough efficiency, and reducing mucus retention. As a result, BS may diminish the occurrence of respiratory infections and the likelihood of respiratory failure, improve gas exchange, improve lung compliance, reduce hospital stays and reduce costs for patients, reduce mortality and morbidity, and thus enhancing the overall quality of life of patients (**Sheers et al., 2023)**.

Breath stacking is classified as a manually assisted cough (MAC) technique. In MAC, once maximal respiratory stacking is achieved and glottic became opening and cough is timed with abdominal thrusts or lateral rib compressions. Additionally, MAC utilizes abdominal thrusts to increase expiratory flow. Abdominal compression creates a sudden increase in abdominal pressure. This results in abdominal contents pushing up against the diaphragm, resulting in an increase in expiratory flow **(Rose et al., 2019)**. Critical care nurses play a key role in improving clinical airway performance once patients are placed on a ventilator. Therefore, this study was conducted to evaluate the effects of the BS technique on respiratory efficiency, airway clearance, and cough intensity in mechanically ventilated patients.

Aim of the study:

This study aimed to assess the effect of breath stacking technique on respiratory efficiency, airway clearance and cough intensity in mechanically ventilated patients.

The hypotheses of this study were:

H0: there was no difference between mechanically ventilated patients who were subjected to breath stacking technique and chest physiotherapy in relation to its effect on respiratory efficiency, airway clearance and cough intensity than who was subjected to chest physiotherapy.

H1: mechanically ventilated patients who were subjected to breath stacking technique and chest physiotherapy had an improvement in respiratory efficiency, airway clearance and cough intensity more than those who were subjected to chest physiotherapy.

H2: mechanically ventilated patients who were subjected to chest physiotherapy had an improvement in respiratory efficiency, airway clearance and cough intensity more than those who were subjected to breath stacking technique and chest physiotherapy.

Operational definition: Respiratory efficiency in this study including normal arterial blood gases and respiratory parameters.

Subjects and methods:

Research design: A research design based on a quasi-experimental approach in such quasi-experimental designs the assignment of participants was based on selection by researcher while subjects cannot be randomly assigned to the study for practical or ethical reasons. Then, the selected subject was randomly allocated in either control or intervention group.

Settings: This study was carried out at 2 ICUs at Alexandria Main University hospital the casualty care unit (unit I), and the general ICU (unit III). The casualty care unit consists of two rooms with four beds each. The general ICU consists of two main halls with seven beds each.

Subjects: A purposive sample of 80 critically ill patients was selected by the power analysis program EPI-info7 calculated an expected population of 100 in three months with a 5% acceptable error, a confidence coefficient of 95%, and a frequency of 50%. Patients who were match the inclusion criteria was equally assigned to two groups group A and group B.

Randomization was applied by using a simple random method (folded paper) for the two groups. The patients in group A were subjected to breath stacking technique and CPT, while those in group B was received CPT. The patient with the following criteria was included in this study: Adult patient (aged ≥18 years≤65 years old), Mechanically ventilated conscious patients, patients with cough reflex intensity score grade one or two, patient with the following parameters: heart rate ≥60 b or ≤100 b/min, blood pressure ≥ 90/60 or ≤150/90 mmHg, central venous pressure ≥ 6 or ≤ 15 cmH2O, respiratory rate ≥12 cycle/min or ≤ 22 cycle/min, temperature ≥ 36.5◦C or ≤ 37.5◦C. Patient with the following criteria will be excluded from the study; patient on sedation, patients who were contraindicated for breath stacking; undrained pneumothorax, severe bronchospasm, rib fracture, obese patients, patients who were contraindicated for abdominal thrust ; pregnant patients, recent abdominal surgery, obese patients, and hyperglycemic patients (RBG ≥ 200 mg/dl) and hyperglycemic patients (RBG ≥ 200 mg/dl).

Tools of the study: This study utilized two tools.

Tool I: Patient respiratory efficiency assessment: This tool was created by the researcher after reviewing the related (**Fernandes et al., 2022, Charu et al., 2023, Magni et al., 2024, Oliveira et al., 2023, &Reyes et al., 2020)** to assess patients' respiratory efficiency after breath stacking technique, it consists of four parts.

Part I: Patient demographic characteristics and clinical data.

This part included demographic characteristics such as age, sex, clinical data included vital signs, level of consciousness using four score scale, past medical and surgical history, current diagnosis, and prescribed medications.

Part II: Respiratory clinical parameters assessment.

This part was used to record physiologic response before and after the application of stacked breathing technique and chest physiotherapy (CPT) which included the following:

- **Oxygenation status parameters** included arterial blood gases (ABG), peripheral oxygen saturation (Spo_2) which was measured by pulse oximeter of bedside monitor, oxygen concentration percent and duration.
- **Mechanical ventilator data** included tidal volume (V_t), peak airway pressure (PIP), plateau airway pressure (P_{plat}), mean airway pressure (M_{PAW}) it was calculated by following formula [M_{PAW} = (inspiratory time x frequency) / 60 x (PIP – PEEP) + PEEP}, static compliance (C_s) it was calculated by following formula [C_s=V_t / (Plateau airway pressure - PEEP)], dynamic compliance (C_{dyn}) it was calculated by following formula [C_{dyn} = V_t / (Peak airway pressure – PEEP)], minute ventilation (VE) it was calculated by following formula [VE= V_t × RR], and duration of mechanical ventilation in days.

Part III: Physiological parameters included respiratory assessment (respiratory rate and breathing sound), heart rate, blood pressure (systolic and diastolic blood pressure), main arterial pressure (MAP) = DP + 1/3(SP – DP), and body temperature.

Part IV: assessment of airway clearance included assessment of breath sound for quality of air entry for both right and left side of chest and measurement of suctioned sputum in milliliter. Breath sounds were scored with 1 if present and 0 if diminished.

