Influence of Forward Head Posture on Myotonometric Measurements of Superficial Neck Muscle Tone, Elasticity, and Stiffness in Asymptomatic Individuals With Sedentary Jobs

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Abstract

Objective: The objective of the study was to assess the influence of forward head posture on the mechanical parameters and pressure pain threshold of superficial neck muscles in clinically nonsymptomatic individuals with sedentary jobs.

Methods: Twenty-five office workers with forward head posture and 25 office workers with normal head posture were matched for sex, age, body mass index, and the nature and duration of their work and were compared at a single point. The study participants were divided into study groups on the basis of photometric craniovertebral angle measurements. The upper trapezius, sternocleidomastoid, and splenius capitis mechanical properties were assessed in the sitting position. Primary outcome measures were muscle stiffness (N/m), muscle tone (Hz), and muscle elasticity. The secondary variable was perceived pain threshold.

Results: No significant differences between the groups were found for biomechanical properties and perceived pain threshold in the studied muscles.

Conclusion: Forward head posture has no impact on muscle stiffness, tone, and elasticity, nor does it increase the pressure sensitivity of superficial neck muscles in healthy, mildly symptomatic office workers. It is most likely that not incorrect posture of the cervical spine, but probably other factors combined with forward head posture, like comorbid acute and chronic cervical pain and musculoskeletal disorders or prolonged sitting, contribute to changes in active myofascial tone and tensegrity as well as increased pressure sensitivity of neck muscles. (J Manipulative Physiol Ther 2019;42:195-202)

Key Indexing Terms: *Neck Muscles; Muscle Tonus; Elasticity; Pain Threshold; Posture*

Introduction

Cervical spine loads in static conditions and sitting positions are much higher than during head movements.[1] Sitting is associated with increased tone and stiffness and decreased elasticity of the myofascial tissue of the descending part of the trapezius muscle.[2] The hardness of the trapezius muscle changes significantly with changes of head inclination in individuals working in sedentary jobs.[3] In normal conditions, the center of gravity of the head falls anterior to the atlanto-occipital joint, and the activity of the muscles stabilizing and maintaining neutral head posture is minimal.[4] On the other hand, muscle activity, especially in the back of the neck, increases rapidly when the head leans forward or when it is shifted forward in the sagittal plane in relation to the trunk.[5] One of the most common postural disorders in the shoulder girdle and the neck occurs when the position of the head is shifted forward in relation to the point of support, the so-called forward head posture (FHP).[6] Forward head posture is a typical disorder in people with sedentary jobs.[7] From the point of view of biomechanics, FHP causes changes in the muscle-tendon unit length of the cervical extensors and flexors and the atlanto-occipital joint.[8] In addition, it impairs the activity of the superficial and deep stabilizing muscles of the neck, often

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causing hyperactivity in the sternocleidomastoid muscle in comparison with the longus colli muscle.[9] People with FHP have been demonstrated to have higher electrical activity of the neck muscles compared with people without FHP. [10-12]

Working with chronic holding of the neck in a forward bent posture or sitting in such a position for a prolonged time during the day has been significantly associated with neck pain.[7] Forward head posture is believed to be a potential risk factor in tension-type headache and chronic neck pain.[13-14] People with FHP are also more likely to have active trigger points in the neck region.[15] Despite the fact that the presence of trigger points in neck muscles, especially in the descending part of the trapezius muscle, is strongly correlated with nonspecific neck pain,[16] a link between FHP and chronic neck pain,[17] or tension-type headache,[18] has not always been unequivocally demonstrated. It seems, therefore, that the presence of FHP alone may not necessarily lead to clinical symptoms like chronic or unpleasant muscle and tissue pain in the neck region, even when the pressure sensitivity of the neck muscles is increased.[3,18]

The present study investigated the influence of FHP on the mechanical parameters and pressure pain threshold of superficial neck muscles in clinically nonsymptomatic individuals working in sedentary jobs. The main objective was to determine whether neck muscle tone and stiffness would be increased in sitting participants with FHP who mildly complain of chronic neck pain and tension-type headache. We assumed that even if local myofascial pain sensitivity of studied muscles was increased in individuals with FHP, the mechanical parameters of the superficial neck muscles would remain unchanged.

