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# RESEARCH ARTICLE

## VENTILATORY FUNCTION RESPONSE TO TRAINING OF CERVICAL MUSCLES IN MECHANICAL NECK PAIN: A RANDOMIZED CONTROLLED STUDY

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**ABSTRACT**

**Background:** Neck pain is a common musculoskeletal complaint with tremendous impact on health and quality of life. Neck pain also leads to pulmonary function restrictive disorder. **Aim:** This study aimed to investigate the effect of deep cervical muscle training using pressure biofeedback device on ventilatory functions in patients with chronic mechanical neck pain. **Subjects:** Forty subjects of both sexes with mean age 24.8± 1.87 years were participated in this study. They were divided into two groups equal in number; the study group (A) and the control group (B) who were suffering from chronic mechanical neck pain. **Methods:** Group A received deep cervical flexor strengthening exercises and traditional physical therapy modalities. Group B received only traditional physical therapy modalities. Both groups were assessed using the neck disability index questionnaire for functional disability, visual analogue scale for pain intensity, craniocervical flexion test for deep cervical flexor muscle strength and spirometric tests for ventilatory functions. Patients were assessed before and after treatment. **Results:** The results of this study showed that there was significant improvement in craniocervical flexion test, maximum voluntary ventilation and peak expiratory flow rate in the study group only ($p = 0.0001$). There was a statistically significant improvement in neck disability index ($p = 0.0001$), visual analogue scale ($p= 0.0001$), forced vital capacity ($p = 0.002$) and forced expiratory volume in 1 second ($p= 0.01$) in both groups, however, there was no statistically significant difference between both groups. **Conclusion:** It is concluded that deep cervical flexor strengthening exercise combined with traditional physical therapy modalities have better clinical effects on the mechanical neck pain and ventilatory functions than traditional physical therapy modalities alone in patients with chronic mechanical neck pain.

## INTRODUCTION

Mechanical neck pain (MNP) is typically reported as diffuse, nonspecific pain, especially with neck movements (1). Activity related neck pain is a prominent symptom of most mechanical neck disorders (MND) which include whiplash assossciated disorders, torticollis and myofascial neck pain (2). Neck pain is a common disabling and costly musculoskeletal disorder with a mean overall prevalence in the general population of approximately 23% (3). It is more common during middle age, with females recording higher prevelance than males (4). MNP may include symptoms in the neck and upper extremity (5). It is characterized by insidious onset, which could originate from multiple factors such as depression, anxiety, poor posture and muscle strain arising from participation in sports and occupational antecedents (6). Its course is characterized by periods of remission and exacerbation, but the majority of patients do not completely recover from their symptoms (7). In addition to neck pain, patients with chronic MNP present with various motor dysfunctions, such as an inhibition of deep cervical flexor (DCF) muscle activation accompanied by hyperactivity and increased fatigability of the superficial neck flexors, increased forward head posture (FHP), (8, 9), sensorimotor disturbances in the form of decreased proproception, neuromuscular disturbances and psychosocial dysfunction (8). Pulmonary function tests (PFT) represents an important part in respiratory medicine. Spirometry is a common test of pulmonary function that provides information regarding the presence of obstruction or possible restriction in people with suspected pulmonary dysfunction (10). Pulmonary restriction is a term used to describe a group of respiratory disorders related to an impaired filling of the lungs with air (11). This predisposes to reduction of lung volumes, respiratory flows and maximum voluntary ventilation (MVV), which are the characteristic and diagnostic signs of restrictive disorders. This is particularly apparent in cases of neuromuscular weakness (12). Neuromuscular weakness is also a physical sign in musculoskeletal pain conditions (11). It was hypothesised that the observed respiratory dysfunction in chronic neck pain patients are caused by: weakness of the deep neck flexor and extensor muscles, reduced stability of the cervical and thoracic spine and changes in rib cage mechanics (13). These mechanical changes leads to alterations in the force length curves of the sternocleidomastoid muscles due to muscle hyperactivity and restricted range of motion of the cervical spine (13). Muscular

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performance of DCF can be increased with the use of pressure biofeedback unit (PBU) training (14). It is generally true that PBU training facilitates effective contraction of the DCF muscles (14, 15), by bending the head instead of the neck through a nodding action so that the DCF musles are activated as opposed to the activation of the superficial ones. Hence, normal neck postures and arrangement are recovered (15). This study was conducted to investigate the effect of DCF training on ventilator functions and deep cervical muscle strength and to find out the effect of this technique on pain and functional disability in patients with MNP.

