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Outcomes of physical therapy program on respiratory and phrenic nerve functions in cervical disc compression

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Khaled Takey Ahmed[1,2], Abla Mohamed Hamed[1], Walaa Mohsen Mohamed[3], Akram M. Helmy[4], Ayman El Khatib[2]

[1] Department of Physical Therapy for Cardiopulmonary Disorders and Geriatrics, Faculty of Physical Therapy, Misr University for Science and Technology, Giza, Egypt
[2] Department of Physical Therapy, Faculty of Health Sciences, Beirut Arab University, Beirut, Lebanon
[3] Department of Physical Therapy for Musculoskeletal Disorders and its Surgeries, Faculty of Physical Therapy, Misr University for Science and Technology, Giza, Egypt
[4] Faculty of Physical Therapy, City University of Cairo, Cairo, Egypt

Abstract

Introduction. Pulmonary compromise may result in further comorbidities and increased mortality among spinal cord lesion patients. The current study was designed to evaluate the planned physical therapy protocol's efficacy on pulmonary function and phrenic nerve activities in cervical disc lesions.
Methods. Thirty participants from the spinal unit – Al Salam International Hospital had an acute fifth and/or upper cervical compressed disc. The mean age range was 43.17 ± 2.90 years. Pulmonary functional tests of vital capacity (VC), forced expiratory volume in the first second (FEV1), forced vital capacity (FVC), maximum voluntary ventilation (MVV), and peak expiratory flow rate (PEF) were measured via spirometry, diaphragmatic excursion via ultrasound, and phrenic amplitude and distal latency (PNL) via electromyography at baseline and 3 months later. The treatment protocol involved a hot pack, cervical traction, and ultrasound, in addition to diaphragmatic breathing exercise training.
Results. The obtained results revealed remarkable improvement in all measured outcomes compared to the mean values of pre- and post-treatment. Highly statistically significant increases in FEV1, MVV, diaphragmatic excursion, and amplitude of the phrenic nerve were determined (0.0001), along with significantly reduced PNL at post-intervention (0.0001) compared to baseline.
Conclusions. The improvement obtained in all measured parameters may be attributed to the effect of the intensive treatment program, which led to controlling pain and increasing respiratory muscle strength.
Key words: cervical disc compression, diaphragmatic excursion, phrenic nerve, pulmonary function testing, ultrasonography

Introduction

The protruded cervical disc may result in damage to the respiratory descending bulbospinal route, which leads to hemidiaphragmatic weakness, and even paralysis [1].

Cervical spinal cord injury leads to breathing difficulties because of the motor phrenic neuronal lesion and subsequent destruction at the neuromuscular junction of the diaphragm. Thus, damaged descending respiratory bulbospinal axons lead to the inactivation of intact phrenic motor neurons [2]. Pulmonary dysfunction is a major contributor to death and illness following spinal cord injury (SCI), both immediately after the injury and in the years that follow. Cervical trauma disrupts the crucial neurological connections that regulate various respiratory muscles, specifically the diaphragm [2].

Spinal cord injuries at the C4–5 levels have revealed that late sequelae of such injuries include disturbed breathing patterns, peripheral motor phrenic neuron damage, and alteration of diaphragmatic function [3].

Pulmonary function testing is a significant global assessment of pulmonary function, which can be influenced by various factors such as the severity of the spinal lesions, duration since the injury, age, respiratory muscle strength, surrounding environment, and concurrent respiratory disorders [4].

Cervical spondylosis is a significant and occasionally overlooked factor that can lead to diaphragmatic paralysis. Therefore, it is recommended to include an MRI scan of the cervical spine when investigating persons who are experiencing diaphragmatic dysfunction and paralysis without an obvious explanation [5].

Understanding the potential and constraints of imaging methods for assessing the diaphragm is an essential starting point in evaluating individuals with suspected diaphragmatic dysfunction. Diaphragmatic ultrasound imaging is an affordable and easily transportable method that enables the evaluation of diaphragmatic thickness and movement at certain times or over time. This approach can also aid in the identification of disease processes that cause diaphragmatic dysfunction and in making clinical decisions [6].

The diaphragm is the main human respiratory musculature that receives phrenic nerve supply and whose compound functional potentials could be evaluated through placing non-invasive electrodes on the chest [7].