Methods

Study Participants

Volunteers were searched among administrative university staff, accountants, and IT specialists. Overall, 50 healthy office workers who met inclusion criteria were included in the study. They were divided in 2 groups of individuals without (normal head posture [NHP], n = 25) or with the FHP (FHP, n = 25). The sample size was determined based on analysis of previous similar research concerning both the measurement of FHP and biomechanical properties of the muscles.[2,19] Participants from both groups were matched for age, height, body weight, body mass index (BMI), and clinical (visual analog scale, neck disability index) and work (length of service, working time) characteristics. The effort was taken to collect the homogeneous samples. Therefore, participants with extreme values of anthropometric characteristics such as age, that is, very young and old, or BMI, that is, underweight or overweight, which may affect muscle mechanical parameters, were not recruited.[20,21] Only healthy individuals without any acute or chronic headaches or neck pain over the preceding 6 months who defined their level of physical activity in their leisure time as average or low were recruited. The study inclusion criteria were as follows: (1) age between 25 and 55 years, (2) BMI between 18.5 and 30, (3) visual analog scale <5, neck disability index < 14 points (mild disability), (4) weekly working time in a sitting position of at least 35 hours, and (6) lack of orthopedic and neurological comorbidities. We excluded individuals after surgeries within the thoracic, shoulder girdle, and cervical spine regions. The basic demographic data are presented in Table 1.

To diminish the potential sources of bias, the individuals from both groups were drawn from the same community of office workers, with the same type of work and very similar working conditions and environment. Measurement of mechanical muscle parameters was performed once, by the same assessor in the participants' workplace. The evaluation and measurements took place in a separate air-conditioned (18°C-22°C) bright room, in the middle of the week (Tuesday or Wednesday) between 9 AM and noon. The study was conducted between October 2016 and September 2017. The institutional review board of Poznan University of Medical Sciences approved the study (no. 538/16). The experimental procedures were conducted in conformity with the Declaration of Helsinki. The relevant guidelines and regulations of the local institute were strictly followed when conducting the study. Each patient signed an informed consent form prior to participation.

Outcome Measures

Primary outcome measures were (1) muscle stiffness (N/m), defined as the resistance of the myofascial tissue to an external force that has changed its original shape; (2) muscle tone (Hz), defined as the maximum frequency of the myofascial tissue oscillation; and (3) muscle elasticity, described as an ability to restore superficial shape and dissipate mechanical energy after the myofascial tissue has been deformed. The secondary variable was perceived pain threshold (PPT).

Measuring the Angle and Diagnosing FHP

To assess FHP, we measured the craniovertebral angle (the angle between the line connecting the seventh cervical vertebra and the tragus of right ear, and the horizontal line running in the sagittal place through the C7 process) by means of the photometric method. The craniovertebral angle is commonly regarded as the most relevant and reproducible in determining FHP.[22] The measurements were taken on the basis of standards defined in the available literature.[19] A camera (Canon SX620HS) (Canon, Ōita, Japan) was placed 1.5 m away, at the height of the acromion of each participant. Each participant was asked to stand naturally and look at a point indicated on the wall for several

Table 1. *Descriptive Characteristics of Studied Participants.*

Descriptive Parameters	NHP (n=25)	FHP (n=25)	Calculated Statistics	(LCI, UCI)	*P* Value
Demographics					
Sex (W/M)	25/5	25/5	–	–	–
Age (y)	39.6 ± 8.1	40.7 ± 6.8	*t*(48)=0.51	(-3.2 to 5.3)	.613
Height (cm)	169.4 ± 9.3	170.4 ± 7.6	*t*(48)=0.42	(-8.1 to 3.3)	.678
Body mass (kg)	67.5 ± 10.7	70.6 ± 9.7	U=241.5	(-2.7 to 8.9)	.170
BMI (kg/m^2)	23.3 ± 2.2	24.2 ± 1.9	*t*(48)=1.42	(-0.3 to 2.0)	.528
Clinical characteristic					
CVA (°)	51.5 ± 2.7	42.8 ± 3.3*	*t*(48)=-10.1	(-10.4 to -6.9)	.000
VAS (points)	2.6 ± 2.0	3.5 ± 1.5	U=725.5	(-0.03 to 2.0)	.082
NDI (%)	10.5 ± 7.7	14.6 ± 8.6	U=727.5	(-0.5 to 8.8)	.082
Work related characteristics					
WExp (y)	16.9 ± 10.0	17.0 ± 7.5	U=287.0	(-5.0 to 5.1)	.627
WWt (min)	421.8 ± 63.0	407.6 ± 63.7	U=266.0	(-50.2 to 21.8)	.366