## PATIENTS AND METHODS

This study is a randomized controlled trial which was approved by the ethical committee of the Faculty of Physical Therapy, Cairo University. Approval from all patients was formally obtained by signing a consent form. This study was conducted in the out clinic of Faculty of Medicine, Cairo University. Forty patients ofboth genders (14 males and 26 females) with chronic MNP were enrolled in this study under the following inclusion criteria: age 20- 30 years old, neck pain duration from six to twelve months and pain complaints at least once per week, body mass index (BMI) < 30 kg/m$^2$ and non smoker patients (current or past). Exclusion criteria were current or past smokers, BMI > 30 kg/m$^2$, pain in any other non related body area, history of: neck pain of traumatic origin, clinical abnormalities or surgeries of the thoracic cage or vertebral column, occupational industrial exposures, serious comorbidities and malignancies. Patients were divided into two groups: Group (A): study group included 20 patients (8 males and 12 females) who received cervical muscle training plus the traditional physical therapy program and Group (B): control group included 20 patients (6 males and 14 females) who received traditional physical therapy program only. Subjects were classified as having MNP based on presence of FHP and protracted shoulders (16), tender trapezius, levator scapulae, rhomboids, supraspinatus, and infraspinatus muscles on palpation (17) and weakness of DCF muscles that stabilize the cervical spine measured by craniocervical flexion test (CCFT) (18). All subjects were familiarized with the objectives, equipment and procedures of the study and received sessions 3 times per week for a total period of 4 weeks.

### Instrumentation

**Instrumentation for cervical evaluation:** 1- PBU (Chattanooga group, Australia, no: 657277) was used to assess the endurance of the DCF by performing the (CCFT). 2- Neck pain intensity, pain induced disability and physical activity level were assessed by adminstration of visual analogue scale (VAS) and the neck disability index (NDI) questionnaire.

**Instrumentation for pulmonary function evaluation:** Pulmonary function tests were assessed by using a spirometer (APS-PRO Jaeger, serial no. 201484-146402, Germany).

**Instrumentation for treatment:** Traditional physical therapy modalities: utrasound (Phyaction CL- uniphy, serial no. 70408, Belgium) and thermal agent (infrared lamp) and the PBU to strength the DCF.

### Outcome measures

Initially, demographic data and patient characteristics were collected, including age, weight (kg) (measured to the nearest 0.1 kg using a standard weight scale) and height (cm) (measured to the nearest 0.1 cm with subject standing erect against a vertical scale). Pain intensity was assessed using the VAS. It represents a horizontal line of 10 cm with word anchors at each end representing the extreme feelings. Patients indicated the point on the line that best corresponded to the pain (19, 20). The NDI questionnaire (score out of 50) was used to measure the patient's perceived disability resulting from their neck pain. There are ten sections in this questionnaire and each section is scored 0-5 points. Its interpretation is 0-20% minimal disability, 21-40% moderate, 41-60% severe, 61-80% crippled and 81-100% bed bound (8). The DCF endurance was examined using the PBU to perform the CCFT (11). CCFT was performed with the subjects in crook lying position. With the PBU placed beneath the occiput and inflated to baseline of 20 mmHg, patients were instructed to perform head nodding. The test consists of 5 incremental stages (22, 24. 26,28 and 30 mm Hg). Three repetitions in each increment were required before progressing to the next one.The test was continued in the same fashion until successful completion (three ten-second holds at 30 mmHg) or substitution of activity of SCM or scaleni was observed or palpated, overshooting target pressure, neck retraction and dial needle flickering (21). Pulmonary function tests or spirometry was performed by using a spirometer (22). Forced vital capacity (FVC), forced expiratory volume in 1 second (FEV1), peak expiratory flow rate (PEF) and maximum voluntary ventilation (MVV) were measured by spirometer (23). All PFT were carried out at a fixed time of the day to minimize diurnal variation (8). A nose clip was used to avoid any potential air leakage and patients sealed their mouths around a disposable mouthpiece and were verbally encouraged to breathe in and out through it (11). The patients were asked to perform a rapid full inspiration, followed by a non hesitated maximum forced expiration, then ending by another rapid maximum inspiration (24).The test was repeated three times and the maximum of the 3 trials was obtained (8).

