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REVISED VERSION

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TITLE PAGE

Full Title:

Pulmonary function of patients with chronic neck pain: a spirometry study

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Disclosures

Findings about the respiratory strength of the same sample of patients with chronic neck pain have been published in *Manual Therapy* journal. Findings about the blood gases of the same sample of patients with chronic neck pain have been accepted for publication by the *American Journal of Physical Medicine and Rehabilitation*.

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Abstract

Background

Chronic neck pain is one of the most common musculoskeletal pain conditions experienced by many people during their lives. Although patients with neck pain are managed predominantly as musculoskeletal patients, there are indications that they also have poor pulmonary function. The aim of this study was to examine whether patients with chronic neck pain have spirometric abnormalities and whether neck pain problems and psychological states are associated with these abnormalities.

Methods

Forty five participants with chronic neck pain and 45 well-matched healthy controls were recruited. Spirometry was used for assessing participants' pulmonary function. Neck muscle strength, endurance of deep neck flexors, cervical range of movement, forward head posture, psychological states, disability and pain intensity were also evaluated.

Results

The results showed that patients with chronic neck pain yielded significantly reduced vital capacity, forced vital capacity (FVC), expiratory reserve volume and maximal voluntary ventilation ($p<0.05$) but peak expiratory flow, Forced Expiratory Volume in one second (FEV_1) and FEV_1/FVC ratio were not affected ($p>0.05$). Strength of neck muscles, pain intensity and kinesiophobia were found to be significantly correlated ($r>0.3$, $p<0.05$) with their respiratory function.

Conclusions

Patients with chronic neck pain do not have optimal pulmonary function. Cervical spine muscle dysfunction in parallel with pain intensity and kinesiophobia are factors that are mainly associated with this respiratory dysfunction.

Keywords: cervical pain, flows, maximal voluntary ventilation, respiration, spirometry, volumes

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Introduction

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 [1]. Pulmonary restriction is a term used to describe a group of respiratory disorders related to an impaired filling of the lungs with air [2]. Although a reduction in lung volume is a sign characteristic of restrictive disorders, respiratory flows and Maximal Voluntary Ventilation (MVV) may also be affected [2–4]. This is particularly apparent in cases of neuromuscular weakness, as the respiratory muscles have a reduced ability to generate optimal levels of pressure and flow [3]. Neuromuscular weakness is also a physical sign in musculoskeletal pain conditions. However, musculoskeletal pain and pulmonary function are rarely considered together in clinical practice.

Chronic neck pain is a musculoskeletal condition affecting many people. Although patients with neck pain are managed predominantly as musculoskeletal patients, weakness and fatigue of cervical muscles, reduced cervical mobility, impaired proprioception, postural abnormalities and psychological compromise have been argued to be factors that are associated with poor pulmonary function [5;6]. Despite mechanistic evidence suggesting pulmonary function may be affected in those experiencing neck pain [5], little is known of the actual respiratory function in this group. A previous pilot study has revealed trends towards pulmonary restriction in patients with chronic neck pain but a small sample size does not allow confirmation of this restrictive pattern [6]. Furthermore, the association of well-known musculoskeletal and psychological manifestations of neck pain with function of the respiratory system remains completely unexplored.

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Considering these gaps in the literature, this study was conducted to investigate pulmonary function in patients with chronic neck pain and to obtain evidence about the association between musculoskeletal and psychological manifestations of their pain with spirometric values.

Materials and Methods

Study subjects

A convenience sample of 45 patients with chronic neck pain (>6 months duration, pain complaints at least once a week) was recruited and has been initially described in a previous publication[7]. Screening for eligibility was performed by using a health questionnaire. Patients were ineligible to participate if they were current or past smokers, had neck pain of traumatic origin, had pain in any other non-related body area, were obese (Body Mass Index>40), had clinical abnormalities or surgeries of the thoracic cage or vertebral column, had occupational industrial exposures, had serious comorbidities (cardiorespiratory, neurological, musculoskeletal, neuromuscular or/and psychiatric disorders), diabetes mellitus or/and malignancies. Forty five healthy controls[7] were additionally recruited by applying the same exclusion criteria and were individually matched with neck pain patients (same gender, age: ±5 years, height: ±10 cm, weight: ±10%). All assessments were undertaken at the Cardiorespiratory laboratory of the Technological Educational Institute of Lamia, Central Greece, during the period 2009-2010 after obtaining written informed consent. The study was approved by the Ethics Committee of the

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Department of Physiotherapy, School of Health and Caring Professions, TEI Lamia, Greece and the University of Manchester Ethics Committee.