NOTE. Data are presented as mean ± SD.
BMI, body mass index; *CVA*, craniovertebral angle; *FHP*, forward head posture; *LCI, UCL*, lower and upper 95% confidence interval for difference of means; *NDI*, neck disability index; *NHP*, normal head posture; *SD*, standard deviation; *VAS*, visual analog scale; *WExp*, work experience; *WWt*, week working time.

seconds. The C7 process and the tragus were marked with markers. The photographs were taken with the participants standing sideways in a resting position. Generally, measuring of craniovertebral angle (CVA) in standing position is considered a more sensitive method of FHP evaluation than in sitting position.[19] Before the measurements were taken, the participants were asked to deeply flex and extend their cervical spine to adopt a natural head position. The photographs were then printed out to measure the angle on a graphic image. A CVA of below 48° is regarded as indicative of FHP.[19,22] That is why the cutoff point for the diagnosis of the CVA was 48 for the purpose of the present study. The participants with a CVA below 48 were defined as FHP and those with a CVA above 48 were defined as NHP.

Procedure

The study was conducted midweek while the participants were performing their daily tasks at work. The participants were sitting on a chair with their hands on their knees. They were asked to look for a few minutes at a text displayed on a screen placed at eye level and to adopt their standard posture while doing their work. Whenever necessary, participants were allowed to wear glasses or contact lenses during testing because visual acuity was not assessed in the study. Measurements of viscoelastic parameters were taken in the middle of the muscle belly by means of the MyotonPRO device (Myoton AS, Tallin, Estonia). First, we measured the descending part of the upper trapezius (UT) muscle, then the sternocleidomastoid (SCM) muscle, and finally the splenius capitis (SC) muscle as the most superficial of the suboccipital muscles. The UT was measured in the neck triangle, halfway between the outermost part of the acromion and the C7 spinous process. The measurement point was marked at the front of the muscle owing to greater accessibility of muscle fibers. The SCM was measured at a point halfway between the attachment to the sternum and the mastoid process of the temporal bone, where both heads were joined. The measurement point for the SC was marked underneath the mastoid process, 1 cm behind the insertion of the SCM. The measurements were taken first on the right and then the left side of the body. Every time, the device probe (3 mm in diameter) was placed perpendicularly to the skin surface with a constant preload (0.18 N). Oscillations of the underlying tissues were evoked by delivering 8 brief (15 ms) mechanical impulses at a low force (0.4 N) and frequency of 1 Hz. The induced dump natural oscillations of the tissues were recorded by a MyotonPRO accelerometer.

Table 2. *Mechanical Parameters of Studied Muscles.*

Mechanical Parameters	NHP (n=25)	FHP (n=25)	Calculated Statistics	d (LCI, UCI)	*P* Value
Tone (Hz)—mean (SD)					
UT	16.3 ± 1.6	15.8 ± 1.0	t(48)=-1.2	0.37 (-1.2 to 0.3)	.249
SC	19.1± 2.4	19.4 ± 2.3	t(48)=0.4	0.13 (-1.1 to 1.6)	.667
SCM	13.5 ± 1.1	13.5 ± 1.2	t(48)=-1.2	0.00 (-0.6 to 0.7)	.826
Stiffness (N/m)—mean (SD)					
UT	285.1 ± 39.5	278.4 ± 29.0	t(48)=-0.7	0.24 (-26.4 to 13.0)	.496
SC	386.0 ± 71.3	395.6 ± 65.2	t(48)=0.5	0.14 (-29.3 to 48.4)	.622
SCM	224.1 ± 33.1	230.2 ± 25.3	t(48)=-0.7	0.21 (-10.7 to 22.9)	.468
Elasticity[log DEC]—mean (SD)					
UT	1.25 ± 0.14	1.27 ± 0.18	t(48)=-0.6	0.12 (-0.07 to 0.11)	.583
SC	1.49 ± 0.19	1.57 ± 0.21	t(48)=1.5	0.40 (-0.03 to 0.20)	.137
SCM	1.45 ± 0.24	1.45 ± 0.21	t(48)=-0.0	0.0 (-0.13 to 0.13)	.992

NOTE. Data are presented as mean ± SD.
d, Cohen's effect size; *FHP*, forward head posture; *LCI, UCL*, lower and upper 95% confidence interval for difference of means; *NHP*, the normal head posture; *SC*, splenius capitis muscle; *SCM*, sternocleidomastoid muscle; *SD*, standard deviation; *UT*, upper trapezius.

