ORIGINAL ARTICLE

CONTENTS

Immediate diaphragmatic relaxation effect on mobility and pain threshold in smartphone users with non-specific cervical spine pain: a randomized placebo-controlled trial

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ABSTRACT

Aim: To compare the manual diaphragmatic relaxation technique and placebo intervention on selected parameters in the neck in smartphone users with non-specific neck pain.

Materials and methods: A randomized placebo-controlled trial included 38 women. Neck range of motion and pressure pain threshold were assessed in participants who were assigned to the Therapy group or a Placebo group. The intervention consisted of a single manual relaxation of the diaphragm in the supine position. Repeat measurements were taken after the intervention.

Results: There was a statistically significant effect of therapy on range of motion in both studied groups ($p < 0.001$; partial $\eta 2 = 0.58$. Statistically significant improvement in the range of motion concerned three planes of movement and all analyzed measurements. There were no statistically significant differences in range of motion between groups. Comparison of pressure pain threshold at the level of the 4th cervical vertebra before and after therapy showed significant differences only in the Therapy group ($p=0.04$, $d=0.45$). No statistically significant differences in pressure pain threshold were found between the groups either before or after therapy.

Conclusions: Global summary of results does not allow for drawing final conclusions regarding the effect of manual diaphragm release on neck parameters in smartphone users with non-specific neck pain, taking into account the results of other researchers, diaphragm therapy is recommended for people with neck pain.

KEY WORDS: diaphragm, pain threshold, neck pain, physiotherapy

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INTRODUCTION

Neck pain (NP) is one of the biggest public health problems in society today [1]. Non-specific NP it is characterised by pain in structures located between the upper nuchal line and the spinous process of the thoracic vertebra [2]. Incorrect positioning during excessive smartphone use can lead to biomechanical changes, the most prominent of which is the positioning of the head in protraction, characterised by a forward extension of the head and neck in relation to the shoulder girdle and trunk [3,4]. Long-lasting strains lead to musculo-articular overload, reduced mobility of the cervical spine and a deepening of the thoracic kyphosis [4]. Postural changes in the spine may also result in impaired mobility in the thorax, leading to increased tension in the diaphragm [5]. In the process of compensation, the breathing pattern may be altered and additional respiratory muscles, also leading to mechanical cervicothoracic dysfunction and subsequent NP [6]. NP is a neuromusculoskeletal disorder that is associated with certain types of dysfunction in other parts of the body [7]. Perri et al. showed that 83% of patients with NP have faulty breathing patterns [6].

The diaphragm is the most important inspiratory muscle innervated by the phrenic nerve, which arises mainly from the anterior branch of the C4 spinal nerve with the addition of C3 and C5 nerve fibres [8] and ivolves both the cervical and brachial plexus [9]. This may affect abnormal afferent drives from the diaphragm and may alter motor control in the neck or shoulder and arm [9]. McCoss et al. were the first

to evaluate the immediate effect of diaphragmatic relaxation on the cervical pressure pain threshold (PPT) [10]. They demonstrated that directing therapy to the diaphragm in healthy subjects induced a hypoalgesic effect at the C4 cervical spine, through activation of afferent neurons of the phrenic nerve.

Most smartphone activities require focusing the eyes and keeping the head in a certain static position, which may consequently contribute to increased chest stiffness making breathing more difficult and negatively affecting diaphragm mobility. In addition, the phrenic nerve runs within the fascia associated with the anterior scaleni muscle [9]. Excessive and chronic tension on the scaleni muscles, e.g. during prolonged forward bending of the head, can result in irritation of the phrenic nerve [9].

As it is a multifactorial condition, it results in a range of symptoms, including reduced range of motion (ROM), asthenia, hyperalgesia and tension in the superficial and deep muscles of the neck [11]. Prolonged pain can result in structural and sensitivity changes, attributed to abnormal central nervous system adaptation. This, in turn, can lead to increased nociceptor activity, which, along with other factors, predisposes the development of central sensitisation (CS) [12]. Understanding the potential mechanisms and clinical significance of CS may aid in the treatment of individuals with non-specific NP and provide new ideas for their treatment [13].