### Treatment procedures

**1. Traditional physical therapy program**

a. **Thermal agent (infrared lamp):** Infrared irradiation was applied for 20 min at a 40 cm distance from the neck region (25).
b. **Therapeutic ultrasound:** Ultrasound was applied on myofascial trigger points to decrease the pain (26, 27). The continuous ultrasound was used with 1.5 W/cm2 intensity and at a frequency of 1 MHz over the neck area for 10 minutes (25).

**2. DCF training:** Pressure biofeedback unit training facilitates effective contraction of the DCF muscles instead of superficial muscles (14, 15). DCF training started with the same preparatory steps of the CCFT. Patients were then instructed to perform head nodding and to hold it for 10 seconds starting with 22 mm Hg increment level and progressively targeting all the 5 increments till 30 mm Hg. Minimum requirement for satisfactory performance was 26 mmHg while 28 and 30 mmHg were targets for ideal performance (21). Training included 3 sets in a session, 10 repetitions per set with 2 minutes rest between sets (28).

**Data collection:** All the outcome measures were collected for both groups before treatment and after 4 weeks.

**Table 1. Descriptive statistics for the mean age, sex and BMI of study and control groups**

| Variable | Study group n=20 | Control group n=20 | p-value |
|---|---|---|---|
| Age (years) | 24.65 ± 2.05 | 24.9 ± 1.68 | 0.67 |
| Sex (male/ female) | female: n=12 (60%) and male: n=8 (40%) | female: n=14 (70%) and male: n=6 (30%) | 0.5 |
| BMI( Kg/m2) | 25.23 ± 2.08 | 24.34 ± 2.93 | 0.27 |

Significance set at p≤ 0.05; n: number .

**Table 2. Means and p-values for NDI, VAS and CCFT pre and post treatment in both groups**

| Variable | Study group | Control group | p- value | Study group p-value (pre and post treatment) | Control group p-value (pre and post treatment) |
|---|---|---|---|---|---|
| NDI (%) Pre | 26.85 ± 3.54 | 25.7 ± 5.55 | 0.44 | 0.0001* | 0.0001* |
| Post | 8.75 ± 2.09 | 10.25 ± 3.66 | 0.12 | | |
| VAS Pre | 6 ± 1.45 | 5.6 ± 1.42 | 0.38 | 0.0001* | 0.0001* |
| Post | 1.9 ± 0.71 | 2.2 ± 0.89 | 0.24 | | |
| CCFT (mm Hg) | | | | | |
| Pre | 23.6 ± 1.39 | 23 ± 1.02 | 0.12 | 0.0001* | 0.11 |
| Post | 29.3 ± 0.97 | 23.55 ± 1.6 | 0.0001* | | |

Data was expressed in means ± SD; NDI: neck disability index; VAS: visual analogue scale; CCFT: craniocervical flexion test; *: significant where p≤ 0.05.

**Table 3. Mean and p-values for FVC, FEV1, MVV and PEF pre and post treatment in both groups**

| Variable | Study Group | Control group | p- value | Study group p- value (pre and post treatment) | Control group p- value (pre and post treatment) |
|---|---|---|---|---|---|
| FVC (L) | | | | | |
| Pre | 3.51 ± 0.57 | 3.44 ± 0.85 | 0.76 | 0.002* | 0.004* |
| Post | 3.65 ± 0.55 | 3.55 ± 0.79 | 0.65 | | |
| FEV1 (L) | | | | | |
| Pre | 3.04 ± 0.35 | 2.94 ± 0.7 | 0.59 | 0.01* | 0.01* |
| Post | 3.21 ± 0.45 | 3.06 ± 0.69 | 0.41 | | |
| MVV (L/min) | | | | | |
| Pre | 71.56 ± 13.7 | 74.42 ±12.12 | 0.49 | 0.0001* | 0.36 |
| Post | 92.48 ± 12 | 75.12± 11.76 | 0.0001* | | |
| PEF (L/min) | | | | | |
| Pre | 5.34 ± 1.28 | 5.19 ± 1.79 | 0.77 | 0.0001* | 0.24 |
| Post | 6.37 ± 1.22 | 5.43 ± 1.37 | 0.02* | | |