Study design

The study was designed to compare the pulmonary function of patients with chronic neck pain with healthy controls and to examine correlations between spirometric indices with musculoskeletal and psychological parameters. Pulmonary function was examined using three different spirometric tests [Vital Capacity (VC), Forced Vital Capacity (FVC) and MVV]. Cervical function was assessed using neck isometric dynamometry (neck muscle strength), ultrasound-based motion analysis (cervical range of movement), lateral photographs (forward head posture) and the craniocervical flexion test (endurance of deep neck flexors). Psychological states (anxiety, depression, catastrophizing, kinesiophobia) and pain characteristics were assessed through questionnaires. The assessment of cervical function and psychological states have been initially described in a previous publication[7]. All the measurements were performed by an appropriately trained physiotherapist. A sample size calculation revealed that for a large effect size (d=0.8), 26 participants were needed per group for a power of 80% (two-tailed hypothesis, α=0.05). However, 45 participants per group were recruited to increase statistical power and accounting for potential missing data.

Methods

Spirometry was performed by using an electronic spirometer (Spirolab II, SDI Diagnostics Inc, USA) and its accompanying software (WinSpiroPRO, Medical International Research, Rome, Italy). Spirometry included three different pulmonary

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tests [Vital Capacity (VC), Forced Vital Capacity (FVC) and MVV] which were performed according to the spirometer manual guidelines with special reference to the recommendations by the American Thoracic Society and European Respiratory Society[8;9]. Vital Capacity and FVC manoeuvres were performed from a standing position, whereas MVV manoeuvres were performed from a sitting position. Participants used a noseclip in all the tests to avoid any potential air leakage, were asked to have their mouth sealed around the cylindrical carton mouthpiece and were verbally encouraged to ensure maximal performance throughout the tests. VC, FEV in one second (FEV_1), FVC and Peak Expiratory Flow (PEF) were reported from the maximum of the trials and FEV_1/FVC calculated accordingly, whereas the average over the trials was used for Tidal Volume (V_T), Inspiratory Capacity (IC) and Expiratory Reserve Volume (ERV). Forced Expiratory Flow at 25% ($FEF_{25\%}$), at 50% ($FEF_{50\%}$), at 75% ($FEF_{75\%}$) and from 25% to 75% ($FEF_{25\%-75\%}$) of forced expiration was also reported from the values of the best loop which was defined as the one with the highest sum of FEV_1 and FVC.

Psychological parameters were measured through completion (in randomized order) of the cross-culturally validated Hospital Anxiety and Depression Scale [10], Tampa Scale for Kinesiophobia [11] and Pain Catastrophizing Scale [12]. Usual and current neck pain intensity, pain-induced disability and physical activity level were assessed by administration of Visual Analogue Scales [13], the Neck Disability Index [14] and the Baecke Questionnaire of Habitual Physical Activity [15] respectively.

Cervical Range of Movement (ROM) assessment was actively performed in a standing position using a Zebris ultrasound-based motion analysis system (Zebris Meditchnic GmbH, Isny, Germany) based on instructions provided in a previous publication [16]. Testing was performed with the participants head in a neutral position

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whilst slowly performing three repetitions for each cervical movement. The best of the three repeats was recorded as the participants' ROM in each direction. The procedure has been reported previously as very reliable [Intraclass Correlation Coefficient (ICC)=0.73-0.86, Standard Error of Measurement (SEM)= 6.5-8.5^{o}][16].

