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Ventilator inspiratory trigger sensitivity adjustment versus threshold device training on pulmonary functions in acute stroke patients

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Abstract

Patients with neurological disorders often need Prolonged Mechanical Ventilation (PMV). In those with sudden neurological issues, 17-33% receives intubation and ventilator support due to breathing difficulties, leading to unfavorable results and hospital death rates of 16-33%. Weakness in inspiratory muscles commonly occurs, particularly during extended ventilation periods, but inspiratory muscle training (IMT) may counteract these issues and support successful ventilator removal. Physical therapy thus contributes importantly by using multiple techniques to build respiratory muscle strength. This research aimed to evaluate ventilator inspiratory trigger sensitivity changes against threshold device exercises for their impact on lung function among patients with recent strokes. The trial involved 40 individuals (26 women, 14 men) aged 40-60 years suffering from acute stroke and needing mechanical ventilation, drawn from the stroke unit at Al-Kaser Al-Ainy Medical School, Cairo University, during June-August 2025. Random allocation placed participants into two equal groups: one using threshold IMT and the other with ventilator trigger pressure modifications. Lung compliance (mL/cmH2O) served as the main measure, alongside blood gas values like pH, PaCO2 (mmHg), PaO2 (mmHg), and HCO3 (mEq/L). Participants receiving ventilator adjustments (MV group) achieved notably larger gains in lung compliance (16.95±1.90) than the IMT group (11.10±1.07; p<0.001). The MV group also showed better PaO2 gains (29.30±0.92 vs. 20.30±2.36; p<0.001), greater PaCO2 drops (-6.66±2.22 vs. -4.21±1.81; p<0.001), higher PaO2/FiO2 rises (90.05±2.09 vs. 59.85±2.08; p<0.001), stronger SaO2 improvements (4.57±0.94 vs. 2.81±0.62; p<0.001), larger pH increases (0.10±0.03 vs. 0.05±0.02; p<0.001), and more significant HCO3 reductions (-3.42±1.68 vs. -0.43±1.47; p<0.001). Ventilator pressure tweaks and IMT both enhanced breathing mechanics and gas exchange in stroke patients on ventilators, yet MV adjustments yielded better results across oxygenation, CO2 clearance, acid-base status, and compliance. These results point to ventilator optimization as a primary option for breathing problems, with IMT as a helpful supplement for cases avoiding or extending beyond mechanical support, potentially improving recovery and lowering complications.

Keywords: Acute stroke, Mechanical ventilation, Pulmonary function, Threshold device training, Inspiratory muscle training S

Introduction

Stroke represents a severe condition and one of the top reasons for neurological hospitalizations globally (Allsassmah, 2020). It continues as a major factor in worldwide deaths and lasting disabilities that can affect quality of life Quality of life (QOL) is a multidimensional term encompassing physical, psychological, and social aspects of well-being (Walid Al-Qerem et al.,2026), frequently causing multiple issues that prolong hospital stays and strain medical resources significantly (Cohen et al., 2016). People with sudden neurological problems often need extended mechanical ventilation (PMV), where 17-33% face intubation and ventilator use from breathing failure, leading to high hospital death rates of 16-33% and overall poor results (Huang et al., 2022).

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This condition heavily affects breathing systems through muscle weakening, poor airway clearing, reduced chest wall flexibility, and irregular breath patterns, all undermining airway safety and cough strength (Liaw et al., 2020). Mechanical ventilation (MV) aids gas exchange in the lungs for those unable to sustain proper air sac ventilation, with common triggers like nerve-muscle disorders, breathing failure from chronic lung blockage, or needs after surgery with full anesthesia. Yet, those on MV beyond 48 hours show elevated one-year death risks, lower daily function, and diminished life quality, as extended MV harms the diaphragm in a process called Ventilator-Induced Diaphragmatic Dysfunction (VIDD) (Ahmed et al., 2019).