Respiratory impairment has been widely reported in cervical lesions, and involvement of the phrenic nerve may be considered a contributory factor [8]. The authors evaluated whether including a physical therapy program with advanced respiratory assessment in an ordinary therapy program would improve respiratory functions.

Correspondence address: Khaled Takey Ahmed, Department of Physical Therapy for Cardiopulmonary Disorders and Geriatrics, Faculty of Physical Therapy, Misr University for Science and Technology, 26th of July Corridor, 6th of October, Giza Governorate, Egypt, e-mail: khaled.takey@must.edu.eg; https://orcid.org/0000-0001-7731-1630

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The purpose of the current study was to evaluate the planned physical therapy protocol's efficacy on pulmonary function and phrenic nerve activities in cervical disc lesions.

Subjects and methods

Thirty patients with cervical myelopathy because of prolapsed disc lesions, mainly at the C5 level and higher, for 6–8 months. Before their involvement in the clinical study, they had not undergone any physical therapy regimen.

Every participant completed a comprehensive medical history assessment and a meticulous clinical examination. Participants who smoked, had concurrent conditions that impair lung function, or had any condition that hinders spirometry were ineligible for participation in this study. Cervical X-ray films were conducted in both the posteroanterior and lateral views, utilising a grading method known as the cervical degenerative index. MRI examination confirmed disc prolapse classified as grade 3 or 4. This study excluded patients with cervical spine injuries and individuals receiving subsequent surgical procedures.

After receiving the participant's agreement, electrophysiological investigations were carried out in a 27°C restful room. Each individual was positioned in a comfortable supine position [9]. The study was carried out with a four-channel electromyography apparatus (Neurosoft E.M.G – SN:1083QZ). A bilateral phrenic nerve conduction study (NCV) was done utilising bipolar stimulation at the clavicular and sternal sternocleidomastoid heads. The xiphoid process was the site of the active (G1) electrode, while the reference (G2) was positioned 16 cm ipsilaterally from the border of the chest relative to G1. A predetermined set of amplitudes (mV), and distal phrenic motor latencies (ms) at supramaximal levels were determined [10]. The NCV was also utilised as an objective technique to determine the phrenic nerve conduction velocity and amplitude from each side.

Bilateral motor diaphragmatic responses, unilateral minimal motor superimposed responses, and reactions to the strongest stimuli were detected. Each participant assessed his or her particular motor-evoked reaction to the peak-to-peak stimuli on both sides [11].

The well-tolerated motor phrenic response was carried out via noninvasive stimuli that are independent of the participant's exertion across the current study. None of the participants had experienced significant phrenic stimuli of unusual reactions [12].

A spirometer (Chestgraph HI-801) was used to assess the pulmonary function of all participants. A physiologist who specialised in pulmonary physiology performed the lung function tests.

Spirometry was used to assess pulmonary functions including both vital capacity (VC), and forced (FVC), as well as forced expiratory volume in the first second (FEV_1), peak expiratory rate of flow (PEF), and maximum voluntary ventilation (MVV) when in a sitting position. VC was determined by instructing the participant to perform a deep nasal inhale and then to gently exhale. To determine FVC, FEV1, and PEF, the patients were instructed to exhale strongly and quickly following full inhalation. This movement was repeated at least three times to determine the MVV according to the spirometer's manual's guidelines, including suggestions from the American Thoracic Society and the European Respiratory Society [13].

Diagnostic ultrasonography (M-sonography model) was used to detect diaphragmatic excursion. In the supine position, we used the M-sonography mode to examine the craniocaudal diaphragmatic excursion amplitude with deep inhalation. We measured the vertical distance on the graph between the baseline and the highest inhalation. This was performed before and after three months of treatment to assess the physiological and mechanical impacts of the program.

Patients participated in a physical therapy program consisting of three treatment sessions per week, each lasting 30 min, for three months. The therapy involved using infrared heat therapy (Infralux Infrared Heat Lamp Device) with a peak power of 580 watts and a frequency of 50–60 Hz on the cervical region. The purpose of this therapy was to relax spasming neck muscles [14] while the participants were in a supported sitting position. An ultrasound device frequency of 3 MHz (ENRAF NONIUS DELFT– SONOPULS 434) was utilised to manage pain. The patient was in a seated position, and the ultrasound was delivered to the paraspinal muscles in the cervical area.

