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Assessment of stiffness of the superficial neck muscles in female office workers with impaired endurance of deep neck flexors: a case-control study

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Piotr Kocur, Daniel Choszczewski, Jacek Lewandowski, Magdalena Goliwąs
Department of Musculoskeletal Physiotherapy, Poznan University of Physical Education

Abstract

Introduction. The objective of this study was to assess the muscle stiffness parameter in the sternocleidomastoid (SCM) and upper trapezius (UT) in a group of office workers who did not attain the norm in the deep endurance flexor test (DEFT).
Methods. In this case-control study, the myotonometric muscle stiffness parameter (MyotonPro, Tallin, Estonia) was compared in the SCM and UT muscles in a group of female office workers who were unable to achieve the norm in the DEFT, i.e. the research group (RG), in comparison to the control group (CON) who attained the norm during the test. Subjects were matched in terms of their gender, age, BMI, nature and duration of their work, as well as the pain intensity and craniovertebral angle.
Results. Subjects in the RG had significantly higher stiffness of the UT (by 8.8%, 291.4 ± 36.5 in RG and 265.9 ± 25.6 in CON; p = 0.015, t = 2.29) and SCM (by 7.3%, 291.4 ± 36.5 in RG and 265.9 ± 25.6 in CON; p = 0.37, t = 1.85) myofascial tissue in comparison with the CON. The magnitude of the effects of the stiffness of the tested muscles on the results obtained by DEFT was stronger in the UT (Cohen's d = 0.82, large effect size) than the SCM (Cohen's d = 0.61, medium effect size).
Conclusions. The women who did not attain the norm in the DEFT had greater stiffness of the superficial UT and SCM muscles. Future studies should evaluate whether SCM and UT stiffness reduction therapy will improve the deep endurance flexor test results.
Key words: deep endurance flexor test, myofascial stiffness, neck pain

Introduction

Musculoskeletal disorders (MSD) in the cervical region contribute to the loss of strength and endurance of both flexors and extensors of the neck [1–5], which negatively affects head posture. Moreover, morphological changes occur in the muscles, e.g. the cross-sectional area increases in the neck flexor layer, and decreases in the extensor layer in patients with non-specific neck pain [6]. The muscle activation pattern is also changed. Superficial muscles, both neck flexors, such as the sternocleidomastoid (SCM) and scalene, as well as extensors, i.e. the upper trapezius (UT), are generally hyperactive relative to deep flexors (e.g. longus coli) and extensors (e.g. multifidus) of the neck, which in turn have the tendency to inhibit their activity [7–9].

Recent studies have also indicated that biomechanical properties, such as muscle stiffness, are important factors that increase as a result of the incidence of neck pain [10, 11]. Stiffness, in this case, is understood as the resistance of the muscle to an external force that deforms its initial shape [12].

It has been indicated that muscle stiffness might be associated with deteriorated capillarisation or blood flow in the muscle [13] and correlate with higher electrical activity of muscles [14, 15]. Greater muscle stiffness can restrict motion [16, 17] and potentially affect joint control. Furthermore, its strong dependency on the body posture and age in the group of superficial neck muscles has been demonstrated [18].

Our study was conducted on a group of individuals who work in the sitting position. The sitting position at work often contributes to work-related neck pain. It appears that the muscle stiffness parameter could become an easy predictor for non-specific pain occurring as an outcome of changes in the myofascial system, as a long-term effect of the sitting position. However, it remains unclear whether greater muscle stiffness is solely a consequence of the appearing pain, or it directly disturbs the normal function of the neck muscles.

Prolonged sitting at work leads to weak endurance of the deep neck muscles [8, 9, 19]. It is likely that this phenomenon occurs simultaneously with higher stiffness of the superficial UT and SCM muscles. Higher stiffness of these muscles can have a negative influence on the activation of the deep layer muscles via reciprocal inhibition of deep and superficial antagonists [19]. Moreover, it appears possible that the stiffness of the superficial UT and SCM may restrict flexion or extension in the atlanto-occipital joint [20]. A recent study showed that deep flexor endurance has a significant negative correlation with the biomechanical parameters of the suboccipital muscles [21]. Therefore, higher stiffness of the SCM and UT probably negatively influences deep endurance flexor test (DEFT) results.