Weakness in breathing-in muscles commonly strikes ventilated patients, worse with longer support times, and inspiratory muscle training (IMT) offers a way to counter or undo these problems, aiding quicker and better ventilator weaning (Elbouhy et al., 2014). Multiple approaches, like IMT, aim to shorten weaning periods and MV lengths, though studies since the 1980s on IMT's role in cutting ventilation and weaning times for long-term MV cases yield mixed, inconclusive results (SIlVa, 2019).

IMT delivers through options like steady or normal CO_2 hyperpnea, resistance-based flow exercises, pressure threshold work, or ventilator tweaks to add inspiratory effort, with loads ramped up by altering trigger sensitivities—typically as a share of peak inspiratory pressure (MIP) (Elkins & Dentice, 2015). As a common ICU life-saver for sudden breathing crises, MV brings rising risks tied to its length; in tube-fed stroke cases, stiffer lungs from low compliance boost breathing effort, trigger low oxygen blood levels, and heighten death chances, worsened by stroke-linked lung damage and swelling that further stiffens ventilation handling. While many trials test IMT separately with threshold tools or ventilator triggers, no head-to-head data exists, calling for strong randomized trials to identify the best IMT type for easing weaning.

This research posits a meaningful gap between ventilator trigger sensitivity tweaks and threshold device exercises in affecting lung compliance (mL/cmH2O), alongside blood gas values like pH, $PaCO_2$ (mmHg), PaO_2 (mmHg), and HCO_3 (mEq/L). results for hard-to-wean patients with acute stroke patients.

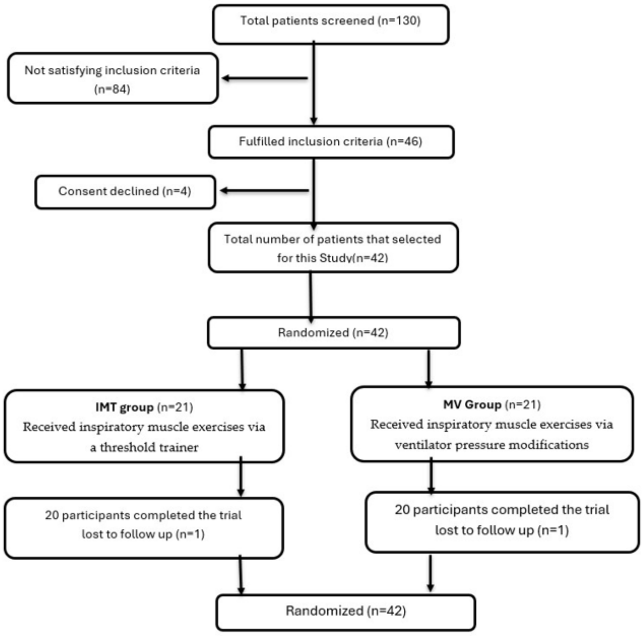
Materials and Methods

Trial design

The study was authorized by the institution's Research Ethics Committee of Alzaytoonah University of Jordan under the number (IRB #1/4/2024-2025) and was listed on ClinicalTrials.gov (NCT07003867). Researchers secured written consent from participants or their representatives before enrollment. Data collection occurred between June and August 2025 in the stroke unit of Al-Kaser Al-Ainy Medical School, Cairo University.

Participants

Enrollment covered 40 individuals (26 women, 14 men) aged 40-60 years diagnosed with recent stroke and dependent on mechanical ventilation for more than 48 h composed the sample. The potential risks and benefits were thoroughly explained to patients' guardians, who signed a consent form. Randomization split them evenly into two cohorts: the IMT group (n=20) performed inspiratory muscle exercises via a threshold trainer, these treatments were daily until the time of weaning, or up to 10 days for failed weaning patients. The MV group(n=20) used ventilator pressure modifications for training. Eligible candidates met criteria including age over 40, BMI 18.5-30, ventilation exceeding 48 hours, alertness (Glasgow Coma Scale ≥13), stable heart function, pressure support mode with $FiO_2 \leq 0.5$, PEEP<25 cmH2O, pH>7.25, SpO_2>90%, MIP 15-30 cmH2O, and capacity for self-triggered breaths. Those excluded had unstable blood flow, intense breathing distress, advancing nerve-muscle conditions, spinal damage, major chest deformities, deep sedation or breath muscle paralysis, excessive airway pressures, or BMI above 35.