An Eltrac 471 device was used for cervical traction to increase the space between the cervical vertebrae. The participants underwent intermittent cervical traction, where the applied force was equal to 8% of their weight, while they maintained a neutral head posture in a supine position.

Physical inspiratory muscular training (IMT) focuses on using specific musculature, i.e. the diaphragm, intercostals and sternocleidomastoid, to repeatedly inhale against resistance. Exhalation, on the other hand, is not restricted.

Participation in the IMT group demanded extensive inhalation efforts. Each breath was performed with an intensity equivalent to 50–60% of the maximal inspiratory pressure (PImax). Each patient was directed to divide the inhaled sets of remaining air in the lungs and to sustain the effort of inhaling until they achieved the highest possible pressure in their lungs for a minimum duration of one second. Throughout the experiment, each participant was required to wear a nose clip during every breath and was oriented to breathe in a relaxed manner (limited frequency), which sustained a normal ventilating pattern [15].

The researchers determined the initial training load, and a pressure threshold device (HS 730-010, Ltd., UK) was used to train all the inspiratory attempts. Each patient was directed to gradually increase the resistance load until it reached an approximate threshold for inhalation musculature endurance. The most successful participants followed the given instructions to fill out perfect respiratory training diaries. All results were evaluated by the same investigator. The experimental techniques were the same for both the pretest and posttest [15, 16].

The valve of the pressure threshold device was opened to facilitate respiration, and the inhalation ceased when the inhalation pressure dropped below the planned threshold. In essence, gradational loading instruments are designed to achieve a precise inhaling pressure required to commence inhalation. Over time, however, the resistance to inspiration gradually decreases, allowing increased inhalation capacity even as exertional output decreases [16].

Statistical analysis

The Shapiro–Wilk test ensured data normality ($p > 0.05$), where outliers were managed, discovered, and checked via box and whisker plots. Levene's test ensured homogeneity of variance ($p > 0.05$). The SPSS program version 25 (Inc., Chicago, IL) was used for statistical analysis. The mean and standard deviation were reported for various demographic variables (age, height, weight, and BMI), VC, FVC, PEF, FEV, MVV, diaphragmatic excursion, phrenic nerve latency, and phrenic nerve amplitude. The sex variable is represented in qualitative data as frequency, expressed as a percentage.

A paired *t*-test compared major variable outcomes between the initial and end of the intervention. The effect size was calculated using Cohen's *d*, where 0.2 was considered to represent a small effect size, a value of 0.5 represents a medium effect size, and a value of 0.8 represents a large effect size. The significance level was set at < 0.05.

Results

This prospective study included a group of 30 patients, comprising 17 males and 13 females, who were diagnosed with cervical spondylotic myelopathy predominantly caused by a prolapsed intervertebral disc. The average values with standard deviations (*SD*) of age, height, weight, and body mass index (BMI) of the patients are presented in Table 1.

Table 1. Clinical general demographic variables

Demographic variable	Prospective study group (*n* = 30)
Age (year, mean ± *SD*)	43.17 ± 2.90
Weight (kg, mean ± *SD*)	74.53 ± 3.18
Height (cm, mean ± *SD*)	167.33 ± 3.66
BMI (kg/m^2, mean ± *SD*)	26.63 ± 1.32
Sex [males : females, *n* (%)]	17 (56.7%) : 13 (43.3%)

The mean ± *SD* values of VC at baseline and post-intervention were significantly higher at post-intervention (0.0001), with a large effect size of 1.47 compared to baseline with a higher percentage (Table 2). The mean ± *SD* values of FVC at baseline and post-intervention were significantly higher at post-intervention (0.0001), with a large effect size of 1.36 compared to baseline with a higher percentage (Table 2). The mean ± *SD* values of FEV_1 at baseline and post-intervention were significantly higher at post-intervention (0.0001), with a large effect size of 2.06 compared to baseline with a higher percentage (Table 2). The mean ± *SD* values of PEF at baseline and post-intervention were significantly higher at post-intervention (0.0001), with a medium effect size of 0.55 compared to baseline with a higher percentage (Table 2). The mean ± *SD* values of MVV at baseline and post-intervention were significantly higher at post-intervention (0.0001), with a large effect size of 1.76 compared to baseline with a higher percentage (Table 2). The mean ± *SD* values of DE at baseline and post-intervention were significantly higher at post-intervention (0.0001), with a large effect size of 0.89 compared to baseline with a higher percentage (Table 2). The mean ± *SD* values of phrenic nerve latency (PNL) at baseline and post-intervention were significantly reduced at post-intervention (0.0001) with a large effect of 1.63 size compared to baseline with a higher percentage (Table 2). The mean ± *SD* values of phrenic nerve amplitude (PNA) at baseline and post-intervention were significantly elevated at post-intervention (0.0001), with a large effect size of 1.25 compared to baseline a higher percentage with a percentage (Table 2).

