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The Impact of Extracorporeal Shockwave Therapy on Pulmonary Function in Mechanical Neck Pain Patients

Kareem Ghaly¹, Nagwa Mohamed Badr², Rasha Mahmoud Attia³, Ramy Salama Draz^{4,5}

¹Assistant Lecturer, Department of Physical Therapy for Internal Medicine & Geriatrics, Faculty of Physical Therapy, Delta University for Science & Technology, Egypt.

²Professor of Physical Therapy for Cardiovascular /Respiratory Disorder and Geriatrics, Faculty of Physical Therapy, Cairo University, Egypt.

³Assistant Professor of Internal Medicine and Nephrology, Mansoura University Hospital, Faculty of Medicine, Delta University for Science & Technology, Egypt.

⁴Assistant Professor of Physical Therapy for Cardiovascular /Respiratory Disorder and Geriatrics, Faculty of Physical Therapy, Cairo University, Egypt.

⁵Assistant Professor of Physical Therapy for Internal Medicine and Geriatrics, Faculty of Physical Therapy, Pharos University in Alexandria, Egypt.

ABSTRACT: Background and purpose: Mechanical neck pain is a common musculoskeletal disorder associated with pain, disability, and impaired ventilatory function. Although extracorporeal shock wave therapy (ESWT) has shown beneficial effects in musculoskeletal disorders, its impact on ventilatory function in mechanical neck pain remains unclear. Objective: To investigate the effects of adding ESWT to conventional physiotherapy on ventilatory function, pain, and neck disability in patients with mechanical neck pain.

Material and methods: Forty male patients aged 20–30 years with mechanical neck pain were randomly assigned to two equal groups ($n = 20$). The control group received conventional physiotherapy, while the ESWT group received the same program plus ESWT once weekly for four weeks. Outcomes included Visual Analogue Scale (VAS), Neck Disability Index (NDI), and spirometric parameters (FVC, FEV₁, PEF, and MVV), assessed before treatment, immediately after treatment, and one month later.

Results: Both groups showed significant improvements in pain, disability, and ventilatory function over time ($P < 0.05$). The ESWT group demonstrated significantly greater reductions in pain and disability at post-treatment and follow-up ($P < 0.001$). Pain improved by 72.46% and 66.67% in the ESWT group versus 58.27% and 46.76% in controls, while NDI improved by 66.74% and 69.28% versus 40.42% and 36.21%, respectively. Although greater percentage improvements in FVC, FEV₁, PEF, and MVV were observed with ESWT, between-group differences were not statistically significant ($P > 0.05$).

Conclusion: Both interventions improved pain, neck disability, and ventilatory function. Adding ESWT resulted in significantly greater improvements in pain and disability, while pulmonary function showed greater clinical improvement without significant between-group differences. ESWT may be a useful adjunct to conventional physiotherapy for mechanical neck pain.

1. INTRODUCTION

Neck pain, a common musculoskeletal disease affecting 20-30% of adults in developed countries, imposes a significant clinical burden characterized by persistent discomfort, functional impairment, and significant socioeconomic expenses, and has emerged as a crucial global public health concern [1]. While a significant proportion of individuals with acute neck pain recover regardless of treatment, a considerable proportion continue to experience persistent or recurrent symptoms of varying severity [2]. In addition to musculoskeletal impairment, chronic neck pain is highly associated with concurrent dizziness and psychological distress. Together, these accompanying symptoms drive increased disability in daily function and lead to a significantly lower quality of life [3]

Due to its widespread occurrence and impact on patients' everyday activities, neck pain has been a prominent subject of investigation across multiple medical fields for an extended period. These investigations have examined the associated factors arising with or resulting from chronic neck pain, together with the impacts of various therapeutic methods. Numerous elements are linked to neck discomfort, including diminished cervical mobility, Dysfunction of cervical mobilisers and stabilisers, compromised proprioception, and alterations in posture. [4].

The physical consequences of chronic neck pain frequently contribute to the development of secondary respiratory dysfunctions. For instance, the associated weakness in the deep neck flexors and extensors compromises both cervical and thoracic spine stability, which subsequently leads to altered rib cage mobility and impaired respiratory mechanics [5]

Additionally, excessive activity in the superficial cervical muscles (sternocleidomastoid, upper trapezius, and anterior scalene), a reduction in cervical mobility, and/or alterations in head posture may result in modifications to the force-length curve of the respiratory muscles. Furthermore, the disruption of proprioception in individuals suffering from chronic cervical pain may modify neuro-motor patterns. [4]

Changes in neuro-motor patterns, alterations in rib cage mechanics, and/or variations in the force-length curve of respiratory muscles may result in respiratory dysfunctions or abnormalities in individuals suffering from chronic neck pain. [6]. Previous evidence has demonstrated that individuals with mechanical neck pain associated with excessive smartphone use exhibit significantly reduced peak expiratory flow (PEF), suggesting that cervical musculoskeletal dysfunction may adversely affect ventilatory function.[7]

The strong anatomical, musculoskeletal, and neurological links between the cervical region and the thoracic spine have motivated several researchers to propose that neck pain could induce biomechanical alterations in the thoracic spine and rib cage, thereby affecting respiratory function. Recently, the importance of the thoracic spine posture and related muscle function in neck kinematics and in the development of neck pain has been emphasised, theorising that there may exist a correlation between neck pain and respiratory dysfunction. [8]

Patients with chronic neck pain commonly exhibit localised hyperalgesia, limited range of motion, and diminished muscle strength. Research shows that patients with chronic neck pain frequently experience a decline in the strength, endurance, and motor control of accessory respiratory muscles, such as the sternocleidomastoid, anterior scalene, and trapezius muscles. This decline is associated with varying degrees of reduction in pulmonary function parameters. [9]

Extracorporeal shock wave therapy has recently emerged as an alternative treatment for myofascial pain syndrome. Extracorporeal shock wave therapy is characterised by a series of individual sonic pulses delivered by a suitable generator to a designated area. The transmission of an acoustic shock wave signal into biological tissue induces cell proliferation and differentiation via a mechano-transduction pathway. The advantages of extracorporeal shock wave therapy include its non-invasive nature and minimal adverse events. [10]

Research on extracorporeal shock wave therapy continues to grow to evaluate its efficacy, particularly for myofascial pain syndrome in the neck muscles, due to its analgesic properties and ability to stimulate soft tissue regeneration and repair. Ji et al., 2012 [11] Demonstrated the effectiveness of four sessions of extracorporeal shock wave therapy (0.056 mJ/mm², 1000 impulses, semiweekly) in alleviating pain in comparison to placebo in patients with myofascial pain syndrome involving the upper trapezius.