Sample size

Investigators determined the cohort size beforehand with G*POWER software (version 3.1.9.2; Franz Faul, University of Kiel, Germany).

Randomization

Participants were randomly assigned to one of two study groups using a computer-generated randomization sequence. The randomization process was carried out by an independent research assistant who was not involved in the trial. To ensure allocation concealment, opaque, sequentially numbered envelopes were prepared, each containing the group assignment for an individual participant. Group allocation was disclosed to the research team only after completion of all baseline assessments. The outcome assessor was blinded to group assignment and was responsible for collecting both baseline and post-intervention measurements and entering the data.

Outcome measures

The key measure was lung compliance (mL/cmH2O) via mechanical ventilation (Puritan Bennett™ 840, Medtronics, USA) (Ghiani et al., 2020). Supporting metrics involved arterial blood gases (pH, PaCO2, PaO2, HCO3) assessing acid-base status, gas flow, and oxygen levels (Zeserson et al., 2018).

Treatment protocols

Threshold Inspiratory Muscle Training (IMT) group via Threshold IMT® (Philips Respironics, Chichester, United Kingdom) : after explaining the procedure to the patient and raising the head of the bed to about 45 degrees, the patient was disconnected from mechanical ventilation and immediately connected to the Threshold IMT device. Then the patient was instructed to exhale maximally before taking deep inspiration as strong as he/she could (Elbouhy et al., 2014). The training pressure was adjusted to the highest tolerable pressure by the patient and consisted of 4–5 sets of training. In each set the patient took from 6 to 10 breaths, and between sets of training, the patient could be reconnected to mechanical ventilation for rest as needed (Martin et al., 2011). Supplemental oxygen may be connected to IMT if the patient's condition needed it (Elbouhy et al., 2014). The intensity started with 30 % NIF of each patient measured by mechanical ventilator, then the load increased on IMT device by 1–2 cmH2O every session. This intervention was performed three times per day with a 4-hour gap at least. The training session lasted for about 5 min. These treatments were daily until the time of weaning, or up to 10 days for failed weaning patients. Ventilator Trigger Sensitivity Adjustment (MV) group via adjusting the trigger sensitivity of mechanical ventilation (Puritan Bennett™ 840, Medtronics, USA) : after explaining the procedure to the patient and raising the head of the bed to about 45 degrees, the mode of mechanical ventilation was shifted to pressure support mode, then the mechanical ventilation trigger sensitivity was adjusted to lowest tolerable pressure by the patient (Martin et al., 2011; Elbouhy et al., 2014). The trigger sensitivity was adjusted to 30 % of maximal inspiratory pressure. The patients were instructed to inhale as maximally as they can after maximal exhalation. The training consisted of 4–5 sets of training, in each set patient takes from 6 to 10 breaths. Between sets of training, the mode of mechanical ventilation might shift to the previous mode for rest as the patient needed. Training was based on decreasing the trigger sensitivity gradually to increase muscle strength and endurance (Vorona et al., 2018). The load increased by 1–2 cmH2O every session. If the patient had any of the following alarm signs, the session finished: saturation less than 90 %, respiratory rate higher than 35 bpm, heart rate higher than 120 bpm, systolic blood pressure higher than 180 mmHg or lower than 90 mmHg, agitation or paradoxical breathing. The whole treatment program started 2–5 days after intubation when the patient was stable and his Glasgow Coma Scale was higher than 13 points, and continued the treatment until weaning or to 10 days

Data analysis

Analysis used SPSS version 26.0 (SPSS Inc., Chicago, IL, USA). Normal data appeared as mean ± SD and ranges; non-normal as median (IQR); categorical as counts/percentages. Normality checks employed Kolmogorov-Smirnov and Shapiro-Wilk tests.

Results

Subject characteristics

No significant demographic differences were observed between groups in age, weight, height, or BMI, confirming group comparability.