Discussion

Chronic cervical compressed spinal roots may result in decreased intercostal muscle tone and autonomic nervous system imbalance, probably contributing to respiratory dysfunction. Predominant sympathetic activity rather than parasympathetic neurons can be considered another cause of dysfunctional breathing [17, 18].

Toyoda et al. [18] stated that the average percentage of VC and FVC notably reduced within cervical myelopathy patients in comparison to lumbar stenosis patients. Myelopathy participants exhibited a greater respiratory rate. The authors also divided the patients in the cervical myelopathic investigation into two groups based on the location of their lesions: those located above C3–C4 and those located below C3–C4. The cephalad group exhibited a considerably reduced percentage of VC in comparison to those with caudal lesions.

Prior research corroborated the present study's findings, indicating the presence of subclinical pulmonary dysfunction among chronic myelopathy patients. This dysfunction manifested as impaired FVC, FEV_1, FEV1/FVC ratio, peak expiratory flow rate (PEFR), and MVV. The lung capacity of these individuals was significantly impaired compared to that of the healthy individuals [19].

Another study verified the current study and affirmed that individuals suffering from chronic cervical pain with diminished VC, minute volume, and exhale reserve volume also have reduced FVC in comparison to the predicted models. Respiratory impairment is connected with cervical spine muscle dysfunction, pain severity, and kinesiophobia [20].

Diaphragmatic nerve palsy has been frequently observed because of a C4 cervical root lesion. Nevertheless, solely

Table 2. Comparison between pre-and post-intervention for main variable outcomes

Variables	Intervention pre- (*n* = 30) mean ± *SD*	Intervention post- (*n* = 30) mean ± *SD*	Change (MD)	95% CI	Improvement (%)	Effect size	*p*-value
VC	55.82 ± 6.50	65.58 ± 6.71	9.76	8.84–10.70	17.48	1.47	0.0001*
FVC	50.68 ± 9.28	62.85 ± 8.56	12.17	10.81–13.50	24.01	1.36	0.0001*
FEV_1	54.75 ± 7.68	68.51 ± 5.45	13.76	11.05–16.46	25.13	2.06	0.0001*
PEF	49.16 ± 10.56	54.63 ± 9.17	5.47	3.81–7.12	11.13	0.55	0.0001*
MVV	46.27 ± 7.27	59.07 ± 7.26	12.80	9.12–16.47	27.66	1.76	0.0001*
DE	3.26 ± 0.36	3.60 ± 0.40	0.34	0.25–0.42	10.43	0.89	0.0001*
PNL	6.37 ± 0.33	5.87 ± 0.28	0.50	0.35–0.65	7.85	1.63	0.0001*
PNA	0.69 ± 0.14	0.90 ± 0.19	0.21	0.15–0.26	30.43	1.25	0.0001*

VC – vital capacity, FVC – forced vital capacity, FEV_1 – forced expiration volume, PEF – peak expiration flow, MVV – maximal voluntary ventilation, DE – diaphragmatic excursion, PNL – phrenic nerve latency, PNA – phrenic nerve amplitude
* significant

relying on radiologic data makes it challenging to promptly identify C4 cervical neural root myopathy, ensured by the paralytic hemidiaphragm. Electrophysiological examinations, such as phrenic NCS and/or electromyographic studies, are highly valuable for diagnostic purposes [21].

Yousefiyan et al.'s [8] results agree with our reported findings. One of the reasons for diaphragmatic dysfunction in individuals with unilateral cervical radiculopathy is the limited diaphragmatic movement because of neural root irritation associated with phrenic innervation. Continued compressed ipsilateral phrenic innervation can ultimately result in trophic alterations and disruption in the nourishment and functioning of the nerve. As a result, there may be a weakening of the diaphragm with an altered breathing pattern.