For assessing the Forward Head Posture (FHP), participants were asked to stand as usual and to focus their vision on a predetermined reference point at a height level with their eyes. Three lateral photographs were then taken (digital colour camera, HDR-SR11E, Sony, Belgium) and FHP calculated from the mean of the three Craniovertebral Angles (CVA) using 3-D drawing software (Auto- CAD 2000, Autodesk Inc., San Raphael, CA). CVA was taken as the angle between the line extending from the tragus of the ear to the 7th cervical vertebra (C7) spinous process and the horizontal line through C7. This procedure is considered highly reliable (ICC = 0.88) [17].

Neck flexor and extensor muscle strength was assessed in randomized order from a stabilized standing position with the head in a neutral position. The measurements were performed after a warm-up period, with a custom made isometric dynamometer with previously reported high reliability (ICC=0.9-0.96, SEM=12.6-20.8 N) [18]. Each participant performed three or more 5-sec maximal isometric contractions until the two best measurements were within 10% of each other. The maximally recorded value was kept for the analysis.

Deep neck flexor endurance was examined using the craniocervical test which has been previously reported by Jull et al [19]. A pressure biofeedback device (Stabilizer, Chattanooga, USA) was placed under the cervical area of participants positioned in crook lying. Participants were required to perform a head-nodding action at 5 different pressure levels in increments of 2 mmHg (from 22 to 30 mmHg).

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A surrogate for endurance was taken as the maximal pressure that the participant could hold steady for three periods of 10-sec without adopting any compensatory strategy. The test has been found to have satisfactory reliability (ICC=0.81-0.91) [20;21].

Analysis

Patients with missing data and their matched controls were excluded from the analysis of the relative variable. Data were missing for left rotation and left lateral flexion ROM (1 patient, software problems), endurance of deep neck flexors (1 patient, no glasses), FHP (1 control, hairclip broken), MVV (1 control, she refused to continue because of dizziness during the first trial). Mean (M) and Standard Deviation (SD) were selected as measures of central tendency and dispersion (M±SD). Differences between percent (%) predicted pulmonary function parameters were examined with independent t-tests and correlations with Pearson correlation coefficients. The software was set to calculate % predicted values based on the combination of "E.R.S. '93 / Knudson" norms[22;23]. Backward stepwise multiple regression analysis (removal=0.1) was performed in patients with chronic neck pain for VC, PEF and MVV by using the strength of neck extensors, endurance of deep neck flexors, sagittal ROM, CVA, usual pain intensity, anxiety, depression, kinesiophobia and catastrophizing as predictors. All the analysis had a significance level equal to 0.05. The analysis of all data was performed with Statistical Package of Social Sciences (SPSS, version 17).

Results

Demographics and pain characteristics

The pain intensity of patients with chronic neck pain was mild to moderate (VAS 45.5±18.8 mm), but mild during the measurements (VAS 19.3±19.1 mm). The patients had mild disability (NDI 10.6±5.2) and pain chronicity of 69.6±57.6 months. The demographics presented no significant difference between the two groups (Table 1)[7;24].

Group differences

The sample of patients used in this study was found to have reduced neck extensor strength, reduced active cervical mobility and impaired function of the deep neck flexors compared to the control group ($p<0.05$). A trend towards reduced neck flexor strength was also observed. Head posture, anxiety and depression were similar to healthy controls ($p>0.05$)[7;24].

Patients with chronic neck pain had significantly decreased VC, ERV, FVC and MVV ($p<0.05$). All the other spirometric indices were not significantly different ($p>0.05$) (Table 2). Two patients with chronic neck pain were found to have mild restriction (% predicted FVC < lower limit of normal but ≥ 70, no reduction in FEV_1/FVC)[25], whereas the others were found to have normal lung function.