We verified whether UT and SCM stiffness affects the results obtained by the examined individuals in the DEFT. SCM is believed to be a muscle in which hyperactivity largely impedes conducting tests assessing the performance of the deep neck flexors [4, 5]. At the same time, it has been demonstrated that SCM remains inactive during free sitting, its stiffness is not changed, and its role in maintaining the correct head position is minimal. In contrast, UT demonstrates considerably greater electric activity during both sitting and lying down [20, 21], and the sitting position influences increased stiffness parameters [22].

We assumed that poorer results obtained during a functional task (DEFT) will depend more strongly on the stiffness of the UT than the SCM. Therefore, individuals with a higher

Correspondence address: Piotr Kocur, Department of Musculoskeletal Physiotherapy, Poznan University of Physical Education, ul. Królowej Jadwigi 27/39, 61-871 Poznan, Poland, pkocur@awf.poznan.pl; https://orcid.org/0000-0003-0749-9919

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value of UT stiffness could exhibit poorer capacity in the performance of certain functional tasks. Such findings expand the interpretation of DEFT with additional diagnostic aspects associated with the stiffness parameter and highlight new variants of MSD therapy in the neck region in office workers. This particularly concerns therapy directed at the improvement of deep neck flexor endurance, which would include UT therapy. The objective of this study was to assess the muscle stiffness parameter in the SCM and UT in a mildly symptomatic group of office workers who did not attain the norm in the DEFT test, as compared with a matched-pair control group who attained the norm during the test.

Subjects and methods

Study participants

The subjects were selected from among 70 administrative and accounting staff of IT corporations and higher education institutions who did not indicate any of the basic criteria for exclusion from the study in the survey. The exclusion criteria were gender (only female subjects were recruited), acute or referred pain (at least 12 weeks without an episode of acute or referred pain), surgery in the neck and shoulder region, and orthopaedic or rheumatologic musculoskeletal disorders. Additionally, all subjects were recruited based on pain intensity measured through the Visual Analogue Scale (VAS) < 5 for current neck pain and a craniovertebral angle (CVA) > 45°, measured with the photometric method. Subsequently, the entire recruited group was subjected to measurement of muscle stiffness in the sitting position, after which DEFT was performed. On this basis, the group of 32 subjects was distinguished who did not attain the norm in the DEFT, along with 38 workers who attained the norm. Effort was made to collect homogeneous samples. Thus, additional exclusion criteria were applied, which could have a considerable impact on the value of muscle stiffness. The additionally exclusion criteria were: age (only between 30 and 50 years), BMI (values only in the range of 18.6–29.9), working time (at least 240 min/day), and duration of employment (only workers over 5 years of employment). Finally, the study featured 16 women who did not attain the norm in the DEFT (< 21.4 s) serving as a research group (RG) and 16 women who attained the norm in the DEFT (> 21.4 s) serving as a control group (CON). Both groups were matched pairs on the basis of the above-described criteria.

Study design

This was a case-control study in which muscle stiffness was measured in two study groups. The sample size was determined based on similar previous research concerning the measurement of biomechanical properties in muscles [23]. However, in the case of the stiffness parameter of the SCM, only a moderate effect size was demonstrated. An a posteriori analysis showed that the sample size for the SCM muscle stiffness measure should be increased to 19 subjects.

In order to avoid the potential influence of confounders, persons performing very similar tasks during their daily professional duties were recruited, and the same measurement conditions were provided, associated with the measurement site and time of day. The study was conducted between March and June 2018.

Outcome measures

The UT stiffness (Figure 1) was measured first in the central point of the neck triangle, on the anterior surface of the muscle. Then SCM stiffness was measured at the central point where both heads were joined (Figure 2). For each measurement, the device probe (Myoton AS, Tallinn, Estonia) with a diameter of 3 mm was placed perpendicularly to the skin surface with a constant preload (0.18 N). Myofascial tissue oscillations were evoked with 10 brief (15 ms) mechanical impulses at a force of 0.4 N and a frequency of 1 Hz. Myofascial stiffness (N/m) was calculated as the product of the maximum acceleration of the soft tissue oscillation and mass of the probe divided by the maximum displacement of the tissue. Previous studies have revealed good to excellent intra-rater and inter-rater reliability in measuring neck muscle mechanical properties [24, 25].