Jeon et al., 2012 [12] Examined the effectiveness of extracorporeal shock wave therapy relative to trigger point injection combined with transcutaneous electrical nerve stimulation in 30 subjects diagnosed with myofascial pain syndrome affecting

the trapezius muscle. Extracorporeal shock wave therapy demonstrated comparable efficacy to trigger point injection combined with transcutaneous electrical nerve stimulation in alleviating pain and enhancing cervical range of motion.

More recently, Faramawy et al., 2024 [13] Investigated the impact of incorporating extracorporeal shockwave therapy into conventional physiotherapy on the pressure pain threshold in individuals with chronic non-specific neck pain. The findings indicate that the addition of ESWT to the traditional physiotherapy regimen may enhance the pressure pain threshold more effectively than traditional physiotherapy alone in this group of patients.

2. MATERIALS AND METHODS

2.1 Participants

(40) male patients with mechanical neck pain were enrolled in this study; they were recruited from students of Delta University for Science and Technology.

They were enrolled into two groups:

- Group A: (20) participants received traditional physiotherapy treatment for mechanical neck pain (massage, hot packs, manual trigger point release, stretching exercises for upper trapezius, scaleneus, and sternocleidomastoid muscles)
- Group (B): (20) participants received traditional physiotherapy treatment for mechanical neck pain (massage, hot packs, manual trigger point release, stretching exercises for upper trapezius, scaleneus, and sternocleidomastoid muscles) in addition to shockwave therapy.

2.2 Subjects and Methods

Participants were eligible for inclusion if they were male patients diagnosed with mechanical neck pain, aged between 20 and 30 years, and with a body mass index (BMI) between 20 and 25 kg/m². Eligible participants had not previously participated in any ventilatory rehabilitation program, had a Neck Disability Index (NDI) score ranging from 10% to 48%, and demonstrated a craniovertebral angle greater than 48°.

Participants were excluded if they had chest disease; cardiovascular disorders, including coronary artery disease or peripheral vascular insufficiency; uncontrolled hypertension; metabolic disorders such as diabetes mellitus; peripheral or central nervous system diseases; tumors; rheumatoid arthritis; ankylosing spondylitis; fractures or dislocations; dermatological conditions or hemorrhagic blood diseases; long-term corticosteroid use; were currently receiving treatment for neck pain; had metal implants near the treatment area; or were smokers. Furthermore, individuals with forward head posture, defined as a craniovertebral angle of less than 48°, were excluded from the study [14].

In this study, FVC forced vital capacity, FEV1 forced expiratory volume in 1st second, MVV maximum voluntary ventilation, FEV1/FVC, and PEF Peak expiratory flow) were measured for each patient before starting the treatment procedure. After the therapy sessions were completed, ventilatory functions were measured again and compared to the results measured before the therapy sessions began, along with neck disability index (NDI) and visual analogue scale (VAS). These measurements were taken again after one month for long-term follow-up and assessment.

2.3 Procedures

Assessment of Craniovertebral Angle Using Kinovea Software

The craniovertebral angle was measured from the lateral view using the Kinovea software. Right-side sagittal-plane photos were captured with a digital camera and saved to a personal computer. Three photographs were taken to minimize bias from the subject's anxiety during photography and to compensate for measurement differences caused by postural sway in the standing position. The resulting images were analyzed using the Kinovea software to calculate the craniovertebral angle, defined as the angle between a horizontal line passing through C7 and a line extending from the tragus to the spinous process of C7. The data were collected and entered into an Excel spreadsheet to calculate the average angle for each participant. A craniovertebral angle of approximately 48° is considered normal, whereas lower values indicate forward head posture.[15]

Evaluation of Pain Severity via the Visual Analogue Scale (VAS)

Pain intensity was assessed using the horizontal Visual Analogue Scale (VAS). The VAS consisted of a 10-cm horizontal line with two anchor points representing "no pain" (0) at one end and "worst imaginable pain" (10) at the other. Participants were instructed to mark on the line the point that best represented the intensity of their neck pain at the time of assessment. The distance (in centimeters) from the "no pain" anchor to the participant's mark was measured and recorded as the VAS score. The horizontal VAS is a valid and reliable tool for measuring pain intensity and demonstrates excellent test–retest reliability and repeatability [16].

Assessment of Neck Disability Using the Neck Disability Index (NDI)

Neck-related disability was assessed using the Arabic version of the Neck Disability Index (NDI), which was translated and validated by [17]. The questionnaire consists of 10 items evaluating pain and activities of daily living. Each item is scored from 0 to 5, with a total score ranging from 0 to 50. The total score was converted into a percentage to determine the level of neck disability. Participants included in the present study had NDI scores ranging from 10% to 48%, corresponding to mild to moderate neck disability according to the classification proposed by [18]. The NDI is a valid and reliable outcome measure for assessing self-reported disability in patients with neck pain [19].

Assessment of Pulmonary Function

Pulmonary function was assessed using spirometry to evaluate ventilatory function. The assessed parameters included Forced Vital Capacity (FVC), Forced Expiratory Volume in one second (FEV₁), Peak Expiratory Flow (PEF), and Maximum Voluntary Ventilation (MVV). Spirometry is a valid and reliable method for assessing ventilatory function and detecting abnormalities in lung volumes and airflow [20].

Spirometry Procedure

Before testing, the purpose and procedures of the pulmonary function tests were explained to each participant using simple and clear instructions. Written informed consent was obtained from all participants before enrollment. Each participant completed the Neck Disability Index (NDI) questionnaire and the Visual Analogue Scale (VAS) for assessment of neck disability and pain intensity, respectively. A complete medical history was obtained, and each participant underwent a medical examination to exclude any contraindications to spirometry. Height and body weight were measured, and body mass index (BMI) was calculated. The craniovertebral angle was measured using Kinovea software. Participants were instructed to avoid consuming a heavy meal for at least two hours before testing.