Correlations

VC was significantly correlated with the strength of neck muscles (r=0.67-0.68), usual pain intensity (r=-0.32) and kinesiophobia (r=-0.39) ($p<0.05$), whereas a trend was observed for its correlation with catastrophizing (r=-0.26). MVV was significantly correlated with neck muscle strength (r=0.57-0.63), usual pain intensity (r=-0.32) and kinesiophobia (r=-0.35) ($p<0.05$). PEF was significantly correlated with

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the neck muscle strength (r=0.64-0.72) and usual pain intensity (r=-0.39) ($p<0.05$), whereas a borderline trend was observed for its correlation with kinesiophobia (r=-0.29) (Table 3).

Regression analysis

In the prediction models of VC, MVV and PEF a significant fit to the data overall was observed ($p<0.05$) with only neck extensor strength remaining a significant predictor (Table 4). Multiple correlation coefficients and generalizability of the prediction models of VC (R=0.7, R^2=0.49, adjusted R^2=0.47), MVV (R=0.65, R^2=0.43, adjusted R^2=0.41) and PEF (R=0.72, R^2=0.52, adjusted R^2=0.51) were satisfactory. The assumption of independent errors, homoscedasticity, linearity and normally distributed errors were met and no influential outlier was detected.

Discussion

Patients with chronic neck pain have been found to have reduced respiratory strength[7] and changes in their blood chemistry[24]. The results of the study show that patients with chronic neck pain have additionally decreased lung volumes and MVV and this seems to be related to neck flexor and extensor strength, pain intensity and kinesiophobia.

In agreement with a previous study [6], time-point flows, PEF and FEV_1/FVC ratio were not found to be affected but forced and quiet breathing vital capacity (FVC and VC) were found to be reduced in patients with chronic neck pain.

Reduction in lung volumes is usual in both obstructive [26] and restrictive pulmonary disorders [2;3] and reduced FEV_1/FVC ratio is a sensitive indice of

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pulmonary disorders particularly when a pulmonary obstruction is present [26–28]. In contrast, in restrictive disorders this indice can be presented as increased or normal [27;28]. The normal FEV_1/FVC ratio in chronic neck pain patients indicates therefore that reductions in lung volumes are more likely to be associated with pulmonary restriction rather than obstruction. This belief is further supported by the fact that VC was not higher than FVC, in contrast to what would be expected in obstructions [1].

Patients with chronic neck pain also presented normal peak and time-point respiratory flows. Reduced peak respiratory flows can be observed in both restrictive and obstructive disorders [1;3;26]. However, the current study does not provide enough evidence to support a change in peak flows. Furthermore, the fact that the time-point flows ($FEF_{25\%}$, $FEF_{50\%}$, $FEF_{75\%}$, $FEF_{25\%-75\%}$) were not affected further supports the assertion that an obstruction was not apparent.

In agreement with previous piloting findings [6], the present study also showed that patients with chronic neck pain demonstrate a decline in their MVV. MVV is a general index of respiratory function depending on airway resistance, respiratory muscle function, lung and chest wall compliance and ventilator control mechanisms [29;30]. Furthermore, MVV is an index of maximal breathing capacity during dynamic exercise [1;30]. MVV is also associated with neuromuscular control and its reduction in neck patients may imply further interference of the nervous system[6;8;9]. This index can be presented reduced in both obstructive and restrictive disorders [4;9;31]. Thus, the reduction in MVV in parallel with the findings about lung volumes contribute to the notion that the respiratory decline observed in patients with chronic neck pain seems to follow a rather restrictive pattern.

According to the results of the current study, respiratory dysfunction in patients with chronic neck pain is associated mainly with cervical muscle dysfunction,

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pain intensity and kinesiophobia. Weakness of common cervical muscles (sternocleidomastoid, scaleni and trapezius) may have had a direct effect on respiratory function but could have led to muscle imbalances and spinal instability [32;33] through an effect on the rib cage mechanics and consequentially the biomechanical function of the respiratory muscles [5;33]. These mechanical changes of respiratory muscles may influence their ability to generate appropriate force levels [6] and can lead to a permanent respiratory weakness due to plastic changes [34]. This respiratory weakness can lead to dysfunction of the respiratory pump compromising its ability to produce optimal maximal flows and to expand the lungs and consequently leading to a general deterioration of respiratory performance [3].