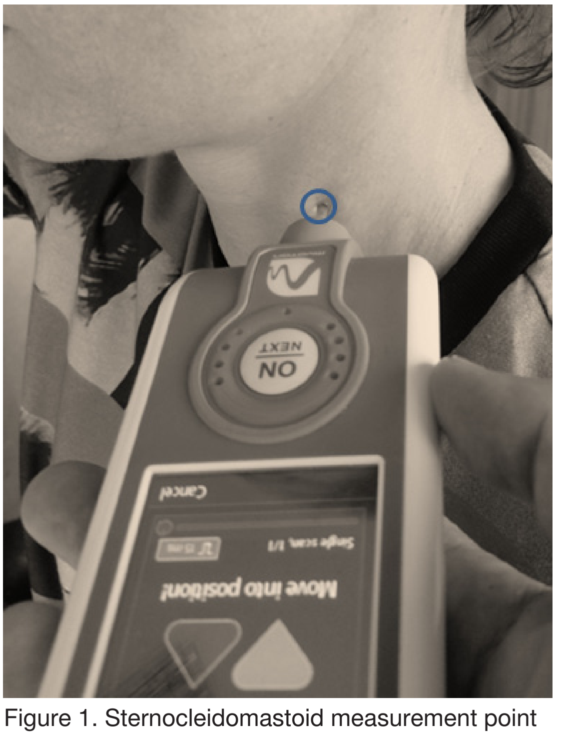

Figure 1. Sternocleidomastoid measurement point

Figure 2. Upper trapezius measurement point

Assessment of neck muscle stiffness

The subjects were sitting on a chair with their hands on their keyboard. They were asked to look at a text displayed on a screen placed at eye level for 15 minutes and to adopt their standard posture while working. The stiffness measurement was performed twice in each tested muscle, on both sides of the body. Our statistical analysis, which has performed before combining the results, showed there was no difference between the stiffness on the left and right side of the body. Therefore, the values of the analysed parameters obtained in successive measurements were averaged for each side of the body and then again averaged for both sides.

Deep endurance flexor test procedure

The test in each individual was performed in line with the procedure described in previous studies [4, 26]. It was always performed by the same physiotherapist twice, at 5-minute intervals, 30 minutes after the measurement of muscle stiffness. At this time, the subjects were informed about the principles of the test, and situations in which the test will be aborted. Subsequently, the patient was familiarised with the chin-tuck position, first in the sitting and then in the recumbent posture. A patient performed the movement a maximum of three times and maintained the position for no longer than 5 s. To better illustrate the movement, a passive demonstration was first made in front of a mirror, and then the patient performed the movement actively, first sitting and then lying down. The test was performed at least 10 minutes after the initial demonstration. The examined individual assumes the expected chin-tuck position and places their head on the fingers of the tester 2.5 cm above the surface of the couch in a relaxed position. Then, without changing the head position, the examined person raises and lowers it until making contact with the fingers of the tester. At this moment, the stopwatch is started. The test was aborted in the following situations; a) the examined person is unable to raise their head 2.5 cm above the couch and loses contact with tester's fingers and raises the head for more than 1 s. or touches/rests the head on the fingers of the tester b) the examined person is unable to maintain the chin-tuck position, or the two skin folds formed along the subject's anterior-lateral neck disappear, c) pain or fatigue of the subject appear, which make it impossible to continue the test.