Table 1 presents the comparison of demographic data between the IMT group and MV group according to demographic data showed no statistically significant differences in age (p=0.494), weight (p=0.344), height (p=0.679), or BMI (p=0.482). This suggests that the two groups were comparable in terms of demographic characteristics, which can help to reduce confounding variables and increase the validity of the study results.

Table (1): Comparison between IMT group and MV group according to demographic data

Parameter	IMT Group (n=20)	MV Group (n=20)	Test value	p-value
Demographic Data				
Age (years)	47.85 ± 4.50 (42-60)	48.80 ± 4.19 (44-60)	-0.691	0.494
Weight (kg)	82.20 ± 6.18 (73-95)	80.25 ± 6.67 (70-92)	0.959	0.344
Height (cm)	173.45 ± 4.73 (162-181)	172.80 ± 5.14 (162-180)	0.416	0.679
BMI [wt/(ht)^2]	27.33 ± 1.71 (23.7-29.7)	26.89 ± 2.18 (22.7-29.8)	0.711	0.482

Using: t-Independent Sample t-test for Mean±SD; p-value>0.05 is insignificant; *p-value<0.05 is significant; **p-value<0.001 is highly significant

Pre-Intervention respiratory and blood gas parameters

Baseline comparisons showed no significant differences in PaO2, PaCO2, PaO2/FiO2, SaO2, pH, pulmonary compliance, or HCO3. Table 2 illustrates the comparison between the IMT group and MV group in pre-intervention according to respiratory function and blood gases parameter.The results showed that the mean PaO2 levels were slightly lower in the IMT group (79.30±5.02) compared to the MV group (81.17±4.96), but the difference was not statistically significant (p=0.245).The mean PaCo2 levels were lower in the IMT group (40.79±3.66) compared to the MV group (42.37±2.96), but the difference did not reach statistical significance (p=0.141).The PaO2/Fio2 ratio was similar between the two groups, with a mean of 206.94±8.47 in the IMT group and 206.45±11.33 in the MV group, and no statistically significant difference was observed (p=0.879).The mean SaO2 levels were slightly lower in the IMT group (94.16±1.04) compared to the MV group (94.51±0.91), but the difference was not statistically significant (p=0.264).The mean pH levels were similar between the two groups, with a mean of 7.38±0.03 in the IMT group and 7.37±0.03 in the MV group, and no statistically significant difference was observed (p=0.131).The mean compliance was lower in the IMT group (41.50±8.08) compared to the MV group (45.15±6.58), but the difference did not reach statistical significance (p=0.126).The mean HCO3 levels were slightly higher in the IMT group (26.93±4.95) compared to the MV group (26.39±5.02), but the difference was not statistically significant (p=0.736).

Table (2): Comparison between IMT group and MV group according to respiratory function and blood gases parameters in pre intervention

Parameter	IMT Group (Mean ± SD, Range) / MD ± SD / % Change	MV Group (Mean ± SD, Range) / MD ± SD / % Change	Test value	p-value
Pre-intervention				
PaO2 (mmHg)	79.30 ± 5.02 (73.96-90)	81.17 ± 4.96 (73.9-95)	-1.180	0.245
PaCO2 (mmHg)	40.79 ± 3.66 (35.92-46.87)	42.37 ± 2.96 (37-49.12)	-1.505	0.141
PaO2/Fio2	206.94 ± 8.47 (193.3-220)	206.45 ± 11.33 (175.7-225.7)	0.153	0.879
SaO2 (%)	94.16 ± 1.04 (92.8-96.7)	94.51 ± 0.91 (93.4-96.7)	-1.135	0.264
pH	7.38 ± 0.03 (7.33-7.43)	7.37 ± 0.03 (7.33-7.42)	1.545	0.131
Compliance	41.50 ± 8.08 (33-68)	45.15 ± 6.58 (32-54)	-1.566	0.126
HCO3 (mEq/L)	26.93 ± 4.95 (20-37.3)	26.39 ± 5.02 (21-38)	0.340	0.736