Before each testing session, the spirometer was calibrated according to the manufacturer's recommendations. The participant was seated comfortably in an upright position with any tight clothing loosened. A disposable sterile mouthpiece was attached to the spirometer, and a nose clip was applied. The participant's demographic data, including age, sex, ethnicity, height, and weight, were entered into the spirometer before testing.

Participants were instructed to maintain a slightly elevated chin with the neck in slight extension throughout the testing procedure. After breathing normally for three tidal breaths, the participant was instructed to exhale completely, followed by a maximal inspiration and then a rapid, forceful, and complete expiration through the mouthpiece until no further air could be expelled. Each maneuver was repeated three times, and the highest acceptable value was selected for statistical analysis.

All spirometric maneuvers were performed according to the acceptability and repeatability criteria recommended by the American Thoracic Society (ATS) and the European Respiratory Society (ERS) [21]. An acceptable maneuver fulfilled the following criteria:

- No excessive hesitation or false start before the forced expiratory maneuver.
- No cough during the first second of forced expiration.
- No performance of a Valsalva maneuver before or during the test.
- No air leakage or obstruction of the mouthpiece by the tongue, teeth, or dentures.
- A rapid and forceful start of expiration.
- No premature termination of expiration; the expiratory maneuver continued for at least six seconds or until an obvious volume plateau was achieved.
- No variable effort during the maneuver.

- Acceptable reproducibility was achieved by obtaining at least three technically acceptable maneuvers with consistent results.

Extracorporeal Shock Wave Therapy (ESWT)

Participants allocated to the study group received extracorporeal shock wave therapy (ESWT) using the Swiss DolorClast® Master (EMS, Nyon, Switzerland). ESWT was administered once weekly for four consecutive weeks. During each treatment session, 2,000 shock wave pulses were delivered at an energy flux density of 0.2 mJ/mm² and a frequency of 10 Hz, according to the treatment protocol described by Taheri et al., 2021. The treatment was applied bilaterally over the accessory muscles of respiration in the neck, including the upper fibers of the trapezius, sternocleidomastoid, and scalene muscles.

Participants were positioned comfortably in the prone position with the head maintained in a neutral position throughout the treatment session. The treatment area was identified, and a conductive ultrasound gel was applied to ensure optimal transmission of shock waves and eliminate air pockets between the applicator and the skin.

The applicator was placed firmly over the treatment area with consistent pressure and moved slowly over the targeted muscles to ensure uniform distribution of shock waves. Treatment was administered bilaterally to the designated muscles. Throughout each session, participants were monitored continuously for any discomfort or adverse reactions.

2.4 Statistical Analysis

Statistical analyses were performed using SPSS version 25 for Windows (SPSS, Inc., Chicago, IL, USA). Prior to analysis, all data were screened for normality and homogeneity of variance. The Shapiro–Wilk test was used to assess the normality of distribution, and outliers were identified and removed using box-and-whisker plots. Homogeneity of variances was verified using Levene's test. Following confirmation that all assumptions were met ($P > 0.05$), parametric statistical tests were employed. Descriptive statistics (mean $\pm$ standard deviation) were calculated for all outcome variables (VAS, NDI, FVC, FEV₁, FEV₁/FVC, PEF, and MVV), as well as for demographic characteristics (age, weight, height, and BMI). Independent samples t-tests were used to compare baseline demographic and clinical characteristics between the two groups. To evaluate the main effects and interactions, a 2×3 mixed-design multivariate analysis of variance (MANOVA) was conducted. The between-subjects factor was group (traditional therapy vs. shockwave therapy), and the within-subjects factor was time (pre-treatment, post-treatment, and 1-month follow-up). For pairwise comparisons, Bonferroni-adjusted post-hoc tests were applied to control for Type I error due to multiple comparisons. Pairwise comparisons were conducted both within each group across the three time points and between the two groups at each time point. Effect sizes were calculated using partial eta squared (η^2) for the MANOVA and Cohen's d for pairwise comparisons, with values interpreted according to Cohen's guidelines (small: 0.2, medium: 0.5, large: 0.8 for d; and 0.01, 0.06, and 0.14 for η^2). All statistical analyses were significant at a probability ($P \leq 0.05$).

3. RESULTS AND DISCUSSION

3.1 Data Analysis

In this clinical trial, 40 males mechanical neck pain patients were participated in this study and randomly distributed into 2 equal groups in numbers ($n=20$ patients/group). The results of patients' clinical demographic data (Table 1) showed that no significant differences ($P > 0.05$) in mean values of patients' age ($P=0.053$), weight ($P=0.631$), height ($P=0.230$), and BMI ($P=0.423$) between the traditional therapy group and shockwave therapy group.

Table 1. Clinical demographic data of patients in both groups

Items	Groups		P-value
	Traditional therapy group (n=20)	Shockwave therapy group (n=20)	
Age (years)	23.55 $\pm$ 2.32	21.70 $\pm$ 3.32	0.053
Weight (kg)	72.50 $\pm$ 5.12	73.65 $\pm$ 9.30	0.631
Height (m)	1.75 $\pm$ 0.06	1.78 $\pm$ 0.08	0.230
BMI (kg/m ²)	23.52 $\pm$ 1.48	23.06 $\pm$ 2.03	0.423

Data are reported as mean $\pm$ standard deviation (SD) and compared by t-independent test.

P-value: probability value

P-value > 0.05 : non-significant

Table (2) summarizes the descriptive statistics and comparative analyses (both within- and between-group) for all outcome measures across the 3 assessment time points (pre-treatment, post-treatment, and 1-month follow-up).

The statistical analysis of within-group comparisons revealed that both treatment groups demonstrated significant improvements over time for the majority of outcome variables (P -value <0.05). The magnitude of the within-group time effect, measured by partial eta squared (η^2), ranged from medium to very large. Notably, the shockwave group exhibited very large effect sizes for pain (VAS, $\eta^2 = 0.904$) and disability (NDI, $\eta^2 = 0.885$), which were larger than those observed in the traditional therapy group (VAS, $\eta^2 = 0.803$; NDI, $\eta^2 = 0.653$). For pulmonary function, both groups showed large time effects for FVC, FEV₁, PEF, and MVV ($\eta^2 = 0.202$ – 0.538), with the shockwave group consistently demonstrating larger effect sizes across these parameters.