Statistical analyses

The statistical analysis was performed with the Statistica statistical software package. To assess the distribution of the data, the Shapiro–Wilk test was performed. Our statistical analysis, which was performed before combining the results, showed that there was no difference between the stiffness on the left and right side of the body Therefore the values of the analysed parameters obtained in successive measurements were averaged for each side of the body and then again for both sides. As all the data had a normal distribution, the Student's t-test for two independent means was used. Cohen's *d* effect size was used to indicate the standardised difference between the means of the compared parameters. With the SCM stiffness parameter, only a moderate effect size was demonstrated. An a posteriori analysis showed that the sample size for the SCM muscle stiffness measure should be increased to 19 subjects. The critical level of significance was set at $\alpha = 0.05$.

Ethical approval

The research related to human use has complied with all the relevant national regulations and institutional policies, followed the tenets of the Declaration of Helsinki, and has been approved by the Institutional Review Board at the Poznan University of Medical Sciences (approval No.: 449/14).

Informed consent

Informed consent has been obtained from all individuals included in this study.

Results

The subjects from both groups did not differ in terms of their basic anthropometric features, length of service, and daily working time, or in the level of perceived pain. The RG individuals performed the DEFT in a significantly shorter time than the CON subjects (Table 1).

Table 1. Basic characteristics of the study groups (n = 32)

Parameters	RG (n = 16) Means ± *SD*	CON (n = 16) Means ± *SD*	*t*-value	*p*-value
Anthropometric				
Age (years)	40.6 ± 6.7	38.4 ± 5.0	–0.42	0.34
Height (cm)	168.5 ± 7.1	166.4 ± 6.4	–0.23	0.23
Weight (kg)	66.7 ± 9.3	62.4 ± 9.4	0.46	0.32
BMI (kg/m^2)	23.2 ± 2.7	22.5 ± 2.4	0.29	0.39
Work				
Duration of employment (years)	17.8 ± 7.6	15.8 ± 5.5	–0.47	0.22
Work time per day (min)	414.7 ± 51.4	410 ± 73.5	0.06	0.47
Pain intensity and disability				
VAS score (point)	2.6 ± 1.9	2.5 ± 1.6	0.32	0.37
CVA (°)	48.0 ± 4.5	48.1 ± 4.8	–0.82	0.21
DEFT (s)	15'30" ± 4.9	32'54" ± 4.9	11.08	0.00*

CON – control group, RG – research group, BMI – body mass index, VAS – visual analogue scale score, CVA – craniovertebral angle, DEFT – deep endurance flexor test; * significant difference between both groups $\alpha = 0.05$

The RG subjects had significantly higher stiffness of the UT myofascial tissue, i.e. 8.8% greater (p = 0.015, t = 2.29) than the CON subjects (291.4 ± 36.5 and 265.9 ± 25.6, respectively). Simultaneously, SCM muscle stiffness was significantly higher by 7.3% (p = 0.02, t = 1.85) in individuals who did not achieve the norm in the DEFT when compared to controls (231.7 ± 22.9 and 214.7 ± 28.9, respectively). The obtained effect size of the stiffness of the tested muscles was large for the UT (Cohen's d = 0.82) and medium for the SCM (Cohen's d = 0.61) (Table 2).

Table 2. Stiffness of myofascial tissue

Parameters	RG (n = 16)	CON (n = 16)	t-value	p-value	Cohen's d
Stiffness (N/m)					
UT	291.5 ± 36.5	265.9 ± 25.6	2.29	0.015*	0.82
SCM	231.7 ± 22.9	214.7 ± 28.9	1.85	0.02*	0.61

Data are presented as means ± *SD*. CON – control group, RG – research group, UT – upper trapezius, SCM – sternocleidomastoid, * significant difference between both groups

Discussion

Within this study, the UT and SCM stiffness was analysed in mildly symptomatic female office workers who did not obtain the norm in the DEFT. It was found that UT and SCM stiffness was higher in the research group as compared to the control group, in which the norm was obtained. In addition, based on the results of the effect size, we have shown that the importance of UT muscle stiffness and DEFT results is probably greater than the importance of SCM stiffness. Nevertheless, we believe that greater stiffness of both superficial muscles probably has an impact on the possibility of maintaining a specific chin-tuck head position, which may be linked to their hyperactivity during the test. These results may also indicate the need to add a therapy decreasing stiffness not only of the SCM muscles but also the UT muscles to stabilisation training of neck deep-layer muscles.