Tool II: Cough reflex intensity scale: this tool was adopted from **Li et al., 2023 and Jia et al., 2021** which is valid and reliable for critically ill patients to assess cough strength. It included four grades grade I (no cough), grade II (weak audible cough), grade III (clear audible cough), and grade VI (strong loud cough).

Methods:

- After explaining the study's objective, the administrative authorities of the previously mentioned setting gave permission to conduct the study.
- The research was approved by the faculty of medicine, Alexandria university research Ethics Committee (no. 0307101)
- Five experts in critical care nursing conducted a check on the validity of the content.
- Reliability of the patient respiratory efficiency assessment tool (tool I) was tested using Cronbach's Alpha test and result was 0.93%.
- To assess the clarity, applicability, and feasibility of the study, a pilot study was conducted on 8 patients (10%) of the sample.
- **Data collection was done as follows:** This study included all mechanically ill patients admitted to the previously mentioned unit who fulfilled the inclusion criteria and consented to be enrolled. The study subjects were being randomized and equally assigned to two groups (group A and group B), each consisted of 40 patients.

For both groups:

- Demographic and clinical data of both groups was obtained by using **tool I Part I,** the consciousness level (by four score) using **Part I of tool I.**
- Cough reflex intensity scale, breath sounds for quality of air entry, amount of suctioned sputum, physiological parameters, mechanical ventilator data and oxygen status parameters were assessed for every patient immediately before, immediately after interventions then after 60-minutes of performing breath stacking and chest physiotherapy.
- Cough was semi -objectively evaluated by the researcher using cough reflex intensity scale **(tool II)** in the presence of two nurses and the final score was determined according the decision of two person versus one. The safety of conventional chest physiotherapy and BS techniques is being investigated, the researcher assessed the physiological parameters; respiratory rate, heart rate, blood pressure **(tool I, Part II)** before interventions as a baseline and stopped the session if there was any change in physiological parameters by 20% from the baseline after implementation of any intervention.
- Conventional chest physiotherapy (CPT) was done by the researcher for both groups as follows; (postural drainage, positioning, chest percussion, chest vibration, and suctioning).
- **Postural drainage** technique was provided by the researcher as follows: position the patient in the left, right, head down, or Trendelenburg positions according to the affected lobe, each position will be maintained for approximately 10 minutes.
- **Chest percussion:** technique was provided as follows: position the patient according to the affected lobe, during the technique, place a folded towel over the patient ' s chest, cup the hand as if to hold water, palm facing downward, and keep the wrist and forearm as relaxed as possible and Percuss the chest wall rhythmically while applying moderate force to the ribs, on the sides of the chest, and on the sides of the back. Each tap should make a hollow sound and be applied for a period of 3-5 minutes for a session.
- **Chest vibration:** the technique was given by placing the patient with their affected lung on top, placing a folded towel over their chest, and firmly placing both hands over the chest wall to be treated, then when the patient breathes out, they should experience a fine shaking movement by tightening the muscles in their forearm and applying moderate downward pressure to the chest and applied for a period of 3-5 minutes for a session.
- In addition to the previous intervention **group A** was received manual-assisted stacked breathing technique as follows:
- The researcher disconnected the patient from ventilator then, attached the patient's endotracheal tube adaptor to the manual resuscitation bag (MRB) with one-way valve. The researcher squeezed the MRB slowly and twisted it to deliver greater airflow into the patient's lungs and held the bag at the end of inspiration for up to 2-3 seconds breaths without breathing out. This sequence was repeated for 2-3, using 'OK' sign to communicate with the

patient once the patient feels their lungs are full, as indicated by the sign. After that, the researcher removed the resuscitation bag and allowed the patient to exhale or cough timed with abdominal thrust.

- Abdominal thrust provided by the researcher as follows: placed his index fingers on the patient's hip bones and slid his thumbs towards the belly button, then placed the heel of one hand one inch above the belly button and place the other hand on top of the first hand, interlocked his fingers with straight elbows and fingers pointed away from the chest. The researcher followed the patient's breathing for mechanically ventilated patients and at the start of expiration applied one quick forceful push inward and upward through the abdomen and asked the patient to cough strongly.
- The previous steps were repeated for 3-5 cycles of breath-stacking for a period of 10 minutes with a break every 5 minutes and any secretions were removed by suctioning.
- The conventional chest physiotherapy interventions alone or combined with stacked breathing technique were performed by the researcher in the form of twice sessions a day for three days and each session lasted for 45-60 minutes.
- The appropriate statistical analysis was used to compare the outcomes between the two groups after the completion of the study.
- Using the appropriate statistical tests the collected data was analyzed included; F test (ANOVA) with repeated measure, partial eta squared, student t-test, and Chi square test to assess the effect of stacked breathing techniques on respiratory function of critically ill patients.

Ethical consideration:

Following an explanation of the study's purpose and an assurance that the data collected would only be used for the study, the relatives who were included in the study provided written informed consent. They were made aware that the patient could leave the study at any moment. the researcher guaranteed the upkeep of namelessness of the subject information employing a code number. the researcher the maintenance of confidentiality of the subject data using a code number. Patients' privacy ensured regarding the collected data was maintained during the implementation of the study.

Results:

Table I shows that 35% of the patients in the study were female, whereas 65% were male in both groups; 37.5% of patients in the CPT group and 47.5% in BS were aged over 50-60 years. Regarding patients' diagnoses, 70% of patients in the BS group and 67.5% in the CPT group experienced respiratory disorders. Furthermore, the mean BMI was 36.3 in the BS group and 42.8 in the CPT group. Additionally, there was no notable distinction between the two groups.