The statistical analysis between-group comparisons showed that at baseline (pre-treatment), there were no statistically significant differences between the two groups for any variable (P -value > 0.05). However, at post-treatment and 1-month follow-up, the shockwave therapy group showed significantly lower VAS and NDI scores compared to the traditional therapy group, with large between-group effect sizes (Cohen's d ranging from -1.28 to -2.79 , $P<0.001$). In contrast, between-group differences for all pulmonary function parameters (FVC, FEV₁, PEF, and MVV) were not statistically significant at any time point (P -value >0.05), with negligible to small effect sizes (Cohen's d ranging from -0.56 to 0.53). These findings indicate that while shockwave therapy provided superior relief for pain and disability, both interventions yielded comparable improvements in respiratory function.

Table 2: Within and between group comparison for main outcome variables

Variables	Items	Time			Effect size (partial η^2)	P -value ¹
		Pre-treatment	Post-treatment	After one month		
VAS	Traditional therapy group (n=20)	6.95 $\pm$ 0.68	2.90 $\pm$ 0.71	3.70 $\pm$ 1.21	0.803	$<0.001^*$
	Shockwave therapy group (n=20)	6.90 $\pm$ 0.64	1.90 $\pm$ 0.85	2.30 $\pm$ 0.73	0.904	$<0.001^*$
	Change (MD)	0.05	1.00	1.40		
	95% CI	-0.47 – 0.57	0.47 – 1.52	0.87 – 1.92		
	Effect size (Cohen's d)	-0.08	-1.28	-1.40		
	P -value ²	0.849	$<0.001^*$	$<0.001^*$		
NDI	Traditional therapy group (n=20)	21.40 $\pm$ 2.66	12.75 $\pm$ 3.04	13.65 $\pm$ 2.8	0.653	$<0.001^*$
	Shockwave therapy group (n=20)	21.65 $\pm$ 2.44	7.20 $\pm$ 2.89	6.65 $\pm$ 2.18	0.885	$<0.001^*$
	Change (MD)	0.25	5.55	7.00		
	95% CI	-1.47 – 1.97	3.82 – 7.27	5.27 – 8.72		
	Effect size (Cohen's d)	0.10	-1.87	-2.79		
	P -value ²	0.774	$<0.001^*$	$<0.001^*$		
FVC	Traditional therapy group (n=20)	3.12 $\pm$ 0.57	3.74 $\pm$ 0.5	3.66 $\pm$ 0.57	0.202	0.003 [*]
	Shockwave therapy group (n=20)	2.59 $\pm$ 0.62	3.99 $\pm$ 0.69	3.79 $\pm$ 0.66	0.470	$<0.001^*$
	Change (MD)	0.53	0.25	0.13		

	95% CI	-0.14 – 1.20	-0.13 – 0.63	-0.26 – 0.51		
	Effect size	-0.89	0.42	0.21		
	P-value ²	0.138	0.201	0.519		
F E V 1	Traditional therapy group (n=20)	2.46 ±0.57	3.11 ±0.46	2.91 ±0.47	0.228	<0.001*
	Shockwave therapy group (n=20)	2.11 ±0.51	3.24 ±0.44	3.10 ±0.47	0.530	<0.001*
	Change (MD)	0.35	0.13	0.19		
	95% CI	-0.04 – 0.74	-0.17 – 0.44	-0.12 – 0.49		
	Effect size (Cohen's d)	-0.65	0.29	0.40		
	P-value ²	0.352	0.399	0.234		
P E F	Traditional therapy group (n=20)	4.72 ±0.88	6.33 ±0.78	5.89 ±0.72	0.423	<0.001*
	Shockwave therapy group (n=20)	4.22 ±0.90	6.22 ±0.79	5.81 ±0.71	0.538	<0.001*
	Change (MD)	0.50	0.11	0.08		
	95% CI	-0.01 – 1.00	-0.40 – 0.61	-0.42 – 0.58		
	Effect size (Cohen's d)	-0.56	-0.14	-0.11		
	P-value ²	0.052	0.686	0.759		
M V V	Traditional therapy group (n=20)	98.52 ±22.98	124.62 ±18.52	116.60 ±18.98	0.227	<0.001*
	Shockwave therapy group (n=20)	94.48 ±20.70	129.92 ±17.99	124.08 ±19.02	0.394	<0.001*
	Change (MD)	4.04	5.30	7.48		
	95% CI	-1.65 – 9.73	-7.09 – 17.69	-4.91 – 19.87		
	Effect size (Cohen's d)	-0.19	0.29	0.39		
	P-value ²	0.402	0.399	0.234		

Data are reported as mean ± standard deviation (SD); MD: Mean difference; CI: confidence interval; η^2 : eta square;; P-value: probability value; *Significant (P<0.05)
P-value¹: probability value among pre, post, and after one month within each group; P-value²: probability value between both groups at pre, post, and after one month

Table (3) presents the pairwise post-hoc comparisons within each group for all outcome measures across the three assessment time points.

For pain and disability outcomes (VAS and NDI), both groups demonstrated highly significant and very large improvements in VAS and NDI from pre-treatment to post-treatment and from pre-treatment to 1-month follow-up (P<0.001; Cohen's d ranging from -2.91 to -7.81). However, the shockwave therapy group consistently exhibited larger magnitudes of change compared to the traditional therapy group for both VAS (MD: 5.00 vs. 4.05 at post; 4.60 vs. 3.25 at 1-month) and NDI (MD: 14.45 vs. 8.65 at post; 15.00 vs. 7.75 at 1-month). Critically, during the follow-up period (post-treatment vs. 1-month), the traditional therapy group experienced a significant rebound in pain (VAS: MD = 0.80, P=0.009, d=1.13), whereas the shockwave group maintained its pain reduction with no significant regression (VAS: MD = 0.40, P=0.392, d=0.47). For NDI,

neither group showed significant changes during follow-up, with the shockwave group even demonstrating a negligible continued improvement ($d = -0.19$, $P=1.000$).

For pulmonary function outcomes (FVC, FEV1, PEF, and MVV), both groups exhibited significant and large to very large improvements in all pulmonary function parameters from pre-treatment to post-treatment and 1-month follow-up ($P<0.05$; Cohen's d ranging from 0.79 to 2.26), with the shockwave group consistently achieving larger mean differences and effect sizes (e.g., FVC Pre-Post MD: 1.40 vs. 0.62; FEV1 Pre-Post MD: 1.13 vs. 0.65). During the follow-up period (post-treatment vs. 1-month), both groups showed small, non-significant declines across all parameters ($P>0.05$; Cohen's d ranging from -0.56 to -0.16), indicating that the therapeutic gains in lung function were largely sustained over the one-month period without significant deterioration.