Pain and kinesiophobia may also constitute inhibiting factors during respiratory manoeuvres impeding patients from exerting maximal effort. However, their role seems to be rather indirect. Kinesiophobia can lead to cervical movement avoidance during daily activities, whereas pain can also change the motor control patterns for limiting the use of painful muscles [35]. These changes may not be optimal for maximal force production and may become a permanent situation due to plastic muscle adaptations [34]. Thus, both pain and kinesiophobia may alter cervical biomechanics further contributing to the development of respiratory dysfunction in chronic neck pain patients.

The overall findings of the present study show an important clinical trend in patients with chronic neck pain. Despite subjects' compromise not being sufficient to classify them as respiratory patients, spirometric function of patients with chronic neck pain presents a pattern similar to pulmonary restrictive disorders and especially neuromuscular weakness. In the long term, the reduction in lung flow and volumes may render the lung tissues, spinal articulations and rib cage stiffer, further

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contributing to the development of a restrictive pattern [36]. Furthermore, it may be expected that patients with more serious neck pain may have more affected respiratory system and in more severe cases they might manifest respiratory pathology.

Independent of the development of a pathologic pulmonary restriction, patients with chronic neck pain present an obvious respiratory dysfunction which necessitates clinical consideration. Future studies should be performed in patients with a greater range of pain and disability. Furthermore, use of plethysmography or other pulmonary function tests can enhance scientific knowledge about the pulmonary function of these patients. The close neuroanatomical relation of cervical region with pulmonary function could also lead researchers to question if patients with pulmonary diseases may also appear neck pain. Finally, the findings of this study reveal a need for case studies or randomized control trials for examining the effectiveness of therapies including respiratory rehabilitation techniques in patients with chronic neck pain.

The main limitations of the study are the potential existence of bias since the participants were not randomly recruited and blind assessors were not used. Moreover, the lack of examination of residual volume and consequentially of total lung capacity did not permit to present the full picture of lung volumes in patients with neck pain, especially considering that a low total lung capacity is an important index for defining a true pulmonary restriction. Furthermore, the examination procedure was quite long with potential testing effects. The incorporation of a number of tests was considered necessary in order to obtain a more complete picture of this respiratory dysfunction. However, the examination of spirometric changes before the

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assessment of cervical function parameters protected the validity of the pulmonary function indices.

In conclusion, patients with chronic neck pain seem to have manifestations of respiratory dysfunction which are quite similar to the ones presented in respiratory patients with neuromuscular weakness. The origins of this weakness are believed to be related to the dysfunction of cervical muscles, whereas pain and kinesiophobia may further directly or indirectly contribute to the development of this dysfunction. The results of the study imply the incorporation of respiratory assessment and rehabilitation into the usual treatment of patients with chronic neck pain. However, the effectiveness of such approaches requires further experimental investigation.

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Table 1: Demographics of patients with chronic neck pain and healthy controls[7;24]

	F/M	Age (yrs) M(SD)	Height (cm) M(SD)	Weight (kg) M(SD)	BMI (kg/m^2) M(SD)	BQHPA M(SD)
Neck Pain group	32/13	35.9(14.5)	165.8(9.2)	71.6(16)	25.9(4.5)	7.9(1.3)
Control group	32/13	35.4(14)	167.1(8.7)	72.3(15.2)	25.8(4.4)	7.6(1.4)

F/M: Females/Males, BMI: Body Mass Index, BQHPA: Baecke Questionnaire of Habitual Physical Activity

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Table 2: Differences in spirometric function (% predicted) between patients with chronic neck pain and healthy controls.