A comparison of the mean changes in physiological parameters between the studied groups can be observed in **Table II**. In the BS group, respiratory rate decreased significantly from 21.6 - 20.9 c/m after 60 mins ($p=0.005$). Furthermore, there was significant difference between group ($p= 0.009$). Considering heart rate, it diminished significantly from 93.3 – 88.5 b/m after 60 mins ($p=0.000$). It is evident that body temperature decreased significantly in the BS group from 37.5^{o}c to 37.3^{o}c ($P = 0.006$), but there was no significant difference between both groups.

Table III displays the mean differences in oxygen levels for the studied groups. In the BS group, there was a notable significant increase in Sao2 from 95.5 to 96.5 after 60 mins ($p=0.000$). Correspondingly the peripheral oxygen saturation levels (SPO_2), significantly rose from 95.7 to 96.8 after 60 mins ($p=0.001$). It can be observed that the fraction of inspired oxygen (FiO2) decreased significantly in the BS group from 41.4 to 40.4 ($P = 0.001$). Additionally, there was insignificant difference between the studied groups in all previously mentioned parameters.

Table IV presents the mean changes in ventilator data for the analyzed groups. In the BS group, there was a significant increase in Vt from 484.7 to 613.3 ($p < 0.00$) and insignificant in VE from 10399.4 to 11210.9 after 60 mins. Furthermore, significant difference in Vt and VE between the groups was observed after 60 mins of the intervention (p = 0.040,0.039) respectively. Regarding PIP, there was a significant decrease from 20.88 to 19.25 after 60 mins (P = 0. 001) In addition, there was significant difference between groups after 60 mins (P = 0.047). It can be observed that the static compliance (C_{stat}) increased significantly in the BS group from 65.91 to 82.41 (P = 0.001), without significant difference between the two groups.

Referring to **table V**, the number of patients in the BS group who had no cough increased from more than half (28 patients) to seven patients after 60 mins of the intervention. Simultaneously, the number of patients had weak audible cough increased from 11 to 20, those with clear audible cough increased from 1 to 8, and others with strong cough increased to 5 with statistically significant difference observed ($P < 0.001$). Moreover, there was significant difference between groups immediately after and after 60 mins (p=0.044, <0.001) respectively.

As proved in **table VI**, the percent of patients with diminished air entry decreased significantly from 40% to 20% (p=0.001). Moreover, there was a significant difference between groups after 60 minutes of performing interventions. In addition, the percent of patients who did not produce sputum while suctioning in BS group decreased significantly from 82.5% to 50% (p=<0.001) and in CPT decreased from 92.5% to 77.5%. Furthermore, there was significant difference between groups immediately after and after 60 minutes (P= 0.04, 0.01) respectively. Also, it was noted that the mean amount of sputum in BS group increased significantly from 42.87 ml to 78.79 ml (p=<0.001) and it increased significantly in CPT grom from 43.81 ml to 62.01 ml (p=<0.001). Furthermore, there was significant difference between groups after 60 minutes (p= 0.002).

As shown in **table VII**, the number of patients who successfully weaned in the BS group was 21, compared to 14 for the CPT group. In addition, there were 27 patients who did not re- intubate in the BS group, compared to 19 for the CPT group, with a statistically significant difference ($P < 0.05$). As a result, there was a significant difference between groups in the duration of mechanical ventilation, with the mean duration in the BS group being 4.8 days as compared with 7.3 in the CPT group (p=005).

Table I: Distribution of the studied groups according to clinical data (n=40):

Patient clinical data	BS group (n=40)		CPT group (n=40)		Test of sig. χ^2	P
	No.	%	No.	%		
Age					1.022	^{MC}p = 0.83
18 – 30	4	10	4	10		
>30-40	7	17.5	8	20		
>40-50	10	25	13	32.5		
>50 - 60	19	47.5	15	37.5		
Sex						
Male	26	65	26	65	0	1
Female	14	35	14	35		
Current diagnosis ≠						
Cardiovascular disorder	4	10	1	2.5	1.92	0.36
Respiratory disorder	28	70	27	67.5	2.15	0.11
Neurological disorder	13	32.5	19	47.5	1.88	0.25
Endocrine disorder	1	2.5	1	2.5	0	1
Renal disorder	3	7.5	9	22.5	3.53	0.12
BMI					**t =**	
Mean± SD	36.36 ±10.29		42.83 ±13.85		6.37	0.12

CPT: chest physiotherapy, BS: breath stacking, ≠: more than one, χ^2: Chi square, MC: Monte Carlo, t: Student t-test

Table II: The mean changes and differences of physiological parameters in studied groups:

Physiological parameters	Immediately before		Immediately after		After 60 mins		F	P	Partial eta squared
	Mean	± SD	Mean	± SD	Mean	± SD			
RR (c/m)									
BS group	21.63	2.54	21.54	2.19	20.95	2.02	5.750*	0.005*	0.733
CPT group	21.86	3.28	22.64	2.87	22.31	2.46	2.914	0.096	0.145
t (p)	0.349 (0.728)		1.929 (0.058)		2.690* (0.009*)				
HR (b/m)									
BS group	93.33	8.99	90.40	8.80	88.53	8.17	36.323*	0.000*	0.992
CPT group	94.50	32.30	93.98	26.81	88.92	10.82	0.853	0.430	0.041
t (p)	0.221(0.826)		0.801(0.425)		0.181(0.857)				
MAP									
BS group	91.38	10.74	91.44	11.27	91.06	11.24	0.837	0.437	0.021
CPT group	92.87	11.24	92.96	11.21	92.91	11.34	0.051	0.951	0.001
t (p)	0.607(0.546)		0.607(0.546)		0.732(0.466)				
Temp (°C)									
BS group	37.54	0.25	37.39	0.24	37.33	0.25	5.538*	0.006*	0.527
CPT group	37.41	0.24	37.42	0.26	37.40	0.21	0.792	0.457	0.020
t (p)	0.605(0.547)		0.629(0.531)		1.465(0.147)				