Post-Intervention outcomes

The MV group demonstrated significantly greater improvements compared to the IMT group in PaO2, PaO2/FiO2 ratio, SaO2, pulmonary compliance, and HCO3 levels (all p<0.01). There were no significant differences in PaCO2 or pH post-intervention. Table 3 compares the post-intervention respiratory function and blood gases parameter between the IMT group and MV group.After the intervention, the mean PaO2 levels were significantly lower in the IMT group (99.61±5.49) compared to the MV group (110.47±5.45), with a highly significant difference (p<0.001).The mean PaCo2 levels were slightly higher in the IMT group (36.58±3.18) compared to the MV group (35.72±2.38), but the difference was not statistically significant (p=0.337).The PaO2/Fio2 ratio was significantly lower in the IMT group (266.79±8.55) compared to the MV group (296.50±11.90), with a highly significant difference (p<0.001).The mean SaO2 levels were significantly lower in the IMT group (96.97±1.20) compared to the MV group (99.07±0.66), with a highly significant difference (p<0.001).The mean pH levels were slightly lower in the IMT group (7.44±0.02) compared to the MV group (7.45±0.03), but the difference was not statistically significant (p=0.089).The mean compliance was significantly lower in the IMT group (52.60±8.31) compared to the MV group (62.10±7.65), with a highly significant difference (p<0.001).The mean HCO3 levels were significantly higher in the IMT group (26.50±5.07) compared to the MV group (22.98±2.33), with a statistically significant difference (p=0.008).

Table (3): Comparison between IMT group and MV group according to respiratory function and blood gas parameters in post intervention

Parameter	IMT Group (Mean ± SD, Range)	MV Group (Mean ± SD, Range)	Test value	p-value
PaO2 (mmHg)	99.61 ± 5.49 (93-111)	110.47 ± 5.45 (102.9-126)	-6.278	<0.001**
PaCO2 (mmHg)	36.58 ± 3.18 (31.83-43.02)	35.72 ± 2.38 (31.76-40.1)	0.972	0.337
PaO2/Fio2	266.79 ± 8.55 (253-281)	296.50 ± 11.90 (262.7-317.7)	-9.069	<0.001**
SaO2 (%)	96.97 ± 1.20 (94.6-98.8)	99.07 ± 0.66 (97.2-99.9)	-6.879	<0.001**

pH	7.44 ± 0.02 (7.41-7.47)	7.45 ± 0.03 (7.41-7.51)	-1.744	0.089
Compliance	52.60 ± 8.31 (44-81)	62.10 ± 7.65 (48-74)	-3.761	<0.001**
HCO3 (mEq/L)	26.50 ± 5.07 (20-39.9)	22.98 ± 2.33 (17-28)	2.824	0.008*

Changes in respiratory function and blood gases

Improvements in oxygenation (PaO2, SaO2, PaO2/FiO2), ventilation (PaCO2), acid-base balance (pH), pulmonary compliance, and bicarbonate levels were all significantly greater in the MV group compared to the IMT group (p<0.001). Table 4 illustrates the comparison between IMT group and MV group according to change of respiratory function and blood gases parameters. The change in PaO2 levels was significantly higher in the MV group (29.30±0.92) compared to the IMT group (20.30±2.36), with a p-value of <0.001, indicating a greater improvement in oxygenation in the MV group. The change in PaCo2 levels was significantly greater in the MV group (-6.66±2.22) compared to the IMT group (-4.21±1.81), with a p-value of <0.001, suggesting a more pronounced decrease in PaCo2 levels in the MV group. The change in PaO2/Fio2 ratio was significantly greater in the MV group (90.05±2.09) compared to the IMT group (59.85±2.08), with a p-value of <0.001, indicating a more substantial improvement in oxygenation efficiency in the MV group.The change in SaO2 levels was significantly greater in the MV group (4.57±0.94) compared to the IMT group (2.81±0.62), with a p-value of <0.001, suggesting a more pronounced increase in oxygen saturation in the MV group.The change in pH levels was significantly greater in the MV group (0.10±0.03) compared to the IMT group (0.05±0.02), with a p-value of <0.001, indicating a more substantial improvement in acid-base balance in the MV group. The change in compliance was significantly greater in the MV group (16.95±1.90) compared to the IMT group (11.10±1.07), with a p-value of <0.001, suggesting a more pronounced increase in lung compliance in the MV group. The change in HCO3 levels was significantly different between the two groups, with a decrease in the MV group (-3.42±1.68) and a minimal change in the IMT group (-0.43±1.47), with a p-value of <0.001, indicating a more substantial change in bicarbonate levels in the MV group.