Table 3: Comparison of main outcome variables between pairwise treatments within each group

Variables	Items	Pairwise post-hoc test							
		Traditional therapy group (n=20)				Shockwave therapy group (n=20)			
		MD (95% CI)	Change %	Effect size	P-value	MD (95% CI)	Change %	Effect size	P-value
VAS	Pre vs. Post	4.05 (3.41 – 4.69)	58.27%	-5.96	0.001*	5.00 (4.36 – 5.63)	72.46%	-7.81	<0.001*
	Pre vs. after one month	3.25 (2.61 – 3.88)	46.76%	-4.78	<0.001*	4.60 (3.96 – 5.23)	66.67%	-7.19	<0.001*
	Post vs. after one month	0.80 (0.19 – 1.43)	27.59%	1.13	0.009*	0.40 (-0.23 – 1.04)	21.05%	0.47	0.392
NDI	Pre vs. Post	8.65 (6.53 – 10.76)	40.42%	-3.25	<0.001*	14.45 (12.33 – 16.56)	66.74%	-5.92	<0.001*
	Pre vs. after one month	7.75 (5.63 – 9.86)	36.21%	-2.91	<0.001*	15.00 (12.88 – 17.11)	69.28%	-6.15	<0.001*
	Post vs. after one month	0.90 (-1.21 – 3.01)	7.06%	0.30	0.908	0.55 (-1.56 – 2.66)	7.64%	-0.19	1.000
FVC	Pre vs. Post	0.62 (0.14 – 1.09)	19.87%	1.09	0.006*	1.40 (0.92 – 1.87)	54.05%	2.26	<0.001*
	Pre vs. after one month	0.54 (0.06 – 1.02)	17.31%	0.95	0.019*	1.20 (0.70 – 1.67)	46.33%	1.94	<0.001*
	Post vs. after one month	0.08 (-0.39 – 0.55)	2.14%	-0.16	1.000	0.20 (-0.27 – 0.67)	5.01%	-0.29	0.899
FEV1	Pre vs. Post	0.65 (0.27 – 1.03)	26.42%	1.14	<0.001*	1.13 (0.75 – 1.51)	53.55%	2.22	<0.001*
	Pre vs. after one month	0.45 (0.07 – 0.83)	18.29%	0.79	0.014*	0.99 (0.61 – 1.37)	46.92%	1.94	<0.001*
	Post vs. after one month	0.20 (-0.17 – 0.58)	5.43%	-0.44	0.607	0.14 (-0.23 – 0.52)	4.32%	-0.32	1.000
PEF	Pre vs. Post	1.61 (0.99 – 2.22)	34.11%	1.83	<0.001*	2.00 (1.38 – 2.62)	47.39%	2.22	<0.001*
	Pre vs. after one month	1.17 (0.55 – 1.78)	24.79%	1.33	<0.001*	1.59 (0.97 – 2.20)	37.68%	1.77	<0.001*
	Post vs. after one month	0.43 (-0.17 – 1.05)	6.95%	-0.56	0.262	0.41 (-0.20 – 1.03)	6.59%	-0.52	0.321
MVV	Pre vs. Post	26.10 (10.90 – 41.29)	26.49%	1.14	<0.001*	35.44 (30.24 – 40.64)	37.51%	1.71	<0.001*
	Pre vs. after one month	18.08 (2.88 – 33.27)	18.35%	0.79	0.014*	29.60 (19.40 – 39.80)	31.33%	1.43	<0.001*
	Post vs. after one month	8.02 (-7.17 – 23.21)	6.44%	-0.43	0.607	5.84 (-9.35 – 21.03)	4.50%	-0.33	1.000

MD: Mean difference; CI: confidence interval; Effect size by Cohen's d ; P-value: probability value between pairwise of 3 different times (post-hoc test); * Significant ($P<0.05$)

3.2 Discussion

The primary objective of this randomized controlled trial was to investigate the therapeutic efficacy of adding Extracorporeal Shockwave Therapy (ESWT) to a traditional physical therapy program on ventilatory function in patients with mechanical neck pain. To address this, forty male mechanical neck pain patients, recruited from Delta University Outpatient Clinics, participated in this study and were randomly distributed into two equal parallel groups (20 participants per group): Traditional physiotherapy group and Combined therapy group (shockwave therapy + traditional therapy).

Preliminary baseline comparison revealed no significant differences ($P > 0.05$) between the two groups in age, weight, height, and Body Mass Index, indicating a well-balanced biometric starting point.

To ensure the internal validity of the outcomes, participant selection was governed by a stringent eligibility protocol. The study was strictly confined to non-smoking male adults aged 20 to 30 years, presenting with a normal Body Mass Index (20–25 kg/m²), mild-to-moderate cervical disability (NDI: 10%–48%), and a Craniovertebral Angle greater than 48°.

In an effort to isolate the true musculoskeletal link between the cervical spine and the respiratory system, candidates were systematically excluded if they presented with underlying cardiopulmonary or metabolic diseases, structural spinal pathologies, neurological deficits, local contraindications to shockwave application, concurrent analgesic therapies, or pronounced Forward Head Posture (CVA < 48°), (Shaghayeghfard et al., 2016). Consequently, this highly homogenized demographic profile effectively neutralized systemic, pharmacological, and bad-posture confounders, confirming that the subsequent ventilatory changes were strictly driven by the applied interventions.

The therapeutic impact was evaluated across three sequential intervals: pre-treatment, post-treatment, and after one month as a follow-up. Using a multi-systemic assessment battery comprising the Visual Analogue Scale (VAS), the Neck Disability Index (NDI), and ventilatory parameters (FVC, FEV1, PEF, and MVV).

- **The Visual Analogue Scale (VAS):**

The current research revealed a notable decrease in pain severity, as assessed by the Visual Analogue Scale (VAS), in both the traditional therapy and shockwave therapy groups following treatment, indicating that both interventions were effective in relieving mechanical neck pain. The improvement observed in the traditional therapy group may be attributed to the combined effects of pain-relieving modalities, stretching, and therapeutic exercises, which reduce muscle spasm, improve cervical mobility, and decrease mechanical stress on pain-sensitive cervical structures. However, the shockwave therapy group achieved a greater reduction in pain, with VAS scores improving by 72.46% compared with 58.27% in the traditional therapy group. Moreover, the between-group comparison demonstrated a statistically significant post-treatment difference favoring the shockwave group, suggesting that extracorporeal shockwave therapy provided additional analgesic benefits beyond conventional physiotherapy alone.