The PPT is the minimum force applied that elicits pain complaint and reflects myofascial pain sensitivity.[23] It was determined in analogous points and order (first on the left and then on the right), like in the myotonometer assessment, by means of an algometer (Digital Force Gauges, Wagner Force One – Model FDIX) (Wagner, Greenwich, Connecticut). The device probe, with a surface of 1 cm^2, was pressed against the skin, with the pressure on the tissue being gradually increased until the first sensation of pain. Two measurements were taken on each muscle at 5-minute intervals.

Data Analysis

Myofascial stiffness (N/m) was calculated as the product of maximum acceleration of soft tissue oscillation and mass of probe divided by the maximum displacement of the tissue. The maximum oscillation frequency of soft tissues (Hz) indicating myofascial tension was computed from the accelerometer signal spectrum using a fast Fourier transform according to established formulas. The higher the values of both parameters, the greater was the stiffness and tension of the examined muscles. Elasticity was calculated as the magnitude of logarithmic decrement (arbitrary units) of the amplitude of the second to first natural tissue oscillation evoked with a single mechanical impulse. The smaller the value of logarithmic decrement, the higher was the muscle elasticity because mechanical energy dissipation was also smaller.[24] In line with the guidelines of earlier research reports,[25] the PPT (Nm/cm^2) was registered as the first discomfort reported by the participant, suggesting the appearance of pain and not a sensation of pressure itself.

Statistical Analyses

The values of studied parameters collected in successive measurements were averaged for each side of the body separately. These averaged values were averaged again for both sides of the body and then compared. The Shapiro-Wilk test for normality evaluation was used to assess the distribution of the data. Since the overall number of studied participants was greater than 30, the significance of the differences between the average values measured in both groups was tested with the parametric independent samples t test if the data were normally distributed and variances were equal, and with the nonparametric Mann-Whitney U test if the distribution was different than normal and variance was nonuniform. The statistical analyses were performed by a person blinded to group assignment. The critical level of significance assumed a priori in the study was $\alpha = 0.05$.

Table 3. *Pressure Pain Threshold.*

Muscles	NHP (n=25)	FHP (n=25)	Calculated Statistics	d (LCI, UCI)	*P* Value
UT	2.17 ± 0.96	1.91 ± 0.65	U=280.5	0.31 (-0.21 to 0.72)	.541
SC	2.21 ± 1.03	2.11 ± 0.81	U=312.5	0.10 (-0.43 to 0.62)	.992
SCM	1.00 ± 0.42	0.92 ± 0.37	U=280.0	0.20 (-0.15 to 0.30)	.535

NOTE. Data are presented as mean ± SD.
d, Cohen's effect size; *FHP*, forward head posture; *LCI, UCL*, lower and upper 95% confidence interval for difference of means; *NHP*, normal head posture; *SC*, splenius capitis muscle; *SCM*, sternocleidomastoid muscle; *SD*, standard deviation; *UT*, upper trapezius muscle.

Results

The analyzed groups did not differ regarding the basic descriptive characteristics. Only the CVA was significantly smaller in participants with FHP (Table 1).

The viscoelastic properties of the muscles are presented in Table 2. Both among the NHP participants and the FHP participants, the highest stiffness and tone values of the analyzed muscles were recorded in the SC and the lowest in the SCM. At the same time, the highest elasticity values were those of the UT muscle. No significant changes in the mechanical parameters of the analyzed neck muscles were found in the FHP participants.

Muscle sensitivity to pressure pain is presented in Table 3. In both groups, the lowest PPT values among the analyzed muscles were those of the SCM and the highest of the SC. No changes in the PPT were recorded in the case of all analyzed muscles in the FHP participants.

Discussion

The present study is the first matched control study evaluating the impact of FHP on the mechanical parameters and pressure pain threshold of neck muscles in individuals working in sedentary jobs. It demonstrated that in the sitting position, the neck muscle tone, stiffness, and elasticity were no different in people with NHP and those with FHP with a mild neck disability. In addition, no change in pressure pain sensitivity was found in the individuals with FHP.