Table (4): Comparison between IMT group and MV group according to change of respiratory function and blood gases parameters

Parameter	IMT Group MD ± SD / % Change	MV Group MD ± SD / % Change	Test value (MD / %)	p-value
PaO2 (mmHg)	20.30 ± 2.36 / 25.70 ± 3.44	29.30 ± 0.92 / 36.19 ± 1.97	-15.858 / -11.822	<0.001**
PaCO2 (mmHg)	-4.21 ± 1.81 / -10.22 ± 3.91	-6.66 ± 2.22 / -15.57 ± 4.49	3.817 / 4.019	<0.001**
PaO2/Fio2	59.85 ± 2.08 / 28.97 ± 1.63	90.05 ± 2.09 / 43.75 ± 2.46	-45.761 / -22.394	<0.001**
SaO2 (%)	2.81 ± 0.62 / 2.99 ± 0.66	4.57 ± 0.94 / 4.84 ± 1.03	-6.971 / -6.760	<0.001**
pH	0.05 ± 0.02 / 0.72 ± 0.15	0.10 ± 0.03 / 1.10 ± 0.28	-4.359 / -4.632	<0.001**
Compliance	11.10 ± 1.07 / 27.50 ± 4.95	16.95 ± 1.90 / 38.13 ± 6.02	-11.971 / -6.096	<0.001**
HCO3 (mEq/L)	-0.43 ± 1.47 / 0.81 ± 0.24	-3.42 ± 1.68 / -10.87 ± 2.70	-5.990 / -19.270	<0.001**

Table (4): Comparison between IMT group and MV group according to change of respiratory function and blood gases parameters.

Discussion

The findings of the present study revealed a significant improvement in pulmonary compliance, arterial oxygenation (PaO_2, SaO_2, and PaO_2/FiO_2