CPT: chest physiotherapy, BS: breath stacking, t: Student t-test for comparing the two groups in each period, F: F test (ANOVA) with repeated measure for comparing different periods in each group *: Statistically significant at $p \leq 0.05$, ±SD: standard deviation, Partial eta squared: Small effect <0.5, Medium effect (0.5- <0.8), Large effect (>0.8)

Table III: The mean differences of oxygen status parameters in studied groups:

ABG	Immediately before		Immediately after		After 60 mins		F	P	Partial eta squared
	Mean	± SD	Mean	± SD	Mean	± SD			
PH									
BS group	7.41	0.04	7.42	0.03	7.42	0.03	0.307	0.736	0.008
CPT group	7.41	0.04	7.42	0.04	7.41	0.03	1.718	0.186	0.042
t (p)	0 (1)		0 (1)		1.216 (0.228)				
PaCO2									
BS group	42.56	8.76	42.82	8.44	43.53	7.10	3.433	0.071	0.081
CPT group	43.60	8.35	43.85	7.69	44.36	6.70	1.760	0.179	0.043
t (p)	0.544 (0.588)		0.571(0.570)		0.540 (0.591)				
HCO3									
BS group	23.32	3.92	23.54	3.53	23.39	3.25	0.246	0.783	0.006
CPT group	23.02	3.56	23.33	3.36	22.85	2.84	0.645	0.527	0.016
t (P)	0.357 (0.722)		0.266 (0.791)		0.786 (0.434)				
SaO2									
BS group	95.57	2.44	96.88	3.76	96.77	3.83	10.156*	<0.000*	0.743
CPT group	95.96	1.94	95.54	4.58	95.32	3.79	2.866	0.098	0.068
t (p)	-0.794 (0.430)		1.430 (0.175)		1.702 (0.093)				
PaO2									
BS group	111.9	24.1	111.9	22.5	110.9	19.5	0.213	0.808	0.005
CPT group	109.9	19.4	109.4	17.0	108.2	14.3	1.117	0.332	0.028
t (p)	0.398 (0.691)		0.544 (0.588)		0.687 (0.494)				
Spo2									
BS group	95.72	1.95	96.47	2.69	96.81	2.79	9.762*	<0.001*	0.708
CPT group	95.61	1.83	95.70	1.84	95.77	3.79	1.335	0.269	0.033
t (p)	0.266 (0.791)		1.494 (0.139)		1.398 (0.166)				
Fio2									
BS group	41.46	7.54	42.21	7.85	40.42	8.99	10.869*	<0.001*	0.976
CPT group	41.58	6.60	43.79	7.35	43.67	7.33	2.418	0.128	0.058
t (p)	0.079 (0.937)		0.931(0.354)		1.772 (0.080)				
Hypoxic index									
BS group	2.90	0.87	2.97	0.94	2.83	0.77	1.278	0.284	0.032
CPT group	2.66	0.79	2.65	0.79	2.67	0.78	0.097	0.908	0.002
t (p)	1.306 (0.195)		1.678 (0.097)		0.904 (0.369)				
Oxygen index									
BS group	4.02	1.04	4.32	2.09	3.99	1.03	0.780	0.463	0.027
CPT group	4.08	0.98	4.24	0.96	4.16	1.02	2.271	0.111	0.063
t(p)	0.244 (0.808)		0.212 (0.833)		0.667 (0.507)				

t: Student t-test for comparing the two groups in each period F: F test (ANOVA) with repeated measure for comparing different periods in each group *: Statistically significant at $p \leq 0.05$, Partial eta squared: Small effect <0.5, Medium effect (0.5- <0.8), Large effect (>0.8)

Table IV: The mean differences of mechanical ventilator data in studied groups:

Mechanical ventilator data	Immediately before		Immediately after		After 60 mins		F	p	Partial eta squared
	Mean	± SD	Mean	± SD	Mean	± SD			
Vt									
BS group	484.7	89.0	532.3	114.1	613.3	160.2	16.898*	<0.00*	0.514
CPT group	528.8	175.3	508.9	108.1	537.1	107.0	0.841	0.435	0.022
t (p)	-1.181(0.242)		0.830 (0.410)		2.125*(0.040*)				
PIP									
BS group	20.88	1.79	19.89	2.43	19.25	2.27	8.701*	0.001*	0.539
CPT group	20.20	2.79	20.25	2.60	20.52	2.71	1.472	0.236	0.038
t (p)	1.170 (0.246)		0.570 (0.571)		2.025* (0.047) *				
Pplat									
BS group	12.01	1.57	11.87	1.29	11.89	1.22	1.225	0.303	0.047
CPT group	12.02	1.58	12.00	1.43	11.99	1.50	0.114	0.892	0.003
t(p)	0.014 (0.989)		0.405 (0.687)		0.270 (0.788)				
M_{PAW}									
BS group	10.34	0.98	11.39	4.50	10.30	0.94	1.369	0.264	0.052
CPT group	10.54	1.48	10.73	1.25	10.42	0.94	2.383	0.099	0.061
t(p)	0.601(0.550)		0.862(0.392)		0.495(0.622)				
Cs									
BS group	65.91	12.25	75.11	65.04	82.41	68.63	10.343*	<0.001*	0.379
CPT group	65.79	14.41	66.76	20.89	70.57	15.78	2.401	0.130	0.061
t(p)	0.011(0.991)		0.740 (0.462)		0.864 (0.395)				
C_{dyn}									
BS group	33.73	8.50	37.02	11.88	37.04	8.65	2.902	0.101	0.104
CPT group	41.72	23.71	35.52	10.92	40.38	14.45	3.905	0.056	0.095
t (p)	1.908(0.062)		0.519(0.606)		1.055(0.295)				
VE									
BS group	10399.4	1918.9	11406.6	2386.3	11210.9	2134.4	3.437	0.076	0.121
CPT group	11601.5	4508.7	11719.6	2948.9	12393.9	2240.6	2.000	0.166	0.051
t (p)	1.461(0.150)		0.449 (0.655)		2.114* (0.039*)				