Earlier studies had demonstrated that myotonometry could be used to reliably diagnose irregularities in biomechanical and viscoelastic properties,[26,27] during aging[21] or in weightlessness.[28] In the present study, the average values of the analyzed parameters in the UT and SCM muscles in the NHP participants were slightly higher than in young and lower than in elderly women in comparison with our earlier study.[29] This may be caused by the fact that the participants were in an age group between the age groups of the participants in the earlier study or that the present study also featured men.

FHP and the Mechanical Properties of Superficial Neck Muscles

In the present study, no significant differences in the tone, stiffness, and elasticity of the UT, SC, and SCM muscles were found in the NHP and FHP participants. Thus FHP, a postural disorder, may not necessarily be associated with changes of the viscoelastic properties of neck muscles in people who in their own view are mildly symptomatic. The results of our study match the observations described in other FHP studies. They suggest that it is extremely difficult to demonstrate a link between FHP and clinical symptoms. Although is it commonly suggested that there is a link between FHP and work-related neck disorders,[12] increased load for the intervertebral disc and joints,[6] and higher electrical activity of neck muscles in office workers,[15] a link between FHP and chronic neck pain[17] or tension-type headache[18] has not always been unequivocally demonstrated. It seems, therefore, that it is not FHP alone but rather the presence of increased pain and disability that may increase the tone and stiffness of neck muscles. Initial results of a myotonometry study by Park et al[30] demonstrated, for example, that in patients with tension-type headaches the tone and stiffness of the UT muscle were significantly higher than in nonsymptomatic participants. Increased stiffness may be related to diminished blood flow[31] and development of regional myofascial pain within neck muscles[32,33] owing to the overly long time spent in the static postures in individuals performing sedentary jobs.

In addition, like in the case of the viscoelastic properties and the PPT of the SCM in our study, an electromyographic test of this muscle did not reveal any significant changes in healthy individuals with FHP in comparison with people with normal head positioning.[34] Also, the recorded UT tone and stiffness parameters were higher than in our study, although the participants were younger. This confirms that changes in neck muscle parameters may depend more on the intensification of clinical symptoms, in this case comorbid headache, than on changes in the position of the head as such. Currently, our team is investigating whether there are changes in the mechanical parameters of neck muscles in people with more severe clinical symptoms. Clinical symptoms in the region of the head and neck may also be triggered by prolonged sitting at work. Earlier studies had indicated that the sitting position increased the tone and stiffness of neck muscles.[2,29] For example, Johnston at al. had demonstrated that there were no clear differences in the electromyogram activity of the neck muscles even between individuals with and without pain doing similar work,[35] although there were differences in comparison with nonworking individuals. However, the impact of prolonged sitting on the viscoelastic parameters of neck muscles has not been investigated so far. In addition, although head posture in a sitting position may contribute to increased UT muscle activity,[36] today it is believed that it is not just the position of the head but the positioning of the arms when working that may increase the activity of this muscle.[37]

FHP and PPT

Our study demonstrated that people with FHP in sedentary jobs did not have increased pressure pain sensitivity in the analyzed muscles. To some extent, this matches the results of earlier research. A study of female office workers showed that in individuals performing similar tasks but with neck or shoulder symptoms, the PPT could decrease in comparison with a nonsymptomatic control group.[38] It was subsequently demonstrated, however, that the PPT at the neck did not correlate with pain intensity[39] and that the PPT was even regarded as a poor marker of central sensitization or that sensitization did not play a major role in patients' reporting of pain and disability.[40] Thus, it seems that in mildly symptomatic individuals FHP does not increase pressure pain sensitivity compared with people in similar jobs with a natural position of the head in the sagittal plane. There are several factors other than FHP that may contribute to changes in the PPT of neck muscles. For example, a significant lowering of the PPT was found after overhead work with an actively shortened muscle.[41] Moreover, Sohn et al[42] demonstrated that although there was a link between FHP and active trigger points in neck muscles in people with chronic headaches, the authors concluded that FHP was a result rather than cause of the headaches. Other studies demonstrated that the PPT closely depended on how much time was spent working with a computer and that it could decrease already after doing such work for just a quarter of an hour or so.[43] Thus, it seems that in people with FHP who sit while doing computer work, a lowering of the PPT in latent trigger points in the neck region is just as likely as in individuals without FHP doing similar work because it depends more on the nature of the work in question. In their study, Wytrążek et al[44] demonstrated that increased electrical activity in muscles was correlated with a lowered PPT in all types of trigger points in neck muscles. This may draw physiotherapists' attention to the treatment and prevention of chronic and occasional tension-type headaches in people with a lowered PPT irrespective of whether FHP is present or whether the head is positioned normally.