The superior pain reduction observed in the shockwave group may be explained by several physiological mechanisms. Extracorporeal shockwave therapy (ESWT) has been reported to exert a powerful analgesic effect through hyperstimulation analgesia, the modulation of nociceptive transmission, the reduction of substance P concentration, and the alteration of pain receptor activity [23], [24]. In addition, shockwave therapy may contribute to the deactivation of myofascial trigger points, the reduction of muscle tension, the improvement of local blood circulation (hypervascularity), and the stimulation of tissue healing processes. These effects collectively contribute to a reduction in pain perception and an improvement in cervical function [25], [26].

Moreover, the comparison between post-treatment and follow-up measurements revealed distinct patterns between the two groups. In the traditional therapy group, pain intensity increased significantly during the follow-up period, indicating a partial loss of treatment gains after the cessation of therapy. In contrast, the increase in pain observed in the shockwave therapy group was not statistically significant, suggesting a greater stability of treatment outcomes over time. This finding aligns with existing literature indicating that the therapeutic effects of shockwave therapy extend beyond the immediate treatment period; the mechanical stimuli trigger biological responses—such as mechanotransduction and tissue regeneration—that continue to influence pain modulation and healing long after the intervention has ended [27], [28].

The sustained improvement observed in the shockwave group may be attributed to the biological effects of extracorporeal shockwave therapy (ESWT), including tissue regeneration, neovascularization, and long-term neuromodulation [23], [28].

Unlike conventional pain-relieving interventions that mainly provide short-term symptomatic relief, ESWT induces structural and physiological changes, such as mechanotransduction-driven cellular repair, resulting in longer-lasting clinical improvements [27], [28]. Therefore, although both treatment approaches effectively reduced pain associated with mechanical neck pain, the addition of ESWT produced superior analgesic effects and better maintenance of treatment outcomes during follow-up, supporting its incorporation into rehabilitation programs when long-term pain control is a primary therapeutic goal.

- **Neck Disability Index (NDI):**

The present study demonstrated significant improvements in neck-related disability, measured by the Neck Disability Index (NDI), in both the traditional therapy and shockwave therapy groups following treatment, indicating that both interventions effectively reduced the functional limitations associated with mechanical neck pain. The improvement in the traditional therapy group may be attributed to pain reduction, increased cervical mobility, improved muscle flexibility, and restoration of normal movement patterns, thereby enhancing daily functional activities. However, the shockwave therapy group achieved greater improvement, with NDI scores decreasing by 66.74% compared with 40.42% in the traditional therapy group. At the one-month follow-up, disability reduction remained greater in the shockwave group (69.28% vs. 36.21%), suggesting that the addition of extracorporeal shockwave therapy produced superior functional outcomes beyond conventional physiotherapy alone.

The greater reduction in disability observed in the shockwave group may be attributed to its superior pain reduction, as mechanical neck pain commonly limits daily activities—including reading, driving, sleeping, concentration, personal care, lifting, and occupational tasks—assessed by the Neck Disability Index (NDI) [29]. Consequently, reduced pain is often accompanied by improved functional performance and lower perceived disability. The marked improvement in NDI scores may also reflect the ability of extracorporeal shockwave therapy (ESWT) to address both the symptomatic and functional consequences of mechanical neck pain [26]. This effect may be explained by ESWT-induced reductions in nociceptive input and muscle hypertonicity, improved local circulation, promotion of tissue healing, and deactivation of myofascial trigger points, leading to enhanced muscle performance, cervical movement efficiency, and restoration of normal functional activities [24], [25]. An important finding was the maintenance of functional improvements during follow-up, with both groups remaining significantly improved compared with baseline and showing no significant differences between post-treatment and one-month follow-up assessments. Notably, the shockwave group demonstrated a slight additional reduction in NDI scores (7.20 to 6.65), whereas the traditional therapy group showed a slight increase (12.75 to 13.65). Although these changes were not statistically significant, they may suggest better long-term maintenance of functional recovery with ESWT, consistent with evidence that it promotes tissue regeneration and repair beyond acute symptom relief [28].

The relationship between pain reduction and disability improvement should be considered when interpreting these findings. The greater pain reduction observed in the shockwave therapy group was accompanied by a greater reduction in disability, supporting the concept that pain is a major contributor to functional limitations in patients with mechanical neck pain. Therefore, interventions that provide superior analgesia and promote structural tissue repair may result in greater improvements in functional status and quality of life [26], [28]. Overall, although both traditional physiotherapy and extracorporeal shockwave therapy effectively reduced neck-related disability, the addition of shockwave therapy produced greater functional improvement and may better preserve treatment benefits over time, supporting its use as an adjunctive intervention for patients with mechanical neck pain, particularly when reducing disability and restoring functional independence are primary treatment goals.

- **Pulmonary Function Outcomes (FVC, FEV₁, PEF, and MVV):**

Subsequent statistical analysis revealed a compelling, dual-layered therapeutic outcome. Although between-group comparisons of ventilatory parameters did not reach statistical significance, likely reflecting the beneficial effects of conventional physiotherapy in both groups, the magnitude of improvement consistently favored the combined intervention. From a quantitative perspective, FVC improved by 19.87% in the conventional therapy group compared with 54.05% in the ESWT group post-treatment, with sustained gains of 17.31% and 46.33% at the one-month follow-up, respectively. Similarly, FEV₁ increased by 26.42% in the conventional therapy group and 53.55% in the ESWT group post-treatment, with maintained improvements of 18.29% and 46.92% at follow-up. For PEF, post-treatment increases of 34.11% and 47.39% were observed in the conventional therapy and ESWT groups, respectively, with corresponding follow-up improvements of 24.79% and 37.68%. MVV demonstrated comparable trends, improving by 26.49% in the conventional therapy group and 37.51% in the

ESWT group post-treatment, with sustained improvements of 18.35% and 31.33% at follow-up. Although a slight decline in treatment effects was observed in both groups at the one-month follow-up assessment, the improvements achieved in the ESWT group remained statistically significant relative to baseline, indicating sustained therapeutic benefits beyond the immediate post-treatment period. The consistency of this pattern across multiple spirometric indices strengthens the likelihood that the observed effects are robust and clinically relevant.