Chest PT group: chest physiotherapy, BS group: breath stacking, t: Student t-test, ±SD: standard deviation, *: Statistically significant at $p \le 0.05$. (V_t): Tidal volume, (VE): Minute ventilation, (PIP)Peak airway pressure, (P_{plat}): Plateau airway pressure, (M_{PAW}): Mean airway pressure, (C_s): Static lung compliance, (C_{dyn}): Dynamic compliance, Partial eta squared: Small effect <0.5, Medium effect (0.5- <0.8), Large effect (>0.8)

Table V: Distribution of studied groups according to cough reflex intensity:

Cough reflex intensity	Immediately before		Immediately after		60 mins		Fr	p	Partial eta squared
	NO.	%	NO.	%	NO.	%			
BS group									
- No cough	28	70	16	40	7	17.5			
- Weak audible	11	27.5	15	37.5	20	50	45.648*	<0.001*	0.891
- clear audible.	1	2.5	9	22.5	8	20			
- strong, loud cough	0	0	0	0	5	12.5			
CPT group									
- No cough	27	67.5	27	67.5	26	65			
- Weak audible	10	25	9	22.5	9	22.5	2.333	0.311	0.045
- Clear audible.	3	7.5	4	10	5	12.5			
- Strong, loud cough	0	0	0	0	0	0			
χ^2 (MCp)	1.025(0.732)		6.237*(0.044*)		20.958*(<0.001*)				

χ^2: Chi square test for comparing the two groups in each period, MC: Monte Carlo, Fr: Friedman test for comparing different periods in each group, *: Statistically significant at $p \le 0.05$, Partial eta squared: Small effect <0.5, Medium effect (0.5- <0.8), Large effect (>0.8)

Table VI: Distribution of studied groups according to assessment of airway clearance:

	Immediately before		Immediately after		After 60 mins		F	P	Partial eta squared
	No	%	No	%	No	%			
Air entry									
BS group									
Present	24	60	25	62.5	32	80	14.25*	0.001*	0.950
Diminished	16	40	15	37.5	8	20			
CPT group									
Present	19	47.5	20	50	21	52.5	3	0.22	0.038
Diminished	21	52.5	20	50	19	47.5			
χ^2 (p)	1.26 (0.26)		1.27 (0.26)		6.77* (0.009*)				
Sputum assessment							**Fr**	**P**	
No sputum									
CPT group	37	92.5	24	60	31	77.5	19.538*	<0.001*	0.846
BS group	33	82.5	15	37.5	20	50	27.263*	<0.001*	0.839
χ^2(p)	1.83(0.18)		4.05*(0.04*)		6.55*(0.01*)				
Amount of sputum (ml)	**Mean**	**± SD**	**Mean**	**± SD**	**Mean**	**± SD**	**F**	**P**	
BS group	42.87	15.77	53.84	17.93	78.79	26.67	83.775*	<0.001*	0.917
CPT group	43.81	20.06	48.31	19.91	62.01	19.91	25.840*	<0.001*	0.464
t (p)	0.23(0.82)		1.31(0.20)		3.19*(0.002*)				

χ^2: **Chi square test** for comparing the two groups in each period, t: Student t-test for comparing the two groups in each period, Fr: Friedman test for comparing different periods in each group, F: F test (ANOVA) with repeated measure for comparing different periods in each group, *: Statistically significant at p ≤ 0.05

Table (VII): Distribution of studied patients in both groups according to weaning success, duration of mechanical ventilation:

Patients' outcome	BS group		CPT group		χ^2	p
	No.	%	No.	%		
Weaning success						
Yes	21	52.5	14	35	2.513	^{MC}p=0.28
No	19	47.5	26	65		
Number of re-intubated patient						
No	27	80.96	19	64.29	4.013*	0.05*
Yes	14	19.04	21	35.71		
Duration of mechanical ventilation/day						
Mean ± SD	4.83 ±3.4		7.3 ± 4.2		t =2.885*	0.005*

χ^2: Chi square test for comparing the two groups in each period, MC: Monte Carlo

Discussion:

Coughing is a natural defense mechanism that clears the airways and stops aspiration. This physiological maneuver necessitates the best possible coordination and use of the larynx, respiratory muscles, and airway caliber (**Enrichi et al., 2020).** In this study, it was found that the number of patients in the BS group who had no cough increased by more than half to seven patients after the intervention. Simultaneously, the number of patients had weak audible cough increased from 11 to 20, those with clear audible cough increased from 1 to 8, and others with strong cough increased to 5 with significant difference between groups in relation to cough strength.

The previously mentioned results may be ascribed to the fact that the breath stacking is designed to facilitate re-expansion of collapsed pulmonary regions, enhance the efficacy of cough reflexes, influence the elastic recoil of the lungs and thereby augmenting the effectiveness of coughing during forced expiration. The principal role of breath stacking is not associated with the mobilization of secretions, as is typically observed in conventional techniques. Indeed, it emulates the mechanisms of coughing and enhances peak cough flow, thereby transporting secretions towards the upper airways **(Chicayban et al., 2020)**.

The preceding findings align with a prior review conducted by **Spinou 2020** evidence suggested that breath stacking significantly enhanced the cough peak flow (CPF), cough strength and effectiveness in patients exhibiting muscular weakness, in comparison to unassisted coughing. Moreover, by increasing inspired volumes, breath stacking can improve mucus clearance and decrease atelectasis by increasing peak cough flow. **(Charu et al., 2023, Magni et al., 2024)**. **Reyes et al., 2020** discovered that expiratory muscle training (EMT) combined with BS voluntary improve CPF more than EMT alone. Up to 30 minutes were spent with elevated PCF values in a previous study done by **Cleary et al., 2021**.