Study Limitations

We examined matched populations of volunteers among office workers (ie, with similar demographic, clinical, and work-related characteristics) and not participants from random independent samples. This certainly might introduce the matching and volunteer bias to the study. The study did not take into account the FHP stage. Perhaps people with severe FHP (CVA <42°) would have had changes in the mechanical parameters of the neck muscles. In addition, although the 2 groups were matched for sex, in both women predominated. Although FHP and work-related neck disorders are more typical of women, in the future it would be worth taking into consideration a larger group of men in such comparisons. Furthermore, in 2 cases, (ie, decreased tone of UT and decreased elasticity of SC) a moderate effect size was found despite a lack of significant differences. In these cases, the relatively small number of the participants may have caused the type II statistical error. Finally, the CVA, although commonly used, is not the only or the best measure of FHP. That is why in the future it would be worth expanding the study to include a classification based on more objective criterion, for example, anatomical landmarks obtained from x-rays of the spine.

Conclusion

In mildly symptomatic office workers with FHP, the biomechanical and viscoelastic parameters of neck muscles and myofascial pressure sensitivity are not changed. This suggests that factors other than FHP are more likely to influence the tone and tensegrity of neck muscles. Presumably, FHP does not contribute to greater risk of pain and neck dysfunction. Therefore, factors other than FHP, like acute and chronic neck pain syndromes caused by orthopedic conditions, positioning of upper limbs, or prolonged sitting at work presumably affect viscoelastic parameters and subjective pressure sensation of neck muscles. That is why it would be worth analyzing the link among FHP, comorbid neck pain, and the biomechanical and viscoelastic muscle parameters.

Funding Sources and Conflicts of Interest

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Contributorship Information

Concept development (provided idea for the research): P.K.

Design (planned the methods to generate the results): P.K., D.Ł.

Supervision (provided oversight, responsible for organization and implementation, writing of the manuscript): P.K., D.Ł.
Data collection/processing (responsible for experiments, patient management, organization, or reporting data): M.G.
Analysis/interpretation (responsible for statistical analysis, evaluation, and presentation of the results): P.K., M.W., D.Ł.
Literature search (performed the literature search): M.G., J.L.
Writing (responsible for writing a substantive part of the manuscript): P.K.
Critical review (revised manuscript for intellectual content, this does not relate to spelling and grammar checking): M.W., J.L., D.Ł.

Practical Applications

- Presence of FHP alone may not necessarily lead to clinical symptoms like chronic or unpleasant muscle and tissue pain in the neck region.
- Forward head posture does not cause any significant changes in muscle biomechanical properties and pressure sensitivity of superficial neck muscles in healthy, mildly symptomatic office workers.
- Other factors, combined with FHP, like comorbid acute and chronic cervical pain and musculoskeletal disorders or prolonged sitting, probably contribute to changes in biomechanical properties, as well as increased pressure pain sensitivity of neck muscles.

