

## **Skeletal muscle tone and motor performance characteristics in dentists as compared to controls**

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**Abstract.** The daily work tasks of dentists are associated with repeated movements and static load during the treatment of patients. Dentists' profession includes manual dexterity and maintaining the occupational posture for a long time. Previously it has been noted that dentists have increased muscle stress in neck, shoulder and lower back regions. The aim of the present study was to compare the muscle tone and motor performance characteristics of neck and shoulder region in dentists and representatives of other professions who do not have similar static load of long-time duration (as controls). Twenty women aged 34–55 years participated in the study: ten dentists with the age (mean and SE) of  $40.2 \pm 3.9$  years and ten controls (bookkeepers, security guards, office workers, printing house workers, laundry and dry cleaning workers) with the age of  $40.9 \pm 2.4$  years; working period was on the average 14 years in both groups. The tone characteristics of *m. trapezius* and *m. extensor carpi radialis* were investigated by device Myoton-2 (Müomeetria Ltd, Estonia) at rest and at maximal voluntary contraction (MVC) in sitting position at the workplace of participants. The cervical range of motion (CROM) and the handgrip strength were measured. Significantly higher ( $P < 0.05$ ) tone and elasticity characteristics of *m. extensor carpi radialis* and lower ( $P < 0.05$ ) tone and elasticity characteristics of *m. trapezius* at rest were noted in dentists compared to controls. At MVC, no significant differences were found in the studied characteristics between body sides in the measured groups. Dentists had lower ( $P < 0.05$ ) CROM of flexion and rotation than controls. In dentists emerged significant difference in muscle elasticity characteristics for the right body side, this is related with stretching for dentistry instruments.

**Key words:** muscle tone, muscle elasticity, handgrip strength, range of motion, dentists.

### **INTRODUCTION**

The daily work tasks of dentists are associated with repeated movements and static load during the treatment of patients. Dentists' profession includes manual dexterity and maintaining the occupational posture for a long time. Previously it has been noted that dentists have increased muscle stress in neck, shoulder and lower back regions (Hope-Ross & Corcoran, 1985). A recent study, where three dentists' work postures were analyzed by the Rapid Upper Limb Assessment Quick Exposure Check in videoanalysis, also indicated that the risk of developing musculoskeletal disease was greater in the lower back and neck area (Park et al., 2015). The dentist works in a very limited area

(the patient's mouth), where they have to use the treatment tools with great accuracy. This kind of work includes both static and dynamic movements that can cause a variety of musculoskeletal ailments (Pope-Ford & Jiang, 2015; Ohlendorf et al., 2016). For dentist the sitting position is good for attaining sufficient support in work operations requiring great precision, but it is not suitable in terms of the range of movement and implementing strength. Therefore, compromises and solutions have to be found to make the posture during work comfortable and efficient (Micholt, 1990).

The working position is partly conditioned by the requirements of the surrounding factors and the necessity of using force, the other part depends on the fitness of the person and his/her command of specific movement skills, including the application of force, as well as the ability to relax between work operations. Consequently, the profession requires a good general working position, establishing suitable individual positions for conducting different procedures, experience and knowing one's body (Micholt, 1990). The study of Ohlendorf et al. (2016) showed that for the most part, dentist is working with the head bent from 45° to 90° (58–83% of the total work time). Tilting one's head down increases the forces necessary for maintaining the position of the shoulders and neck and for the contraction of the respective muscles (Micholt, 1990). In review article of Gupta et al. (2013) it was concluded that repetitive motion, exertion, extreme posture evoke muscle fatigue and imbalance, which could lead to changes in musculoskeletal system (increase of tension, compression, tears probability, as well as laxity, constraint and instability in joints) and to microtrauma, and in some cases to cumulative trauma disorder. Less attention in the literature has been paid to the evaluation of shoulder and neck muscle tone in dentists.

The aim of the present study was to compare the muscle tone and motor performance characteristics of neck and shoulder region in dentists and representatives of other professions who do not have similar static load of long-time duration (as control group).

## **MATERIAL AND METHODS**

### **Participants**

Twenty women aged 34–55 years participated in the study: ten dentists and ten non-dentists as controls (bookkeepers, security guards, office workers, printing house workers, laundry and dry cleaning workers). The dentists had been working on the average for 14 years and at least 8 hours per day. Control group participants had the similar mean duration of work. The selection criterion was 8-hour work daily during the period of 10 or more years. The following exclusion criteria were accepted: cardiac illnesses, neurological illnesses or any other illness which could interfere with motor functions, arterial blood pressure higher than 140/90 mm/Hg and lower than 110/70 mm/Hg; obesity (body mass index (BMI) greater than 30 kg m<sup>-2</sup>) or being underweight (BMI lower than 18 kg m<sup>-2</sup>), history of cerebrovascular disease; acute febrile illness within the previous month; significant emotional distress or depression within the previous year; and upper limb arthritis or joint replacements other reason for inability to perform maximal contractions of upper limbs without severe pain.

Age and anthropometric data of participants are presented in Table 1. All participants were right-handed.