Data was expressed in means ± SD; FVC: forced vital capacity; FEV1: forced expiratory volume in 1 second; MVV: maximum voluntary ventilation; PEF: peak expiratory flow rate; *: significant where p≤ 0.05.

**Statistical Analysis:** All statistical analyses were performed using the statistical package for social studies (SPSS) version 19 for windows. Descriptive statistics and t- test was conducted for comparison of the mean age and BMI of both groups. Chi squared test was conducted for comparison of sex distribution between both groups. T-test was conducted for comparison of NDI, VAS, CCFT, FVC, FEV1, MVV and PEF between both groups. Paired t-test was conducted for comparison between pre and post treatment mean values of NDI, VAS, CCFT, FVC, FEV1, MVV and PEF in each group. The level of significance for all statistical tests was set at $p \leq 0.05$.

## RESULTS

Comparing the demographic characteristics of the subjects of both groups revealed that there was no significant difference between both groups in the mean age and BMI ($p > 0.05$) and no significant difference between both groups in sex distribution ($p = 0.5$), as shown in Table 1.

**NDI, VAS and CCFT in both groups:** As shown in Table 2, there was no significant difference between the study and control groups pre treatment regarding the NDI (p=0.44), VAS (p=0.38) and CCFT (p=0.12), while there was a significant decrease in the NDI in both the study group and control group as well as, a significant decrease in the VAS in both groups post-treatment compared with pre-treatment (p= 0.0001). The study group had a significant increase in the CCFT post treatment compared with pre treatment (p=0.0001), however, the changes were non significant in the control group (p = 0.11). T-test for comparison between post treatment mean values of CCFT of study and control groups showed a significant increase in CCFT of the study group compared with that of control group post treatment (p = 0.0001), however no significant difference was noted in NDI and VAS between both groups.

**FVC, FEV1, MVV and PEF in both groups:** Table 3 showed that there was no significant difference in the FVC (p=0.76), FEV1 (p=0.59), MVV (p=0.49) and PEF (p=0.77) between the study and control groups pre treatment, while there was a significant increase in the FVC (p=0.002) and FEV1 (p=0.01) values in the study group post-treatment compared with pre-treatment. Almost similar changes were noted in FVC (p=0.004) and FEV1 in the control group (p=0.01). MVV and PEF increased significantly in the study group post- treatment compared to pre-treatment (p=0.0001), however the same variables showed no significant difference in the control group post- treatment. T-test for comparison between post treatment mean values of MVV and PEF between both groups post treatment showed a significant increase in study group compared to control group; (p=0.0001) for MVV and (p=0.02) for PEF. However, non significant difference was found in the FVC and FEV1 between study and control groups post treatment; (p= 0.65) for FVC and (p=0.41) for FEV1.