Cervical spondylosis is a commonly overlooked factor that contributes to delayed distal motor latency (DML) of the phrenic nerve. An association exists between phrenic DML and cervical spondylotic severity, which is in agreement with the current study [9].

The patients in an experiment with cervical spondylosis had remarkable phrenic DML compared to the control participants. This delay may indicate demyelination, which could be caused by hypoxia resulting from compression that affects the myelination and conduction of impulses [22].

It is worth noting an unobserved substantial decrease of the compound phrenic motor action potential amplitude in the group of patients. It is hypothesised that this phenomenon may be attributed to the preservation of the phrenic nerve axons, which remain uninjured by the compression and lack of oxygen induced by spondylosis. Severe disc prolapse and myelopathies are associated with increased degrees of compression [23].

Ali et al. [9] observed a substantial and meaningful association between DML exhibited by grade four X-ray score radiological. Furthermore, there was a lack of a significant link between phrenic conduction evaluation (NCS) values, plus chronic extent of neck pain. This suggests that phrenic DML is primarily influenced by spondylotic severity rather than discomfort duration.

Transcutaneous stimulation of the phrenic nerve demonstrated a right-side amplitude reduction exceeding 50% in comparison to the left side [23].

The primary approach to enhance ventilatory function involves training the inspiratory muscles, systemic aerobic metabolism ability, and improving thoracic mobility. These interventions aim to strengthen and increase diaphragmatic and intercostal musculature endurance, thereby reducing the likelihood of restrictive ventilation [24].

The specificity of inspiratory muscle training has been found to result in significant improvements in inspiratory muscle endurance and strength, as well as a notable reduction in dyspnoea, which holds clinical relevance. Furthermore, those who experienced respiratory muscle weakness and engaged in inspiratory muscle training demonstrated improvements in both the strength and endurance of their respiratory muscles [25].

Ultrasound has been utilised for assessing diaphragmatic performance. Ultrasound offers numerous benefits, such as its safety, avoidance of radiation, and convenient availability at the bedside. Several ultrasonographic approaches, including two-dimensional (BD) and M-mode measurement of diaphragmatic excursions and alterations in diaphragmatic thickness during inhalation, have been suggested. The methodology for assessing diaphragmatic function using ultrasonography has been established. Ultrasound can offer a straightforward remedy in cases or conditions where the phrenic nerve or diaphragm muscle may be impacted [26].

In the same line, Boussuges et al. [27] utilised the M ultrasonographic mode for assessing diaphragmatic mobility in individuals with hemidiaphragm paralysis. The affected side of the diaphragm did not show substantial thickening and, in some cases, even grew thinner. The statistical analysis showed a notable reduction in the average rest and deep-breathing diaphragmatic excursion in the examined individuals in favour of the control participants.

In contrast, the current findings contradict the results of Laghi et al. [6], who examined the effectiveness of ultrasound imaging methods in evaluating diaphragmatic dysfunction. They determined a minimal correlation between diaphragmatic thickness and its excursion, and an association between diaphragmatic excursion and a weak or non-existent output pressure.

Limitations

The current study has a limited population size, which restricts the ability to achieve more precise results. Conducting the study on a larger scale will address this restriction. We advise conducting additional examinations, including cervical magnetic resonance imaging for all participating individuals, electromyography of the diaphragm for those who have reduced phrenic compound muscular action potential, and neuromuscular phrenic ultrasonography.

Conclusions

Patients suffering from chronic neck discomfort have respiratory dysfunction symptoms that closely resemble those observed among pulmonary individuals with reduced neuromuscular capabilities. The underlying cause of such weakened musculatures is explained by associated with neck musculature malfunctioning, although discomfort and fear of movement may be a dysfunction-developing issue, either directly or indirectly. Our findings endorse the integration of pulmonary management as part of standard care for those suffering from persistent neck discomfort. Nevertheless, additional experimental inquiry is necessary to determine the efficacy of these procedures.

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Ethical approval

The research related to human use complied with all the relevant national regulations and institutional policies, followed the tenets of the Declaration of Helsinki, and was approved by the Institutional Review Board of Cairo University (approval No.: P.T.REC/012/004375). The registration number for the Clinical Trials website (www.clinicaltrials.gov) is NCT05817565.

Informed consent

Informed consent was obtained from all individuals included in this study.

Disclosure statement

No author has any financial interest or received any financial benefit from this research.

Conflict of interest

The authors state no conflict of interest.

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