ratio), and acid-base balance (pH) in the ventilator inspiratory trigger sensitivity adjustment group compared to the threshold inspiratory muscle training group. This enhancement may be attributed to the direct modulation of ventilator settings, which allows precise control of the inspiratory load and respiratory drive. Adjusting the trigger sensitivity can facilitate active participation of the respiratory muscles while maintaining adequate ventilatory support, thereby promoting gradual strengthening of the diaphragm and accessory muscles without causing fatigue or barotrauma ((Elkins & Dentice, 2015;Bissett et al., 2019).This mechanism aligns with the concept of ventilator-assisted inspiratory muscle training, where lowering the trigger sensitivity increases the patient's work of breathing in a controlled manner, stimulating respiratory muscle hypertrophy and endurance (Ahmed et al., 2019 [16]). Improved muscle recruitment enhances alveolar ventilation, reduces atelectasis, and improves ventilation-perfusion matching, which explains the observed rise in PaO_2 and SaO_2 (Elbouhy et al., 2014 [17]; Eugênio, 2015 [18]). In contrast, threshold devices depend solely on patient effort and are limited by fatigue and inconsistent pressure generation, particularly in critically ill stroke patients with impaired neuromotor control. Moreover, the marked improvement in lung compliance in the trigger sensitivity group can be explained by enhanced alveolar expansion and prevention of Ventilator-Induced Diaphragmatic Dysfunction (VIDD). Regular adjustments of the trigger sensitivity reduce the duration of passive ventilation, preserving diaphragm contractility and elastic recoil (Ghiani et al., 2020; Huang et al., 2022). These physiological benefits contribute to a more efficient respiratory pattern and better gas exchange, as indicated by the significant reduction in $PaCO_2$ and improvement in PaO_2/FiO_2 ratio in this group.Previous studies have demonstrated similar outcomes. (Liaw et al., 2020) and (Elkins & Dentice, 2015) found that inspiratory muscle training—when combined with ventilator adjustments—enhances weaning success rates and shortens mechanical ventilation duration. In line with their results, the present study suggests that trigger sensitivity adjustment provides a more individualized and titratable approach to inspiratory muscle loading compared to conventional threshold IMT. This approach is particularly beneficial in acute stroke patients, where respiratory muscle weakness, impaired coordination, and altered central drive are common. Therefore, the significant improvement in the trigger sensitivity group underscores the importance of integrating ventilator-based inspiratory muscle training into standard care protocols for mechanically ventilated stroke patients. Such strategies may improve pulmonary mechanics, expedite weaning, and ultimately reduce ICU stay and mortality rates. Although the present study demonstrated significant improvements in pulmonary compliance and gas exchange following ventilator inspiratory trigger sensitivity adjustment, some previous studies have reported inconsistent or non-significant results regarding inspiratory muscle training in mechanically ventilated patients. Caruso et al. (2005) reported that inspiratory muscle training was ineffective in mechanically ventilated critically ill patients. The discrepancy with the present study may be explained by the different patient population—Caruso's participants were deeply sedated (GCS < 8) and unable to generate sufficient voluntary inspiratory effort. Furthermore, their intervention lasted only five days without progressive load adjustment, which likely limited neuromuscular adaptation. In contrast, the patients in the current study were more alert and received progressive load increments guided by the Borg scale, resulting in more effective respiratory muscle engagement.Similarly, Chang et al. (2011) found that ventilator-adjusted inspiratory muscle training did not improve weaning outcomes in difficult-to-wean patients. However, their sample included individuals with Chronic Pulmonary Diseases (COPD and ARDS), in whom respiratory mechanics are dominated by airway obstruction and chronic hyperinflation rather than central neuromotor weakness. The current study, conducted on acute stroke patients, targeted a different pathophysiological mechanism where central drive impairment and respiratory muscle weakness are the main contributors to ventilatory dysfunction. Cader et al. (2010) observed improvements in weaning indices but no significant changes in arterial oxygenation or lung compliance following threshold device training. This divergence could be attributed to the type of training device used, as threshold devices depend solely on patient effort and provide limited control over load progression. In contrast, the ventilator-trigger adjustment used in the present study allowed a titratable, precise inspiratory workload within a safe range, leading to more consistent improvements in pulmonary function.

The findings of the present study coincided with the results reported by (Abuzaid et al., 2024) who investigated the effects of trigger sensitivity adjustment on weaning outcomes in ventilator-induced diaphragmatic dysfunction. Their study demonstrated that optimizing trigger sensitivity improved patient–ventilator synchrony and facilitated weaning, which is consistent with our observation that ventilator adjustments can positively influence respiratory outcomes.

Similarly, the results are in agreement with (Zhang et al., 2022) who conducted a systematic review and meta-analysis on respiratory muscle training after stroke. They found that respiratory muscle training significantly reduced pulmonary complications and improved swallowing function. This supports our conclusion that Inspiratory Muscle Training (IMT) has broader rehabilitative benefits beyond ventilation weaning.

Our findings also align with those of (Ahmed et al., 2019) who provided a narrative review on IMT in patients with prolonged mechanical ventilation. They highlighted that IMT counteracts diaphragm weakness and improves inspiratory pressures, which is consistent with the improvements in tidal volume and maximal inspiratory pressure observed in our study.

In addition, the results are comparable to (Ismail et al., 2021) who studied the effect of modifying ventilator trigger sensitivity on arterial blood gases in ICU patients. Their findings showed significant improvement in PaO_2 and $PaCO_2$ following sensitivity adjustments, which coincides with our observation of improved oxygenation parameters.