Higher stiffness and DEFT results

The study conducted at our laboratory fell within the general conclusions based on existing experience concerning various risk factors for work-related neck disorders. However, the simultaneous measurements of biomechanical parameters and deep muscle strength have not been a subject of research thus far. However, it is known that lower DEFT values can be linked to an increased risk of the appearance of neck pain [4, 5, 27]. Similarly, higher muscle stiffness – particularly UT stiffness assessed in women performing office tasks – occurs solely in those indicating neck pain [10]. The study of persons with neck pain via sonoelastography also indicated greater UT stiffness [28]. A study by Taş et al. [29] with the use of ultrasonography indicated that greater muscle stiffness in neck pain patients occurs not only in the UT but also in the SCM, but they noted that it does not correlate with pain severity. The concomitant assessment of muscle size and a performance test showed that patients with neck pain have both worse performance in the test as well as clear changes in muscle thickness and the cross-sectional area of both extensors and flexors of the neck [30].

The above study further confirmed that differences in muscle stiffness are independent of the forward head posture (FHP), which is expressed in our study as the CVA angle. Even though the influence of the FHP factor was neutralised in our study by the selection criteria requiring persons with extreme values of this parameter (range of CVA angle between 45 and 52 degrees), and the tested groups were matched in terms of FHP, a difference in the superficial muscle stiffness was noted. Ghamkhar et al. [30] observed that, even in patients with chronic neck pain, no relationship exists between FHP and the pain intensity and disability parameters. It was demonstrated that, in asymptomatic patients with FHP, no visible differences in the biomechanical parameters exist relative to persons with normal head posture [31]. Despite the decreased strength of deep neck flexors assessed in the DEFT, often linked to the appearance of FHP disorder, the impact of this disorder on the test results is debatable. Moreover, in our study, differences were noted in the stiffness parameters in asymptomatic women who did not differ in FHP. It appears that greater UT and SCM stiffness is not the direct cause of pain and postural disorders, but it may cause initial disturbances in the normal function and the muscle balance in the neck muscle region. This dysfunction, exhibited via hyperactivity of superficial muscles relative to the deep layer, may lead to pain being the result of chronic stress of the muscle and an energy crisis in the muscle fibre [32].

UT and SCM relationship

We assume that the greater stiffness of both the UT and SCM may influence DEFT outcomes [33]. However, in our study, a large effect size (Cohen's d = 0.82) for the UT stiffness parameter and medium effect size (Cohen's d = 0.61) for the SCM stiffness parameter were demonstrated. Research points to a strict functional relationship between SCM and UT in terms of both the same innervations of these muscle groups, and the possible influence of antagonists on antagonists [34]. For these reasons, the necessity for concomitant therapy of these muscles has already been suggested [35]. The UT seems to be a muscle in which changes of the biomechanical parameters, including stiffness, are more dynamic and more perceptible. When seated, the UT remains in an isometric tension, preventing forward movement of the head [36], whereas the electrical activity and the role of the SCM in the correct head position is minimal [37, 38], which is further expressed by visible differences in the change of stiffness or elasticity [18, 39]. Perhaps this is why differences in the effect size for UT and SCM stiffness were demonstrated.

Influence of myofascial stiffness on muscle function

With regard to motion mechanics, we suspect that the higher muscle activity of the UT and SCM has a possible impact on certain components of the test, such as the chin-tuck position. According to the function of these muscles [40], when the head is raising, flexion in the atlanto-occipital joint in the chin-tuck position could be limited.

An explanation for biomechanical and morphological variations in the superficial neck muscles in the neck region is that a strict relationship exists between the amount of non-twitching-connective or adipose tissue in myofascial tissues and higher passive muscle stiffness. At the same time, it has been shown that the content of connective tissue has a direct impact on the quality of muscle contraction, because muscle fibres transmit the force to the surrounding connective tissue [41–43]. As a result of the assumed body position during work and prolonged seating, permanent changes may occur in the extracellular matrix morphology [41] with additional collagen cross-linking [42]. This leads to changes in the biomechanical properties of different muscle groups. It is therefore likely that high muscle stiffness may directly influence muscle endurance [34]. We have concluded that superficial muscle stiffness may influence the performance and the endurance of the deep flexors, as our research group had significantly higher stiffness of the UT and SCM muscles.