References

1. Moroney S, Schultz AB, Miller AB. Analysis and measurement of neck loads. *J Orthop Res.* 1988;6(5):713-720.
2. Viir R, Virkus A, Laiho K, Rajaleid K, Selart A, Mikkelsson M. Trapezius muscle tone and viscoelastic properties in sitting and supine positions. *SJWEH.* 2007;3:76-80 Suppl.
3. Horikawa M. Effect of visual display terminal height on the trapezius muscle hardness: quantitative evaluation by a newly developed muscle hardness meter. *Appl Ergon.* 2001;32(5):473-478.
4. Harrison DD, Harrison SO, Croft AC, Harrison DE, Troyanovich SJ. Sitting biomechanics part I: Review of the literature. *J Manipulative Physiol Ther.* 1999;22(9):594-609.
5. Szeto GP, Straker LM, O'Sullivan BP. A comparison of symptomatic and asymptomatic office workers performing monotonous keyboard work – 2: neck and shoulder muscle recruitment pattern. *Man Ther.* 2005;10(4):281-291.
6. Patwardhan AG, Havey RM, Khayatzadeh S, et al. Postural consequences of cervical sagittal imbalance: a novel laboratory model. *Spine (Phila Pa 1976).* 2015;40(11):783-792.
7. Cagine B, Danneels L, van Tigglen D, De Loose V, Cambier D. Individual and work related risk factors for neck pain among office workers: a cross sectional study. *Eur Spine J.* 2007;16(5):679-686.
8. Khayatzadeh S, Kalmanson OA, Schuit D, et al. Cervical spine muscle-tendon unit length differences between neutral and forward head postures: biomechanical study using human cadaveric specimens. *Phys Ther.* 2017;97(7):756-766.
9. Kisner C, Colby LA. *Therapeutic Exercise Therapy Foundation*. 5th ed. Philadelphia, PA: F. A. Davis Co; 2007:383-391.
10. Cheon S, Park S. Changes in neck and upper trunk muscle activities according to the angle of movement of the neck in subjects with forward head posture. *J Phys Ther Sci.* 2017;29(2):191-193.
11. Schüldt K, Ekholm J, Harms-Ringdahl K. Effects of changes in sitting work posture on static neck and shoulder muscle activity. *Ergonomics.* 1986;29(12):1525-1537.
12. Knight JF, Baber C. Neck muscle activity and perceived pain and discomfort due to variations of head load and posture. *Aviat Space Environ Med.* 2004;75(2):123-131.
13. Fernández-de-las-Peñas C, Alonso-Blanco C, Cuadrado M, Pareja JA. Forward head posture and neck mobility in chronic tension-type headache: A blinded, controlled study. *Cephalalgia.* 2006;26(3):314-319.
14. Silva AG, Punt TD, Sharples P, Vilas-Boas JP, Johnson MI. Head posture and neck pain of chronic nontraumatic origin: a comparison between patients and pain-free persons. *Arch Phys Med Rehabil.* 2009;90(4):669-674.
15. Ferracini GN, Chaves TC, Dach F, Bevilaqua-Grossi D, Fernández-de-Las-Peñas C, Speciali JG. Relationship between active trigger points and head/neck posture in patients with migraine. *Am J Phys Med Rehabil.* 2016;95(11):831-839.
16. Cerezo-Téllez E, Torres-Lacomba M, Mayoral-Del Moral O, Sánchez-Sánchez B, Dommerholt J, Gutiérrez-Ortega C. Prevalence of myofascial pain syndrome in chronic nonspecific neck pain: a population-based cross-sectional descriptive study. *Pain Med.* 2016;17(12):2369-2377.
17. Lau KT, Cheung KY, Chan KB, Chan MH, Lo KY, Chiu TT. Relationships between sagittal postures of thoracic and cervical spine, presence of neck pain, neck pain severity and disability. *Man Ther.* 2010;15(5):457-462.
18. Fernández-de-las-Peñas C, Alonso-Blanco C, Cuadrado ML, Pareja JA. Neck mobility and forward head posture are not related to headache parameters in chronic tension-type headache. *Cephalalgia.* 2007;27(2):158-164.
19. Shaghayegh Fard B, Ahmadi A, Maroufi N, et al. Evaluation of forward head posture in sitting and standing positions. *Eur Spine J.* 2016;25(11):3577-3582.
20. Jian DW, Wang TG, Wang YC. Neck muscle stiffness quantified by sonoelastography is correlated with body mass index and chronic neck pain symptoms. *Ultrasound Med Biol.* 2013;39(8):1356-1361.
21. Agyapong-Badu S, Warner M, Samuel D, Stokes M. Measurement of ageing effects on muscle tone and mechanical properties of rectus femoris and biceps brachii in healthy males and females using a novel hand-held myometric device. *Arch Geront Geriatr.* 2016;62:59-67.
22. Salahzadeh Z, Maroufi N, Ahmadi A, et al. Assessment of forward head posture in females: observational and photogrammetry methods. *J Back Musculoskelet Rehabil.* 2014;27(2):131-139.
23. International Association for the Study of Pain. *(IASP) Pain Supplement 3: Classification of Chronic Pain, Descriptions of*