Furthermore, the preliminary study by (Chang et al., 2022) on IMT in prolonged ventilator-dependent patients reported significant improvements in weaning parameters, including tidal volume and maximal inspiratory pressure. This supports our findings that IMT enhances respiratory muscle strength and facilitates weaning readiness.

The practical guide by (Bissett et al., 2019) also reinforces our results, emphasizing the importance of a multidisciplinary approach to IMT in ICU patients. Their recommendations highlight the role of physiotherapists and clinicians in ensuring safe and effective implementation, which is consistent with our clinical observations.

Moreover, Chen et al. (2012) demonstrated that exercise training improves pulmonary mechanics and functional status in prolonged mechanical ventilation patients. Their findings coincide with ours, showing that structured respiratory training enhances both physiological and functional outcomes.

However, our findings partially differ from those of Finally, (Condessa et al., 2013) reported no acceleration in weaning among patients with chronic critical illness after inspiratory muscle training. These patients had been ventilated for more than 30 days and exhibited severe diaphragmatic atrophy and poor neuromuscular responsiveness. Conversely, the patients in the present study were acutely ventilated (≥48 hours), making their respiratory muscles more capable of recovery and adaptation to training. Collectively, these contrasting findings highlight the importance of patient selection, disease acuity, and appropriate load titration in determining the effectiveness of inspiratory muscle training interventions. The current results suggest that early, progressive, ventilator-based inspiratory training is more effective in acute neurological populations than in chronically ventilated or heavily sedated patients.

Additionally, (Hao et al., 2021) discussed mechanical ventilation strategies for pulmonary rehabilitation based on patient–ventilator interaction. Their work supports our findings by emphasizing the importance of synchrony and individualized ventilator settings to optimize rehabilitation outcomes.

Finally, the narrative review by (Ambrosino & Vitacca, 2018) on patients needing prolonged mechanical ventilation coincides with our conclusions, stressing the complexity of care and the necessity of integrated approaches—including IMT, exercise, and ventilator optimization—to improve long-term outcomes.

Conclusions

Both approaches uplifted breathing and gas metrics, but ventilator changes excelled in PaO_2, $PaCO_2$, PaO_2/FiO_2, SaO_2, pH, and compliance. Clinically, this favors ventilator tweaks for breathing woes, with

IMT as backup for non-vent or long-support needs.

Limitations

Small sample limits broad application, and short trial misses lasting effects, urging bigger, longer studies with firm measures.

Clinical impact

Ventilator trigger shifts (MV) and threshold training (IMT) aid lung management in fresh stroke on vents as non-invasive adds, boosting function, weaning, and discharge while needing standardized probes for diverse groups.

Declaration of competing interest

The authors declare that there are no competing interests regarding the publication of this paper.

Declaration of generative AI in scientific writing

The authors confirm that no generative AI tools were used in the writing or data analysis of this manuscript.

Submission declaration and verification

By submitting this manuscript, the authors affirm that the content is original and has not been published elsewhere. All necessary permissions for data use, including patient consent, have been obtained.

Preprints

This manuscript has not been posted as a preprint and is being submitted to *Applied Ergonomics* for the first time.

Use of inclusive language

The authors affirm that the language used in this manuscript is inclusive and free from bias. Efforts have been made to ensure that all individuals, regardless of sex, gender, or background, are represented respectfully.

Reporting sex- and gender-based analyses

The study includes analysis based on sex and gender, and all data are reported with appropriate consideration of sex and gender differences where applicable.

Author contributions

Mohamed S. Zidan & Amira Abd ElHay: Conceptualization, methodology, data collection, and manuscript writing. Amir Abdel Moneam Mohamed Abo: Data analysis and interpretation, manuscript revision. Sara Rabie Elhadad: Literature review and manuscript editing.

Changes to authorship

No changes to authorship have been made after the submission of this manuscript.

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Responsible sharing

The authors commit to ensuring responsible sharing of data and materials, with appropriate access for verification purposes while respecting patient confidentiality.

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Informed consent statement: Secured from all involved.

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