The results concerning this research display that the percent of patients with diminished air entry and the percent of patients who did not produce sputum while suctioning in both groups decreased significantly and the mean amount of sputum with suctioning after the usage of BS increased significantly. The preceding findings align with a prior result of studies done by **Marbate et al., 2022 and van der Lee et al., 2021**. It was concluded in these studies that stacked breathing was effective to improve patients expiratory flow rate and thereby improve and promote airway clearance. Moreover, breath stacking technique can increase inspired volumes that lead to greater peak cough flow, allowing for improvements in mucus clearance and reduction in atelectasis **(Dorça et al., 2020)**

The findings of this research indicate that the implementation of breath stacking led to a significant reduction in respiratory rate, heart rate, and body temperature, while no alterations were observed in mean arterial blood pressure. Furthermore, there was a significant increase in Vt, VE and static compliance. Moreover, there was a significant decrease in PIP. These results might be linked to the fact that the decrease in respiratory rate (RR) and heart rate (HR) following the BS performance can be understood by the lowered energy demands caused by enhanced lung volume (Vt), improved static pulmonary compliance and the recruitment of alveoli. Furthermore, bag squeezing can facilitate airway clearance by effectively removing secretions leading to reduced PIP and lower bacterial colonization which, in turn results in a decrease in body temperature (**Fernandes et al., 2022, Oliveira et al., 2023, Luthfianto & Irdawati 2023**).

It was reported by **Mani et al., 2022 & Brito et al., 2025** that patients could inhale larger volumes and sustain inspiration for extended durations by using a one-way valve device, which encouraged the accumulation of consecutive inspiratory volumes while preventing expiration. It has been demonstrated that increasing the mobilization of secretion cannot be achieved by stimulating cough or tracheal aspiration without first utilizing physical therapy techniques. **(Almeida et al., 2020)**. Another trial done by **van der Lee et al., 2021** comparing the trial group with the cough assist device to the control group, the researcher observed improvements in tidal volumes and lung compliance.

The end results of using manual cough assisted techniques in a previous case report showed improvement in heart rate, blood pressure, oxygen saturation, and respiratory rate at the end of the fourteenth day of intervention (**Kumar & Kamble 2023**). The breath stacking technique is based on physiological principles that include improving depth of breathing, increasing lung volume and elastic recoil, improving rib cage mobility and flexibility, and stretching respiratory muscles. (**Charu et al., 2023 and Magni et al., 2024**).

In the contrary to the results of this study **Sheers et al., 2021, 2022** reported that there were no changes in static lung volumes and no treatment effect on lung volumes between studied groups. Moreover, **Oh et al., 2022** reported that there was a decrease in systolic arterial pressure during lung volume recruitment. In the earlier randomized clinical trial performed by **Fernandes et al., 2022** there was no changes in heart rate. Our findings are in conflict with those of **Siriwat et al., 2018** who compared the effects of air stacking by using mechanical insufflation-exsufflation with conventional chest physical therapy found no significant difference in the two groups' physical measurement data for RR, and HR. Nevertheless, after four days, there was no statistically significant change between the groups', heart rates, and breathing patterns according to daily recorded data. Also, HR significantly increased in both treatment arms after 1 hour in another study done by **Martí et al., 2022**.

The current study results indicated a significant increase in Sao2 within the BS group, while the fraction of inspired oxygen (FiO2) decreased considerably. But there was no significant difference with CPT group. The reason behind this improvement in oxygen saturation might be, stacked breathing induce slow and deep breathing. Stacking of air for 10 seconds improves the collateral ventilation and surface area for the better oxygenation purpose. There is an improvement in inspiratory capacity and lung volume which resulted in better ventilation and effective gaseous exchange thereby improving oxygen (**Delgado & Bajaj 2023)**.

The previous findings were in the line with the findings of **Fernandes's et al., 2022** and O**h et al., 2022** studies there were a significant increase in PaO_2 /FiO_2 and SpO_2 after BS. In another study done by **Marbate et al., 2022** assessed the instant impact of the stacked breathing technique on SpO_2, conducted six sessions and it was found an extremely significant improvement with each session each day. Additionally, it was noted that stacked breathing might be more beneficial than deep breathing exercises for enhancing gas exchange in a study done by **Gayathiri & Anandhi 2021**. Moreover, the present study validated the findings of **Knudsen et al., 2020** who reported that patients undergoing MV improved their oxygen saturation levels quickly and required less oxygen therapy. SaO_2 and Pao_2 significantly increased after 1hour (**Martí et al., 2022**). **Li et al., 2024** found that after comparison to the control group, there was a significantly higher partial pressure of oxygen, lower levels of oxyhemoglobin saturation, and a lower partial pressure of carbon dioxide in the cough machine assistance and care bundle combined therapy. In the contrary to this study finding no change was found in SpO_2 in previous studies done by **Pellegrino et al., 2021** and **Siriwat et al., 2018.**

In this research, the number of patients who remained free from re-intubation in the BS group exceeded that in the CPT group, accompanied by a shorter duration of mechanical ventilation since the capacity to clear obstructive debris from the airway and a robust cough are essential for effective weaning from mechanical ventilation, it is logical to assume that cough strength assessed before extubation could offer valuable insights into the likelihood of extubation failure (**Chicayban et al., 2020).** Utilizing BS has been demonstrated to improve airway clearance as a result, it aids in extubation. Acute respiratory failure (ARF), which follows extubation and leads to re-intubation and weaning failure, may be caused by a decrease in airway clearance efficiency and respiratory muscle weakness. In patients who have acquired weakness in the intensive care unit, air stacking in conjunction with chest physical therapy appears to have no effect on preventing post-extubation acute respiratory failure. (**Wibart et al., 2023)**.