AIM

The aim of this study was to compare the manual diaphragm relaxation technique and a placebo intervention to find out whether the diaphragm relaxation technique improves neck mobility and affects the pain threshold of people with non-specific NP which are smartphones users. We also tested whether there was a relationship between the Central Sensitisation Index (CSI) and superficial pain threshold in people with non-specific NP.

MATERIALS AND METHODS

A randomised placebo-controlled trial was conducted at the Medical University of Lublin. The study was approved by the Bioethics Committee (KE-0254/257/12/2022) and was conducted in accordance with the ethical principles of the Declaration of Helsinki. All participants were informed about the aims of the study, given the opportunity to ask any questions and to withdraw from it at any point and gave their written consent to participate in the study. 45 participants were invited to participate in the study. They were students of the Medical University of Lublin. 5 people did not meet the inclusion criteria and 2 people declined to participate.

This study involved 38 woman, between 18 to 26 years old using a smartphone at least 4 hours a day, who rate the severity of NP in the last 24 hours as moderate (3-7) on the visual analogue pain scale (VAS), and who have had pain for more than 3 months [14]. Participants were excluded if they had a history of neck injury within the past 5 years, neurological symptoms or were currently taking analgesics or anti-inflammatory drugs.

The sample size was estimated using the G*Power 3.1 program (Franz Faul, University of Kiel, Kiel, Germany) for the ANOVA test for repeated measures (within-between interaction), assuming the following parameters for sample estimation: significance level $\alpha=0.05$, power $1-\beta=0.80$, effect size $d=0.25$ ($\eta 2=0.06$, medium effect). The calculations show that the minimum number of participants in both groups should be 34 in total. Participants were randomly allocated to two groups by drawing from an opaque envelope. The study assessor who collected the outcome measurements was blinded to the study group allocation. The therapist was blinded to the group to which the participant would be assigned until immediately before the intervention. Both groups received a single intervention during the session, following the same pattern. All participants underwent the same tests before and after the intervention. For descriptive purposes, anthropometric measurements were taken at the start of the study.

The Polish version of the Neck Disability Index (NDI – Polish Version) was used to assess the degree of disability. The NDI is the most commonly used questionnaire to measure disability related to NP [15].

CSI was used to determine the severity of pain in CS. We used the Polish language version [16]. The CSI consists of two parts. Twenty-five questions from Part A are used to assess CS pain. Part B assesses previously diagnosed disorders associated with CS, which was not included in this study.

The average pain intensity over the previous 24 hours was measured using a VAS [17]. Participants were asked to provide a score ranging from 0 to 10 cm (0 points indicating no pain and 10 points indicating the worst pain).

CERVICAL RANGE OF MOTION (CROM)

CROM was measured using an inclinometer (Baseline 12- 1057), in the sitting position. The CROM

Table 1. Numbers in groups according to disability level and central sensitization index

Group	No disability	Mild disability	Moderate disability	Statistics
NDI				
Placebo	0	16	2	Pearson Chi^2=2.13 p=0.34
%	0.00%	88.89%	11.11%	
Therapy	2	15	3	
%	10.00%	75.00%	15.00%	

CSI	Severe	Moderate	Mild	Subclinical	
Placebo	3	7	7	1	Pearson Chi^2=1.43 p=0.70
[%]	16.67%	38.89%	38.89%	5.56%	
Therapy	2	9	6	3	
[%]	10.00%	45.00%	30.00%	15.00%	

Neck Disability Index (NDI), Central Sensitisation Index (CSI), value (p)

Table 2. Group characteristics

Variables	Placebo n=18			Therapy n=20			Statistics	
	M	Me	SD	Mean	Median	SD	t/Z	p
Weight [kg]	64.45	62.50	15.10	57.10	56.50	7.11	1.35	0.18
Height [cm]	168.94	169.00	6.66	165.65	165.00	5.40	1.68	0.10
Time spent on phone [hours]	6.08	6.00	1.42	5.60	5.25	1.23	1.13	0.27
VAS	4.22	4.00	1.48	4.15	4.00	0.93	-0.38	0.70