% Predicted values	**Neck pain M(SD)**	**Controls M(SD)**	**Mean difference (95% CI)**	**r**
VC	96(14.8)	103.4(15)	-7.4(-13.6, -1.1)*	0.24
IC	96.9(19.9)	101.2(21)	-4.2(-12.8, 4.3)	0.10
ERV	85.7(30.8)	98.2(28.8)	-12.6(-25.1,- 0)*	0.21
FEV_1	103.1(13.8)	106.6(15.7)	-3.5(-9.7, 2.7)	0.12
FVC	103.4(11.8)	110(16.7)	-6.5(-12.6, -0.5)*	0.22
FEV_1/FVC	103.5(6.1)	101.5(6.8)	2.1(-0.6,4.8)	0.16
$FEF_{25\%-75\%}$	92.4(20.8)	92(23.3)	0.4(-8.8, 9.6)	0.01
$FEF_{25\%}$	94.4(18.5)	100.6(20.6)	-6.2(-14.4, 2)	0.16
$FEF_{50\%}$	91.1(21.8)	90.2(25.3)	0.9(-9, 10.8)	0.02
$FEF_{75\%}$	80.4(26)	79.1(26.6)	1.3(-9.7, 12.3)	0.03
PEF	98.1(15.8)	102.7(17.9)	-4.6(-11.6, 2.5)	0.14
MVV	92.2(20.7)	104.4(21.7)	-12.2(-21.2,-3.2)**	0.28

*p<0.05, **p<0.01

VC: Vital Capacity, IC: Inspiratory Capacity, ERV: Expiratory Reserve Volume, FEV_1: Forced Expiratory Volume in one second, FVC: Forced Vital Capacity, $FEF_{25\%-75\%}$: Forced Expiratory Flow from the 25% to 75% of forced expiration, $FEF_{25\%}$: Forced Expiratory Flow at the 25% of the forced expiration, $FEF_{50\%}$: Forced Expiratory Flow at the 50% of forced expiration, $FEF_{75\%}$: Forced Expiratory Flow at the 75% of forced expiration, PEF: Peak Expiratory Flow, MVV: Maximal Voluntary Ventilation, M: Mean, SD: Standard Deviation, 95%CI: 95% Confidence Intervals, r: effect size expressed as Pearson correlation coefficient.

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Table 3: Correlations between chronic neck pain manifestations and Vital Capacity (VC), Maximal Voluntary Ventilation (MVV) and Peak Expiratory Flow (PEF).

	VC	**MVV**	**PEF**
	Pearson r	**Pearson r**	**Pearson r**
Strength of neck extensors	0.68***	0.63***	0.72***
Strength of neck flexors	0.67***	0.57***	0.64***
Endurance of deep neck flexors	0.11	0.22	0.25
ROM in sagittal plane	0.01	0.02	-0.16
ROM in frontal plane	0.15	0.06	-0.05
ROM in transverse plane	0.18	0.13	0
Craniocervical angle	0.09	0.02	0.05
Usual pain intensity	-0.32*	-0.32*	-0.39**
Current pain intensity	-0.03	-0.1	-0.04
Neck disability index	-0.12	-0.2	-0.22
Anxiety	-0.22	-0.22	-0.25
Depression	-0.01	-0.03	-0.1
Kinesiophobia	-0.39**	-0.35*	-0.29
Catastrophizing	-0.26	-0.13	-0.23

*p<0.05, **p<0.01, ***p<0.001
ROM: Range of Movement

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Table 4: Regression models for the prediction of Vital Capacity (VC), Maximal Voluntary Ventilation (MVV) and Peak Expiratory Flow (PEF). This table presents the beta values (B) with their 95% Confidence Intervals (95% CI) and their Standard Error (SE B) as well as the standardized beta values (β) for the prediction of VC, MVV and PEF in patients with chronic neck pain.

VC Prediction	**B (95% CI)**	**SE B**	**β**
Constant	2.34 (1.87, 2.8)***	0.23	
Strength of neck extensors	0.08 (0.06, 0.11)***	0.01	0.7
MVV Prediction			
Constant	67.26 (49.81, 84.72)***	8.65	
Strength of neck extensors	2.71 (1.73, 3.69)***	0.49	0.65
PEF Prediction			
Constant	4.74 (3.86, 5.63)***	0.44	
Strength of neck extensors	0.17 (0.12, 0.22)***	0.03	0.72

***$p<0.001$