The observed improvements in pulmonary function following rehabilitation are consistent with prior evidence demonstrating that patients with chronic neck pain frequently exhibit reduced respiratory performance, including lower FVC, FEV₁, and MVV, compared with individuals without neck pain [30], [31]. These impairments may be primarily attributed to the close interrelationship between cervical musculoskeletal function and respiratory biomechanics. Chronic mechanical neck pain has been associated with altered cervicothoracic biomechanics, reduced thoracic mobility, diminished respiratory muscle strength, and increased activity, stiffness, and dysfunction of the accessory respiratory muscles, including the sternocleidomastoid, scalene, upper trapezius, and levator scapulae muscles [4], [5], [30], [32]. Pain and muscular tightness may disrupt normal neuromuscular control, restrict cervical and upper thoracic mobility, and impair the coordinated activity of cervical and respiratory muscles. These alterations can compromise both inspiratory and expiratory efficiency, resulting in reduced lung volumes, diminished airflow, and impaired ventilatory capacity. Furthermore, studies have demonstrated altered activity of accessory respiratory muscles, including the upper trapezius, anterior scalene, and related cervical muscles, in individuals with chronic neck pain, supporting the concept that pain and muscle dysfunction may disrupt coordinated breathing mechanics [33], [34]. More broadly, cervical proprioceptive and sensorimotor disturbances are recognized features of neck pain and may further contribute to restricted movement, altered muscle control, and reduced ventilatory efficiency [35].

Rehabilitation may reverse or mitigate these impairments through a set of interrelated mechanisms supported by the literature. Pain reduction can lessen protective muscle guarding and facilitate the restoration of cervical range of motion, which may subsequently improve the coordination between cervical and respiratory muscles [22], [25]. Improvements in neck function may also relieve mechanical constraints on the rib cage, enhance thoracic mobility, and support more efficient breathing mechanics, particularly in individuals with reduced pulmonary function and altered respiratory muscle strength [4], [5], [33]. Respiratory training has likewise been reported to improve pulmonary function and cervical mobility in individuals with non-specific chronic neck pain, further supporting the view that restoring movement patterns and neuromuscular control can enhance ventilatory performance [34], [36]. Collectively, these findings indicate that both rehabilitation approaches were effective in enhancing respiratory performance in patients with mechanical neck pain and reinforce the concept that cervical musculoskeletal dysfunction exerts a measurable influence on pulmonary mechanics.

The consistently greater improvements observed in patients receiving extracorporeal shockwave therapy (ESWT) compared with conventional rehabilitation alone may be attributed to the additional physiological, biological, and neuromuscular effects conferred by this therapeutic modality. Accumulating evidence indicates that ESWT exerts potent analgesic effects and is particularly effective in alleviating muscular pain, reducing tissue stiffness, and improving functional disability in patients with musculoskeletal disorders, including cervical myofascial pain syndromes [22], [25], [37], [38]. One of the principal mechanisms underlying these benefits appears to be the modulation of myofascial dysfunction. ESWT has been shown to decrease muscle hypertonicity and stiffness through both immediate and delayed effects. Acutely, the therapy reduces tissue stiffness at active myofascial trigger points, while delayed responses include reductions in stiffness in adjacent muscular regions, suggesting broader neuromuscular adaptations beyond the directly treated tissues [39]. This reduction in trigger-point sensitivity and muscular tension may contribute to normalization of cervical muscle function, restoration of more efficient movement patterns, and improvement in cervical mobility.

Beyond these mechanical and neuromuscular effects, ESWT also induces important regenerative biological responses. The mechanical stimulus generated by shockwaves promotes tissue healing through several interconnected pathways, including stimulation of growth factor release, modulation of inflammatory processes, activation of the innate immune response, and enhancement of local microcirculation [40]. In particular, ESWT has been shown to stimulate angiogenesis, leading to the formation of new blood vessels and improved tissue perfusion. Such improvements in local circulation may facilitate oxygen delivery, metabolic exchange, and recovery of dysfunctional cervical musculature, thereby contributing to sustained reductions in pain and disability.

The superior clinical outcomes observed in the ESWT group are therefore likely the result of these combined analgesic, regenerative, and neuromuscular mechanisms. In patients with neck-related myofascial pain, previous studies have consistently demonstrated that ESWT reduces pain intensity and neck disability while simultaneously improving tissue-level recovery and decreasing myofascial trigger-point sensitivity [22], [25], [37], [38]. These effects may have particular relevance to respiratory function because increasing evidence suggests that cervical pain and myofascial dysfunction are closely associated with impaired respiratory muscle performance, altered breathing patterns, and reduced thoracic mobility [5], [33]. Pain, muscular guarding, and cervical stiffness can adversely affect the coordinated activity of accessory respiratory muscles, including the sternocleidomastoid, scalene, and upper trapezius muscles, thereby limiting thoracic expansion and compromising ventilatory efficiency. Consequently, the ability of ESWT to reduce pain, normalize muscle tone, and restore cervical biomechanics may indirectly facilitate more effective activation of respiratory musculature during both inspiration and expiration. Improved cervical mobility and reduced myofascial restrictions may also enhance thoracic excursion and chest wall mechanics, providing a plausible explanation for the greater improvements in ventilatory parameters observed in the shockwave therapy group compared with conventional rehabilitation alone. Taken together, these findings suggest that the benefits of ESWT extend beyond simple pain relief and may involve a multidimensional therapeutic effect encompassing analgesia, restoration of neuromuscular function, enhancement of tissue regeneration, and improvement of biomechanical factors that influence respiratory performance. Such integrated mechanisms may explain why the addition of ESWT resulted in superior functional outcomes and greater improvements in ventilatory function among patients with mechanical neck pain.

The improvement in MVV deserves particular consideration, as it reflects the integrated performance of the respiratory system, including respiratory muscle strength and endurance, airway patency, thoracic mobility, and neural control of breathing. [41]. The observed increases in MVV suggest that rehabilitation not only improved isolated aspects of pulmonary function but also enhanced the overall capacity for sustained ventilatory effort. This finding further supports the hypothesis that addressing cervical musculoskeletal dysfunction can yield meaningful improvements in global respiratory performance.