Mean (M), standard deviation (SD), median (Me), statistical test result (t/Z), value (p), Visual Analogue Scale (VAS)

Tabela 3. Results of variance analysis (ANOVA)

	Before intervention				After intervention									
	Placebo n=18		Therapy n=20		Placebo n=18		Therapy n=20		Statistics					
Before intervention	M	SD	M	SD	M	SD	M	SD	Groups		Repeated measurements		Interaction	
									F	p	F	p	F	p
Flexion	59.62	10.03	55.93	11.97	65.53	9.96	63.49	13.38	0.68	0.41	23.47	**<0.001** η^2 =0.39	0.35	0.56
Extension	62.36	10.52	64.56	14.97	68.55	10.60	67.35	15.07	0.02	0.90	19.37	**<0.001** η^2 =0.35	2.79	0.10
Flexion to the right	46.04	8.50	44.21	9.93	50.86	9.88	47.58	11.99	0.63	0.43	27.96	**<0.001** η^2 =0.43	0.88	0.35
Flexion to the left	44.32	8.00	41.23	8.20	49.93	9.83	46.47	12.03	1.21	0.28	28.45	<0**.001** η^2 =0.44	0.03	0.86

ANOVA statistical test result (F), value (p), standard deviation (SD), mean (M)

was assessed in flexion, extension and right and left lateral flexion. Participants were assessed in a sitting position with legs flexed 90 degrees at the knees and hips [18]. Two measurements were taken and the average was taken. ROM assessment by inclinometer is considered reliable [19].

PRESSURE PAIN THRESHOLD

We used a digital algometer (FDIX, Wagner Instruments, Greenwich) in the study. PPT locations included the cervical spine on both sides (0.5 cm lateral to the spinous process of C4) [10]. Distal PPT was measured using an allograft on both tibialis anterior muscles (5