Conclusion:

According to the statistical analysis, it is determined that the stacked breathing technique is notably effective in enhancing cough intensity and airway clearance, thereby promoting respiratory efficiency. Additionally, stacked breathing has demonstrated safety in restoring pulmonary function, enhancing lung volumes, maximal respiratory pressures, and oxygen saturation, while also decreasing patients' respiratory effort

Recommendation:

1- The use of breath stacking technique is part of daily care for mechanically ventilated patients who are complaining of secretion with a weak cough.

2- Organizing in-service training for critical care nurses on the performance of breath stacking technique.

3- Replicate the study to evaluate and compare the effect of annual breath stacking on non-mechanically patients.

4- Replicate the study to compare between annual breath stacking as a method of cough assisted device and other mechanical methods such as PEEP-ZEEP maneuver, mechanical insufflation/exsufflation for mechanically ventilated patients

Limitation of study:

The study's limitations were primarily reflected in the inability to obtain a larger sample size for a variety of reasons. To start, the rate of successful spontaneous breathing trials is inconsistent and insufficient. Secondly, patients with exclusion criteria ensure that the sample meets the relatively strict inclusion criteria in order to eliminate any doubts about the efficacy of the technique. This results in a small sample size and impacts the generalization of findings. Due to hemodynamic instability or other vital abnormalities, two patients in group (A) experienced transient hypotension, which ended the session. The process and the outcome may be impacted by the weariness or exhaustion of the patients. Another drawback is that APACHE was not used to assess the severity of the patients' conditions.

References:

Almeida F, Teodoro R, Chiavegato L. 2020; Maneuvers and strategies in respiratory physical therapy: time to revisit the evidence. J Bras Pneumol; 46(4): e20200443

Bissett B, Gosselink R & van Haren F. 2020; Respiratory Muscle Rehabilitation in Patients with Prolonged Mechanical Ventilation: A Targeted Approach. Crit Care 24(103). https://doi.org/10.1186/s13054-020-2783-0

Bureau C, Hollebeke V, Dres M. 2023; Managing respiratory muscle weakness during weaning from invasive ventilation. Eur Respir Rev 32: 220205.

Belli S, Prince I, Savio G, Paracchini E, Cattaneo D, Bianchi M, et al. 2021; Airway Clearance Techniques: The Right Choice for the Right Patient. Front Med 4 (8):544826. doi: 10.3389/fmed.2021.544826.

Brito R, Morais C, Arellano D, Gajardo A, Bruhn A, Brochard L, et al. 2025; Double cycling with breath-stacking during partial support ventilation in ARDS: Just a feature of natural variability? Critical Care (29)1.

Charu Taneja C, Mehra S, Singh M, Sikka G. 2023; Effect of Stacked Breathing Technique to Reduce Postoperative Pulmonary Complications and Improve Pulmonary Functions: A Brief Review. International Journal of Science and Healthcare Research. 8(3).

Chicayban L, Hemétrio A, Azevedo L. 2020; Comparison of the effects of voluntary and involuntary breath stacking techniques on respiratory mechanics and lung function patterns in tracheostomized patients: a randomized crossover clinical trial. J Bras Pneumol. 46(4): e20190295. https://doi.org/10.36416/1806-3756/e20190295

Cleary S, Misiaszek J, Wheeler S, Kalra S, Genuis S. 2021; Lung volume recruitment improves volitional airway clearance in amyotrophic lateral sclerosis. Nerve. 64:676–82.

Delgado B, Bajaj T. 2023; Physiology, Lung Capacity. Stat Pearls [Internet] July 24.

Dorça A, Livia A,Sisterolli D, Sarmet M, Ricardo S, Vicente L,Franco H, Maldaner V.2020; Comparison between breath stacking technique associated with expiratory muscle training and breath stacking technique in amyotrophic lateral sclerosis patients: Protocol for randomized single blind trial. Contemporary Clinical Trials Communications (19):100647. doi https://doi.org/10.1016/j.conctc.2020.100647.

Enrichi C, Zanetti C, Gregorio C, Koch I, Vio A, Palmer K, et al. 2020; The assessment of the peak of reflex cough in subjects with acquired brain injury and tracheostomy and healthy controls. Respir Physiol Neurobiol. 27 4:103356. doi: 10.1016/j.resp.2019.103356.

Fernandes D, Righi N, Rubin Neto L, Bellé J, Pippi C, Ribas C, et.al. 2022; Effects of the breath stacking technique after upper abdominal surgery: a randomized clinical trial. J Bras Pneumol. 48(1):1-8.

Gayathiri T & Anandhi D. 2021; Efficacy of Incentive Spirometry in Expiratory Muscle Training Following Abdominal Surgery. Biomed Pharmacol J. 14(1):335-41.

Jia W, Wang J, Walline J, Gao R, Xu R, Chen X, et al. 2021; The Cough Reflex Intensity Score in Critically Ill Patients' Airway Management:

Study Protocol for a Multicenter, Prospective, Observational Trial. https://assets-eu.researchsquare.com/files/rs-167255/v1/06ad4dc0-7454-42ce-9869-a36530465ae6.pdf?c=1645462372

Knudsen F, Sprehn M, Vestbo J. 2020; Mechanical insufflation/exsufflation compared with standard of care in patients with pneumonia: A randomized controlled trial. European Journal of Anesthesiology. 37 (11): 1077- 80.

Kumar N & Kamble K. 2023; A combination effect of manual assisted cough techniques and respiratory proprioceptive neuromuscular facilitation on ventilatory decompression craniotomy patients: a case report Int J Res Med Sci. 11(2):719-22

Luthfianto M & Irdawati I. 2023; The Effect of Chest Physiotherapy on Oxygen Saturation and Respiratory Rate in Pediatric Pneumonia. Journal Keperawatan. 15 (4): 325-34.