Chronic Pain Syndromes and Definitions of Pain Terms. Amsterdam, Netherlands: Elsevier; 1986.
24. Gavronski G, Veraksits A, Vasar E, Maaroos J. Evaluation of viscoelastic parameters of the skeletal muscles in junior triathletes. *Physiol Measur.* 2007;28(6):625-637.
25. Farasyn A, Meeusen R. The influence of non-specific low back pain on pressure pain thresholds and disability. *Eur J Pain.* 2005;9(4):375-381.
26. Lin KC. Reliability, validity, and responsiveness of myotonometric measurement of muscle tone, elasticity, and stiffness in patients with stroke. *Arch Phys Med Rehabil.* 2012;93(3):532-540.
27. Van Deun B, Hobbelen JS, Cagnie B. Reproducible measurements of muscle characteristics using the MyotonPRO device: comparison between individuals with and without paratonia. *J Geriatr Phys Ther.* 2018;41(4):194-203.
28. Demangel R, Treffel L, Py G, et al. Early structural and functional signature of 3-day human skeletal muscle disuse using the dry immersion model. *J Physiol.* 2017;595(13):4301-4315.
29. Kocur P, Grzeskowiak M, Wiernicka M, Goliwas M, Lewandowski J, Łochyński D. Effects of aging on mechanical properties of sternocleidomastoid and trapezius muscles during transition from lying to sitting position—A cross-sectional study. *Arch Gerontol Geriatr.* 2017;70:14-18.
30. Park SK, Yang DJ, Kim JH, Heo JW, Uhm YH, Yoon JH. Analysis of mechanical properties of cervical muscles in patients with cervicogenic headache. *J Phys Ther Sci.* 2017;29(2):332-335.
31. Cagnie B, Dhooge F, Van Akeleyen J, Cools A, Cambier D, Danneels L. Changes in microcirculation of the trapezius muscle during a prolonged computer task. *Eur J Appl Physiol.* 2012;112(9):3305-3312.
32. Lluch E, Nijs J, De Kooning M, et al. Prevalence, incidence, localization, and pathophysiology of myofascial trigger points in patients with spinal pain: a systematic literature review. *J Manipulative Physiol Ther.* 2015;38(8):587-600.
33. Turo D, Otto P, Shah JP. Ultrasonic characterization of the upper trapezius muscle in patients with chronic neck pain. *Ultrason Imaging.* 2013;35(2):173-187.
34. Valenzuela S, Miralles R, Ravera MJ, et al. Does head posture have a significant effect on the hyoid bone position and sternocleidomastoid electromyographic activity in young adults? *Cranio.* 2005;23(3):204-211.
35. Johnston V, Jull G, Souvlis T, Jimmieson NL. Neck movement and muscle activity characteristics in female office workers with neck pain. *Spine (Phila Pa 1976).* 2008;33(5):555-563.
36. Caneiro JP, O'Sullivan P, Burnett A, et al. The influence of different sitting postures on head/neck posture and muscle activity. *Man Ther.* 2010;15(1):54-60.
37. Shin SJ, Yoo WG. Effects of overhead work involving different heights and distances on neck and shoulder muscle activity. *Work.* 2015;51(2):321-326.
38. Levoska S. Manual palpation and pain threshold in female office employees with and without neck-shoulder symptoms. *Clin J Pain.* 1993;9(4):236-241.
39. Lauche R, Cramer H, Langhorst J, Dobos G, Gerdle B. Neck pain intensity does not predict pressure pain hyperalgesia: re-analysis of seven randomized controlled trials. *J Rehabil Med.* 2014;46(6):553-560.
40. Hübscher M, Moloney N, Leaver A, Rebbeck T, McAuley JH, Refshauge KM. Relationship between quantitative sensory testing and pain or disability in people with spinal pain—A systematic review and meta-analysis. *Pain.* 2013;154(9):1497-1450.
41. Shin SJ, An DH, Oh JS, Yoo WG. Changes in pressure pain in the upper trapezius muscle, cervical range of motion, and the cervical flexion–relaxation ratio after overhead work. *Ind Health.* 2012;50(6):509-515.
42. Sohn JH, Choi HC, Lee SM. Differences in cervical musculoskeletal impairment between episodic and chronic tension-type headache. *Cephalalgia.* 2010;30(12):1514-1523.
43. Yoo WG. Changes in pressure pain threshold of the upper trapezius, levator scapular and rhomboid muscles during continuous computer work. *J Phys Ther Sci.* 2013;25(8):1021-1022.
44. Wytrążek M, Huber J, Lipiec J, Kulczyk A. Evaluation of palpation, pressure algometry, and electromyography for monitoring trigger points in young participants. *J Manipulative Physiol Ther.* 2015;38(3):232-243.