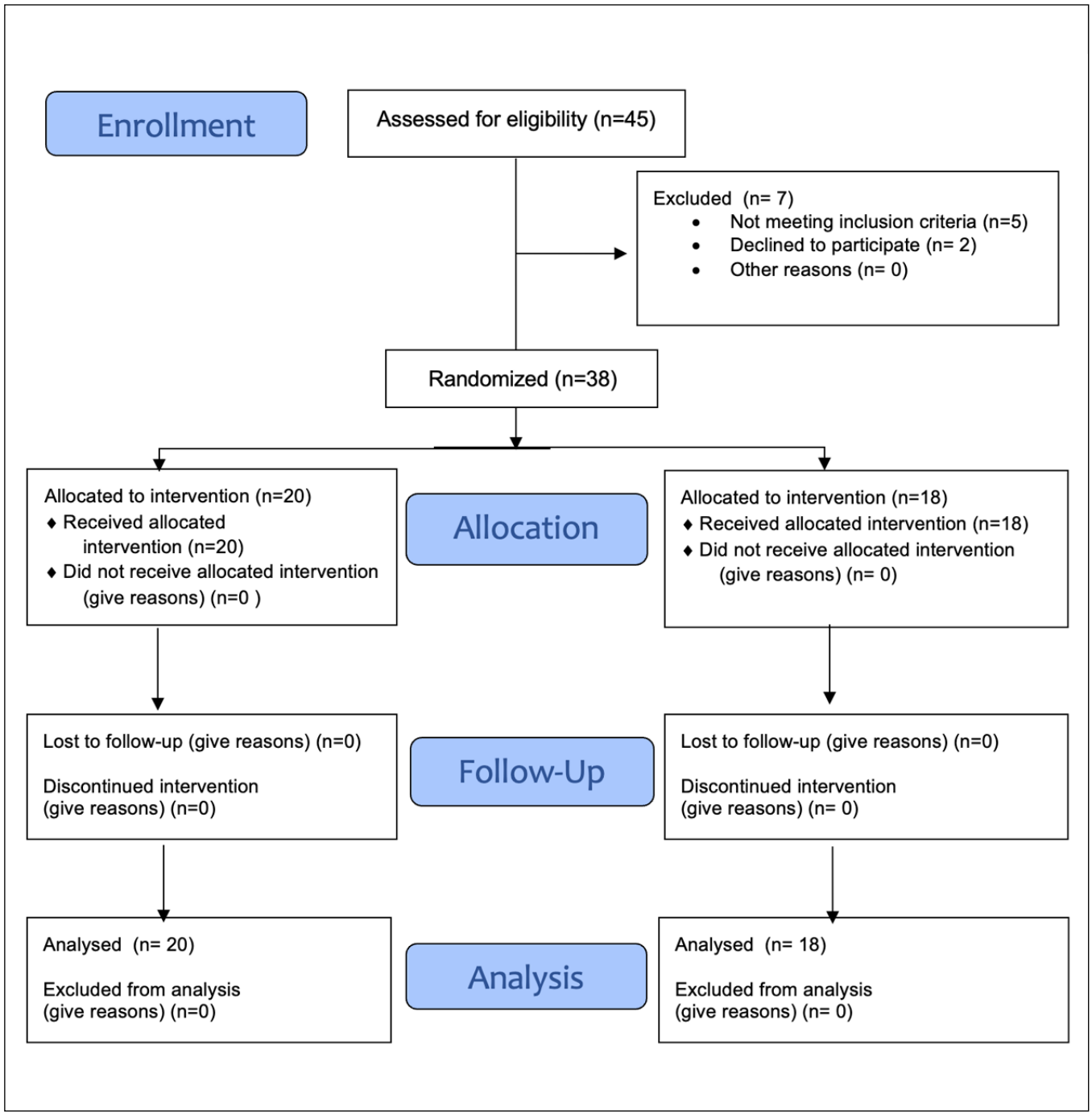

Fig. 1. CONSORT 2010 Flow Diagram

cm distal to the tibial tuberosity and 2.5 cm lateral to the tibial crest). The choice of the tibialis anterior muscle was based on its previous use by other researchers as a distal comparison site for people with NP [20,21].

The researcher applied pressure through the algometer at a constant rate of 5 N/s-1. A single measurement was taken before and after the diaphragm relaxation intervention [20]. Participants were instructed to tell the examiner the precise moment the sensation had become painful or uncomfortable, to prevent the painful stimulus from continuing.

PPT measurement is reliable and valid and is widely used in the clinic as well as in research to assess the effect of different therapeutic interventions [22].

INTERVENTION

Subjects were randomly assigned by selecting a sealed envelope to one of two groups—the experimental group or the placebo group. After completing the previous measurements, subjects received either the diaphragmatic technique or the placebo inter-

Table 4. Pressure pain threshold

Variables	Before intervention						After intervention						Comparison of groups before intervention		Comparison of groups after intervention		Comparison of measurements before and after the intervention			
	Placebo n=18			Therapy n=20			Placebo n=18 Placebo Therapy			Therapy n=20										
	Me	Min	Max	Me	Min	Max	Me	Min	Max	Me	Min	Max	Z	p	Z	p	Z	p	Z	p
Pain c4(r)	1.56	1.06	4.08	1.63	0.76	5.14	3.72	1.88	5.03	4.38	1.20	5.00	-0.06	0.95	-1.78	0.07	1.11	0.27	1.42	0.16
Pain c4(l)	1.79	0.64	3.16	1.57	0.72	5.00	1.64	1.04	3.34	1.81	0.80	4.40	0.73	0.46	-0.97	0.33	1.22	0.22	2.02	**0.04 d=0.45**
Tibialis anterior pain (r)	4.10	2.12	5.08	4.21	1.62	5.00	1.55	0.98	2.18	1.73	0.88	4.40	0.43	0.67	0.13	0.89	0.08	0.94	1.02	0.31
Tibialis anterior pain (l)	3.72	1.88	5.03	4.38	1.20	5.00	4.23	1.58	5.26	4.21	1.52	5.00	-0.51	0.61	-0.16	0.87	0.60	0.55	0.68	0.50

Statistical test result (Z), value (p), median (Me), minimum (Min.), maximum (Max.), right (r), left(l)