Li Y, Liu Y, Jia W, Yang J, Xu J. 2023; Construction of cough reflex intensity score for critically ill patients based on the Delphi method. World J Emerg Med. 14(3):235-7.

Li X, Zhang M, Li N, Wei W 2024; Effect of Cough Machine Assistance and Care Bundle Combined Therapy on Burned Patients with Moderate to Severe Inhalation Injury. J Burn Care Res. 45(1):32-9. doi: 10.1093/jbcr/irad056. PMID: 37083702.

Marbate R, Bhalerao A, Pillai L, Bidve J, Khan S 2022; immediate effect of stacked breathing technique on oxygen saturation and peak expiratory flow rate in cardiothoracic surgery patient-an experimental study. IJCRT (10) 7.

Mani P, Hathila V, Jayaprakash D 2022; Combined Effect of Active Cycle of Breathing Technique and Autogenic Drainage on PEFR and Inspiratory Capacity in Participants Following Upper Abdominal Surgery-A Randomized Controlled Clinical Trial Study. IJPESH. 12:26-36.

Magni E, Hochsprung A, Matos R, Carrasco M, Camacho B, Marcos I, et al. 2024; Effects of Respiratory Training on Pulmonary Function, Cough, and Functional Independence in Patients with Amyotrophic Lateral Sclerosis. Neurol. Int. 16, 1332–42. https://doi.org/10.3390/neurolint16060101

Martí J, Martínez-Alejos R, Pilar-Diaz X 2022; Effects of mechanical insufflation-exsufflation with different pressure settings on respiratory mucus displacement during invasive ventilation. Respir Care. 67(12):1508-1516. doi:10.4187/respcare.10173

Oliveira T, Peringer V, Junior L, Eibel B 2023; PEEP-ZEEP Compared with Bag Squeezing and Chest Compression in Mechanically Ventilated Cardiac Patients: Randomized Crossover Clinical Trial. Int. J. Environ. Res. Public Health 20, 2824. https://doi.org/10.3390/ijerph20042824

Oh E, Lee E, Heo Burn, Huh J, Min J 2022; Physiological benefits of lung recruitment in the semi-lateral position after laparoscopic surgery: a randomized controlled study. Scientific Reports.12(1):4.

Patel N, Chong K, Baydur A 2022; Methods and Applications in Respiratory Physiology: Respiratory Mechanics, Drive and Muscle Function in Neuromuscular and Chest Wall Disorders. Front. Physiol. 13(1).

Pellegrino G, Corbo M, Marco F, Pompilio P, Dellacà R, Banfi P, et al. 2021; Effects of air stacking on dyspnea and lung function in neuromuscular diseases. Arch Phys Med Rehabil. 102(8):1562–7. doi: 10.1016/j.apmr.2021.01.092

Rose L, Adhikari N, Leasa D, Fergusson D, McKim D 2019; Cough augmentation techniques for extubation or weaning critically ill patients from mechanical ventilation. Cochrane Database Syst Rev. 1(1):CD011833. doi: 10.1002/14651858.CD011833.pub2.

Reyes A, Castillo A, Castillo J. 2020; Effects of Expiratory Muscle Training and Air Stacking on Peak Cough Flow in Individuals with Parkinson's Disease. Lung. 198 (1): 207-11. doi:10.1007/s00408-019-00291-8

Sheers N, Howard M, Rautela L, Chao C, Rochford P, Berlowitz D 2021; Lung volume recruitment therapy in people with neuromuscular disease. Respirology. 26(S2):24. doi: 10.1111/resp.14021

Sheers N, Berlowitz D, Dirago R, Naughton P, Henderson S, Rigoni A, et al. 2022; Rapidly and slowly-progressive neuromuscular disease: differences in pulmonary function, respiratory tract infections and response to lung volume recruitment therapy (LVR). BMJ Open Respir Res. 9: e001241.

Sheers N, O'Sullivan R, Howard M, Berlowitz D 2023; The role of lung volume recruitment therapy in neuromuscular disease: a narrative review. Front Rehabil Sci. 26; 4:1164628.

Spinou A 2020; A Review on Cough Augmentation Techniques: Assisted Inspiration, Assisted Expiration and Their Combination. Physiol Res. 27;69: S93-S103.

Siriwat R, Deerojanawong J, Sritippayawan S 2018; Mechanical insufflation-exsufflation versus conventional chest physiotherapy in children with cerebral palsy. Respiratory Care, 63 (2): 187-93.

Sykes D, Morice A 2021; The Cough Reflex: The Janus of Respiratory Medicine. Front. Physiol.12.

Vanhorebeek I, Latronico N, Van den Berghe G 2020; ICU-acquired weakness. Intensive Care Med. Apr;46(4):637-53. doi: 10.1007/s00134-020-05944-4.

Valer B, Bonczynski G, Scheffer K, Forgiarini S, Eibel B, Cordeiro A, et al. 2022; Ventilator versus manual hyperinflation in adults receiving mechanical ventilation: A systematic review. Physiother Res Int. 27: e1936. https://doi.org/10.1002/pri.1936

Van der Lee L, Hill A, Jacques A. 2021; Efficacy of respiratory physiotherapy interventions for intubated and mechanically ventilated adults with pneumonia: A systematic review and meta-analysis. Physiotherapy Canada. 73 (1): 6-18.

Wibart P, Réginault T, Garcia-Fontan M, Barbrel B, Bader C, Benard A, et al. 2023; Effects of mechanical in-exsufflation in preventing postextubation acute respiratory failure in intensive care acquired weakness patients: a randomized controlled trial. Crit Care Sci. 35(2):168-76.