Across outcomes, improvements were observed not only immediately post-treatment but were also largely maintained at the one-month follow-up, with no statistically significant differences between post-treatment and follow-up measurements within either group. This pattern suggests that the therapeutic gains achieved were not transient but rather reflect sustained improvements in respiratory mechanics and neuromuscular function following rehabilitation. Importantly, the sustained improvements observed at follow-up suggest that both interventions may promote persistent adaptations in neuromuscular function, postural control, and movement patterns. Notably, although between-group comparisons did not reach statistical significance for any pulmonary parameter, the shockwave therapy group consistently demonstrated greater percentage improvements from baseline across all variables, both immediately after treatment and at follow-up. The consistent trend favoring the extracorporeal shockwave therapy group is plausible given that ESWT has been reported to improve pain and function in cervical myofascial pain and other musculoskeletal disorders [22], [25], [37]. The superior maintenance of treatment effects in the shockwave therapy group is further supported by previous evidence indicating that extracorporeal shock wave therapy exerts prolonged biological and analgesic effects beyond the immediate treatment period. These longer-term benefits may be attributed to its ability to modulate nociceptive activity, influence fascia-related pain mechanisms, reduce peripheral sensitization, and improve muscle function, thereby contributing to the continued preservation of clinical gains over time [23]. Furthermore, recent clinical findings demonstrating sustained improvements following ESWT in patients with myofascial pain syndrome provide additional support for the notion that shockwave therapy can induce longer-lasting therapeutic effects compared with conventional interventions alone [42]. Collectively, this recurring pattern may indicate a clinically meaningful advantage associated with the addition of extracorporeal shockwave therapy, despite the absence of statistical superiority.

Although no statistically significant between-group differences in pulmonary function were observed, several factors may explain this finding. First, the conventional physiotherapy program itself was highly effective, producing significant improvements in all spirometric parameters through pain reduction, improved cervical mobility, and restoration of more efficient respiratory mechanics [43], [44]. Furthermore, although patients with mechanical neck pain commonly exhibit impaired respiratory function, the participants in the present study were young, non-smoking males without cardiopulmonary disease, obesity, neurological disorders, or forward head posture. Therefore, their respiratory dysfunction was likely mild and primarily related to mechanical neck pain rather than underlying respiratory pathology. This may explain why both groups demonstrated significant improvements, while the ESWT group consistently showed greater percentage gains that did not reach statistical significance.

[45] reported a partially inconsistent finding, investigating the effects of breathing re-education combined with conventional physiotherapy in patients with chronic neck pain. Their randomized controlled trial demonstrated a significant between-group improvement in FVC; however, no significant differences were observed between groups for FEV₁ or the FEV₁/FVC ratio. Several methodological differences may explain this discrepancy. First, the primary intervention in their study consisted of breathing re-education, which specifically targets ventilatory mechanics and respiratory muscle coordination, whereas the present study employed extracorporeal shock wave therapy aimed primarily at reducing pain and improving cervical soft tissue function. Second, their study included a relatively small sample (15 participants per group), which may have limited the statistical power to detect between-group differences in some spirometric variables. Finally, pulmonary adaptations following breathing exercises may occur differently from those induced indirectly through pain reduction and restoration of cervical muscle function after ESWT.

Overall, these findings reinforce the concept that pulmonary dysfunction in patients with mechanical neck pain is, at least in part, a secondary consequence of musculoskeletal impairments rather than a primary respiratory disorder. Both traditional physiotherapy and extracorporeal shockwave therapy appear effective in addressing these impairments and improving respiratory outcomes. Although statistical superiority of shockwave therapy was not demonstrated, the consistently greater magnitude and persistence of improvement across all pulmonary parameters suggest a potential additional clinical benefit. Further large-scale randomized controlled trials with extended follow-up durations are warranted to determine whether these clinically meaningful differences can be confirmed statistically and to better elucidate the mechanisms underlying these effects.

- **Limitations of the Study**

Several limitations should be considered when interpreting the findings of the present study. First, the relatively small sample size may have limited the statistical power to detect significant between-group differences in pulmonary function outcomes despite the consistently greater percentage improvements observed in the extracorporeal shockwave therapy (ESWT) group. Second, the study included only young male participants aged 20–30 years with normal body mass index, which limits the generalizability of the findings to females, older adults, overweight individuals, or patients with different clinical characteristics. Third, the follow-up period was limited to one month; therefore, the long-term sustainability of the observed therapeutic effects remains uncertain. Finally, although pulmonary function was comprehensively assessed using spirometry, no direct measurements of respiratory muscle strength, chest wall mobility, diaphragmatic function, or cervical muscle activity were performed. Future studies incorporating these physiological assessments, together with larger and more diverse samples and longer follow-up periods, are recommended to further clarify the mechanisms underlying the observed improvements and to determine the long-term clinical benefits of ESWT in patients with mechanical neck pain.

4. CONCLUSION

Both conventional physiotherapy and extracorporeal shock wave therapy combined with conventional physiotherapy were effective in reducing pain, improving neck disability, and enhancing ventilatory functions in patients with mechanical neck pain. Although no statistically significant between-group differences were observed in pulmonary function parameters, the ESWT group demonstrated greater clinical improvements in ventilatory function together with significantly superior reductions in pain intensity and neck disability. Therefore, ESWT can be considered a valuable adjunct to conventional physiotherapy in the rehabilitation of patients with mechanical neck pain.

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AUTHOR CONTRIBUTIONS

Kareem Ghaly: Conceptualization, methodology, investigation, data collection, data analysis, and writing of the original manuscript.

Nagwa Mohamed Badr: Supervision, methodology, and critical revision of the manuscript.

Rasha Mahmoud Attia: Supervision, methodology, and critical revision of the manuscript.

Ramy Salama Draz: Statistical analysis, interpretation of results, and critical revision of the manuscript.

All authors reviewed and approved the final version of the manuscript.

CONFLICT OF INTEREST

The authors declare that there is no conflict of interest.

ETHICS STATEMENT

The study was approved by the ethical committee of the Faculty of Physical Therapy, Cairo University (No: P.T.REC/012/005775), and the principles of the Declaration of Helsinki were followed. A signed informed consent form was obtained from each participant's parents before the evaluation procedures began.

DATA AVAILABILITY STATEMENT

Data supporting the findings of this study are available from the corresponding author upon reasonable request.

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