In our study, we recruited only mildly symptomatic office workers who were different in the endurance of the deep neck muscles, as assessed by the DEFT. These results confirm that muscle disorders in the neck region appear even in asymptomatic subjects. We have concluded that the superficial muscle stiffness parameter may influence the normal performance of the test assessing the endurance of deep flexors. Moreover, both groups had different levels of UT and SCM muscle stiffness. Therefore, neck pain can appear as a result of both impaired deep flexors of the neck and higher stiffness of the superficial neck muscles. This is in line with the findings Bonilla-Barba et al. [44], who showed hyperactivity of superficial extensors and flexors during the craniocervical flexion test in women with neck pain. We suggest that deep neck flexor training should also include concomitant therapy for the SCM and UT, directed at a reduction in muscle stiffness.

This leads to specific recommendations for the group of office workers, in order to prevent work-related neck disorders. Some studies have shown that training the deep flexors improves their activation and may contribute to a reduction in neck pain [45, 46, 47]. On the other hand, there is no indication that such training improves the endurance of these muscles [48]. Thus, it might be necessary to include techniques to reduce the UT and SCM stiffness for the improved efficiency of deep neck flexor training [49]. Higher muscle stiffness may limit the range of motion and simultaneously have a linear relationship with the force of the muscles, which may be a predictor of poorer activation in deep neck flexors [50]. In order to achieve muscle balance [51], specific autotherapy or self-performed exercises at the place of work should be recommended, such as foam rolling [52], ischemic compression at trigger points [53], or 7 minutes of massage to reduce UT stiffness [54].

Study limitation: Although our study provides some interesting information that may be useful for the prevention of work-related neck disorders, there are a few limitations that should be accounted for.

Our study has shown that the superficial muscle stiffness parameter of the UT and SCM may negatively influence the functional test that assesses endurance in deep flexors of the neck. Nevertheless, it is difficult to find a direct relationship between the stiffness parameter, which is tested via myotonometry, and muscle endurance. Certainly, the performance of concomitant imaging analysis of the muscle and myotonometry would be necessary in order to be able to indicate a structural or morphological cause for the poorer functional performance of muscles [55].

We studied only female workers, which makes impossible to draw a conclusion for the population at large. Still, women working in offices are nearly three times more likely to develop neck pain than men [56] and it has also been demonstrated that the deep endurance flexor test is more reliable for women (ICC: 0.93–0.94) [57]. We therefore concluded that it was worth conducting the first study on a homogenous, carefully selected group of office workers.

Even though we observed an increase in the stiffness of the SCM myofascial tissue, only a moderate effect size for this parameter was demonstrated. Therefore, it is highly likely that SCM stiffness did increase in the women with abnormal function, but due to the relatively small sample size, the statistical power was not sufficient (~0.6) to verify this. An a posteriori analysis showed that the sample size for the SCM muscle stiffness measure should be increased to 19 subjects. Finally, the DEFT is commonly used in clinical practice because of its easy interpretation. Therefore, in our opinion, it could be used as a comparative test in a specific homogeneous study group. However, some studies have shown that the minimum change required to represent a real change in muscle endurance is 17.8 seconds, which indicates a high degree of deep muscle endurance Thus, in the future, in studies assessing the effects of various forms of therapy, another test should be taken into account as a primary outcome measure, such as the craniocervical flexor test [58]. Further studies are needed to resolve these questions.

Conclusions

The women who did not attain the norm in the deep endurance flexor test had greater stiffness of the superficial UT and SCM muscles. It is likely that the superficial muscle stiffness parameter may influence the normal performance of the test assessing the endurance of deep flexors via their hyperactivation and inhibition of deep layer muscles. Future studies should evaluate whether SCM and UT stiffness reduction therapy, such as foam rolling, ischemic compression and stretching, will improve the deep endurance flexor test results.

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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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