Table 5. Spearman correlation results

Pair of Variables	Spearman Rank Order Correlations	
	Spearman r	p-value
CSI & VAS	0.35	**0.03**
CSI & NDI	0.64	**<0.001**
CSI & pain c4(r)	-0.24	0.15
CSI & pain c4(l)	-0.36	**0.03**
CSI & tibialis anterior pain (r)	-0.13	0.44
CSI & tibialis anterior pain (l)	-0.19	0.26

Central Sensitisation Index (CSI), Visual Analogue Scale (VAS), Neck Disability Index (NDI), right (r), left (l)

vention. All participants received a single diaphragmatic relaxation session. Treatment was performed in both groups by the same physical therapist with 13 years of experience. Before receiving the diaphragmatic intervention, each participant was told, " Today you will receive a commonly taught and used diaphragmatic release technique in physical therapy". Participants assigned to the experimental group received a manual diaphragmatic release technique in a supine position. The therapist was positioned at the participant's head and made manual contact with the lower costal cartilages with the therapist's forearms aligned with the participant's shoulders. During inhalation, the therapist gently pulled the contact points with both hands cranially and slightly outward. During exhalation, the therapist deepened the contact toward the inner costal margin. The maneuver was performed in two sets of 10 deep breaths, with a 1-min break between breaths. In the control group, the manual contacts, therapist and participant positions, and duration of intervention were the same as in the experimental group, but the therapist maintained manual contact only on the same anatomical landmarks, without applying pressure or traction [23,24].

Afer a ten minute rest interval [25], new evaluations of CROM and PPT were performer.

STATISTICAL ANALYSIS

Statistical analyses were performed using Statistica™ (v. 14.0.0.15, TIBCO Software Inc., Palo Alto, CA, USA; 2020). The normality of the distribution was verified using the Shapiro-Wilk test. The Mann-Whitney U test was used to compare paired groups in the case of non-conformity with the normal distribution and the Student's t-test in the case of a normal distribution. The Wilcoxon Matched Pairs Test was used to compare repeated measures. Cohen's guidelines for the effect size (ES) of Z (nonparametric data) are as follows: a large effect is scored 0.5, a medium effect 0.3, and a small effect 0.1. To analyze the qualitative variables, the Pearson Chi-square test was used. To analyze the relationship between quantitative variables, Spearman's rank correlation was employed. The correlation coefficient (r) values were interpreted as follows: a range of 0 to 0.3 indicates a weak correlation, 0.3 to 0.5 signifies a moderate correlation, 0.5 to 0.7 represents a strong correlation, and a range of 0.7 to 1 indicates a very strong correlation.

Multivariate analysis of variance (MANOVA) with repeated measures was performed on the parameters of CROM. Provided that the MANOVA was significant, a univariate one-way ANOVA with repeated measures was performed on each dependent variable. A Mauchly test was used to check the assumption of sphericity. Levene's test was used to check the homogeneity of variances. The ANOVA effect size was expressed by its its partial eta squared (ηp2): 0.01 was interpreted as a small effect size, 0.06 was indicative of a medium effect size and 0.14 was indicative of a large effect size.

Descriptive statistics of quantitative variables in the tables present the mean (M), standard deviation (SD), median (Me) and the minimum (Min.)-maximum (Max.) range. Qualitative variables are presented as numbers (n) and percentages (%). For all tests performed, the level of statistical significance was assumed at p=0.05.

RESULTS

CONSORT 2010 FLOW DIAGRAM

Figure 1 shows CONSORT 2010 Flow Diagram.

No statistically significant correlations were found between the level of NDI and the CSI and membership in the study or placebo group (Table 1).

There were no differences between groups in weight, height, time spent using phone, and VAS (Table 2).

Multivariate analysis of variance showed that there was a statistically significant effect of therapy on CROM in both studied groups $F(4, 33) = 11.77$, $p < 0.001$; Wilk's lambda = 0.41, $\eta p^2 = 0.58$. Statistically significant improvement in the ROM concerned three planes of movement and all analyzed measurements. There were no statistically significant differences between groups ($F(4, 33) = 0.66$, $p = 0.62$; Wilk's lambda = 0.93, $\eta p^2 = 0.07$) or interaction of factors $F(4, 33) = 1.14$, $p = 0.35$; Wilk's lambda = 0.88, $\eta p^2 = 0.12$. Results of univariate analysis of variance with repeated measures (Table 3).