# DISCUSSION

The present study investigated the ventilatory functions response to training of DCF muscles using PBU in patients with chronic MNP. The current results indicated that improvements in ventilatory functions were more marked in the study group compared to the control group. Our results regarding the significant improvements in NDI and VAS in both groups post-intervention as compared to pre-intervention, were similar to the results found by (Amr and Amira) in which they stated that there was a significant decrease in the VAS and a significant improvement of the NDI after one month of intervention in both groups, one group received ultrasound, thermotherapy and TENS and the other one received the same modalities in addition to DCF strength exercise (25). However, (Chan and colleagues) used only thermotherapy and TENS for his control group and proved non significant changes in both the NDI and VAS post-treatment compared to pre-treatment (29). (Jasper and colleagues, Graham and colleagues) also considered the ultrasound to be of no benefit in reduction of neck pain (30, 31). Contradictory results were found by (Sihawong and colleagues) regarding the DCF training, as they investigated the effects of an exercise program focusing on muscle stretching and endurance training on the 12-month incidence rate of neck pain in office workers. Using NDI and VAS in their assessment, they found that there was no significant difference in these variables between the intervention and control groups (32). The thermal and non-thermal effects of US would transiently increase the flexibility of tendons, ligaments, and joint capsules, which consequently decreases joint stiffness, pains, and accompanying muscle spasm and temporarily increases blood flow (33) ; (25). Thermotherapy is recommended by practitioners for chronic neck pain patients (34) ; (35) due to its physiological effects of increasing blood flow and metabolism, and increasing elasticity of connective tissue, thereby relieving pain (36) ; (37).

The FHP of subjects with chronic neck pain (26, 38), has been associated with compressive loading of the cervical tissues (25, 39). The improved cervical posture created through DCF exercise, may have an additional long-term benefit of reducing recurrent episodes of neck pain (25, 40). The results of the current study proved that DCF training exercises lead to a significant increase in the CCFT values, thereby reflecting improvements in strength and endurance of the DCF muscles of the study group compared to the control group. These results agreed with (Izquierdo and colleagues) as they proved significant improvements in the CCFT in the group receiving DCF training (41). However, these results disagree with (O'Leary and colleagues) as they found that the group receiving DCF exercise using the PBU, didn't have any significant increase in strength and endurance (42). DCF exercise, is an exercise/examination method that is characterized by low loading and induces proper postures and activation of deep, instead of superficial, muscles (15, 43). This method bends the head instead of the neck so that the DCF muscles are activated as opposed to activation of the SCM and AS. Hence, normal neck postures and arrangement are recovered (15, 44). The significant improvements in FVC and FEV1 of the control group in the current study, is suggested to be due to the physiological effects of heating therapy on muscles stated above. Therefore, relaxation of the shortened accessory respiratory muscles and increase of its flexibility is thought to be a reason for improving respiratory function and increasing the FVC and FEV1 values. (Izquierdo and colleagues, Jull and colleagues) considered DCF training as a form of exercise that enhances the DCF activation, restores the coordination between the deep and superficial cervical flexors and enhances the neuromuscular control of the cervical flexor muscles (41, 45). MVV is suggested to be an indicator of neuromuscular control (13, 46) and is affected by loss of co-ordination of respiratory muscles (47). Therefore, this crucial role of DCF muscles in neuromuscular control and cervical stability is a good explanation for the significant increase of MVV in the study group only. However (Kennedy and colleagues) proved that DCF are capable of only small peak flexion torque or compression forces, therefore have a limited capacity to contribute to cervical stability (48). PEFR is the maximum rate of flow in forced expiration starting from full inspiration. PEFR not only reflects airway calibre but also muscle strength and voluntary effort (49).

Since DCF training improves the strength and endurance of the DCF and corrects the muscle imbalance between the superficial and deep flexors, thus this explains the statistically significant increase in the PEFR in the study group which is dependent on muscle strength and voluntary effort. A study by (Jintae and colleagues) proved that the FVC and FEV1 were statistically decreased in the FHP group as compared to the normal posture group. They stated that this was due to the weakness of cervical muscles secondary to the bad neck posture, which in turn decreased the FVC and FEV1 (50). Weaknesses of the neck muscles resulted in a FHP in addition to decline in thoracic mobility (9, 51), which means increased kyphosis in the upper thoracic region and a reduction in the volume of the thorasic cage. This creates a resistance to exhalation and therefore lowers the FVC and FEV1. DCF has a major postural function in supporting and straightening the cervical lordosis (52, 53). Therefore, retraining the DCF muscles improves the ability to maintain an upright posture of the cervical spine which decreases the FHP (53, 54). This proves our results, as the DCF training corrected the FHP which in turn lead to significant improvement in FVC and FEV1in the study group.

### Conclusion

The results of this study supported the importance of management of neck pain using deep cervical flexor training program and its effect on improving the ventilatory functions.

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