Comparison of pressure sensitivity at the C4 level on the left side before and after therapy showed statistically significant differences only in the Therapy group (p=0.04, d=0.45). No statistically significant differences were found between the groups either before or after therapy (Table 4).

A statistically significant correlation was found between VAS, NDI and the initial pain threshold at the left C4 level and CSI. In the case of VAS, the correlation was found to be positive with moderate strength (r=0.35, p=0.03). In the case of NDI, a strong positive correlation was found with CSI (r=0.64, p<0.001). In the case of the C4 pain threshold, the correlation was found to be negative with moderate strength (r=-0.36, p=0.03) (Table 5).

DISCUSSION

The aim of this study was to evaluate the effect group of manual diaphragm relaxation technique on neck mobility and PPT in smartphone users with non-specific NP compared to placebo group.

Our studies show that there is a statistically significant effect of therapy on the CROM in both studied groups. A statistically significant improvement in the CROM concerned three planes of movement and all analyzed measurements, however, no statistically significant differences were found between the groups.

In the Yeampattanaporn et al. [26] study, researchers described the immediate effect of respiratory re-education on improving CROM. We can speculate that, as in the Yeampattanaporn et.al. study, and in this case too, the positive consequences of an increase in ROM may be due to an improvement in diaphragm contraction or a reduction in accessory muscle activity that followed deep breaths during the diaphragm relaxation intervention.

In the study by Perri M. et al. [6] the researchers show how abnormal breathing patterns can affect NP. In their conclusions, they suggested that in NP rehabilitation, assessments a and treatment of abnormal breathing patterns should not be overlooked. This reinforces the importance of targeting diaphragm work in the treatment of non-specific NP.

The results of Francisco et al. [27] show that a single stretch of the diaphragm causes a significant improvement in neck mobility, especially neck extension and neck flexion to the right and left, but there is a problem with the comparison with our study because the study included healthy subjects. Marizeiro et al. [28] studied the effect of diaphragm relaxation on, among other things, cervical and lumbar mobility in women with sedentary lifestyles. The authors highlighted disorders of the respiratory system, including the diaphragm, as a consequence of spending long periods of time sitting. We can assume that smartphone users also excessively adopt this position. Some studies show an association between the incidence of musculoskeletal pain and the time spent on daily use of the smartphone [29]

The study by McCoss et al. [10] conducted in young asymptomatic individuals showed an immediate statistically significant effect after treatment on the PPT measured at the level of the C4 spinous process. In our study, there was also a statistically significant difference, but only on the left side and only in the experimental group before and after treatment. However, there was no difference between the groups before and after treatment. It is difficult to interpret this result and the possibility of improvement due to chance cannot be excluded. We also noted a statistically significant negative correlation of moderate strength between PPT on the left side of C4 and CSI. In our study, the inclusion criteria were participants with non-specific NP. In addition, individuals who spend at least 4 h using smartphones. Therefore, we cannot clearly state that the changes generated by diaphragmatic treatment mediated by phrenic afferent fibers entering the fourth cervical segment could have a significant contribution.

We also found a strong positive correlation between CSI and NDI. This is consistent with the study by Jafari et al. who studied people with migraine and NP [30].

There are some limitations to the study that need to be considered. The physiotherapist responsible for performing the procedure could not be blinded due to the nature of the proposed therapeutic procedures. In our study, we investigated the effect of a single intervention, it would be interesting to to investigate what effect repeated interventions would have and how they would affect the participants in the longer term.

CONCLUSIONS

Our results are inconclusive and do not allow for drawing definitive conclusions regarding the effect of manual diaphragm relaxation on neck parameters in smartphone users with non-specific NP. However, taking into account the results of other researchers, diaphragm relaxation is recommended for people with NP. Analysis of the effect of diaphragmatic release on selected myofascial parameters may contribute to the expansion of manual work in the treatment of non-specific NP. In addition, this study will raise awareness among young people about the possible consequences of excessive smartphone use on body posture and pain.

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CONFLICT OF INTEREST

The Authors declare no conflict of interest.

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