**Table 1.** Age and anthropometric data of participants

Characteristics	Dentists (n = 10)	Controls (n = 10)
Age (year)	40.2 ± 3.9	40.9 ± 2.4
Body height (cm)	165.7 ± 1.2	164.6 ± 1.5
Body mass (kg)	66.7 ± 2.7	67.8 ± 2.9
BMI (kg·m <sup>-2</sup> )	25.1 ± 1.7	26.5 ± 1.1

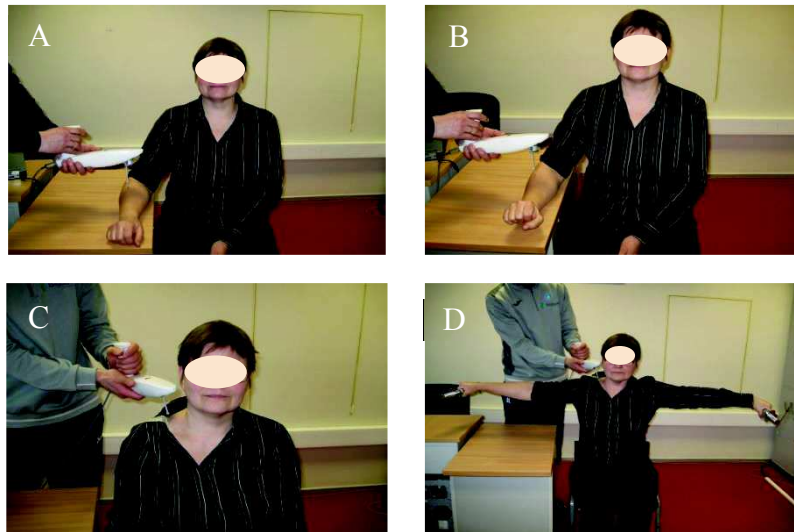
Note: BMI – body mass index. Data are mean and standard error (SE); difference between dentists and controls is not significant ( $P > 0.05$ ).

The persons were asked to avoid caffeine consumption for 24 h before the experiment and avoid participation in any sports activity one day before the testing. The direct ergogenic effect of caffeine on the skeletal muscle's force and duration of contraction has been shown (Tarnopolsky, 2008; Olorunschola & Achie, 2011). The study was performed at participants' workplace. Before the testing the participants had a rest of about 20 min sitting on the chair with a back support. The room temperature was maintained at 24 °C. All measurements were conducted in the same time of day and their sequence is described below in Methods. All subjects signed a written informed consent for participation in the study.

In the present study, the following parameters were measured: tone characteristics of skeletal muscles, range of motion in cervical part of spine and hand grip strength.

### Muscle tone measurements

The tone characteristics of *m. trapezius* and *m. extensor carpi radialis* were measured by device Myoton-2 (Müomeetria Ltd, Estonia) at rest and at maximal voluntary contraction (MVC) for right and left body sides (Fig. 1). This method has been described previously by Vain et al. (2015). Studies have demonstrated that Myoton-2 is a reliable device for measuring muscle tone characteristics (Bizzini & Mannion, 2003; Viir et al., 2006). Measurements of the central part of muscle belly were performed in sitting position on chair without support on back-rest and armrests, and without chair height control. *M. extensor carpi radialis* was tested while the arm was flexed in elbow joint approximately at 90 degrees; for measurement at rest the participant was asked to relax the arm muscle, and for MVC the participant was asked to extend the hand with maximal strength and maintain the contraction during 2–3 s. *M. trapezius* was tested with arm positioned on the thigh, and the participant was asked to relax shoulder girdle and neck muscles; for MVC the participant was asked to maintain the standard load of 2.25 kg in each hand during 2–3 s (straight arm at 90 degrees of adduction). Five measurements in each muscle point were performed using MultiScan mode, and mean data of the following characteristics were used for data analysis: frequency of muscle oscillations (FMO, Hz) – characteristic of muscle tone or stress, and logarithmic decrement of the dampening of muscle oscillations (LDMO) – characteristic of muscle elasticity. Lower LDMO values characterize muscle with better elasticity.



**Figure 1.** Measurements of tone characteristics at rest and at maximal voluntary contraction in *m. extensor carpi radialis* (A and B, respectively) and in *m. trapezius* (C and D, respectively).

#### **Cervical range of motion measurement**

The active cervical range of motion (CROM) was measured by Keno® cervical measurement system (Kuntoväline Oy & David Fitness Medical Ltd, Helsinki, Finland). The device is aligned on the nose and ears and fixed on the head by a velcro belt. Measurements were performed in sitting position. Participants received instruction to incline the head towards the chest as far down as possible (to measure flexion); to incline the head to the right (or to the left) (to measure lateral flexion), and to turn the head to the right and left side as far as possible with keeping the neck straight (to measure rotation). Previously the good reliability of the measurement device has been noted (Peolsson et al., 2000). Three measurements were performed for each head movement and the best result was accepted for data analysis.

#### **Muscle strength measurement**

The hand grip strength was recorded for the right and left arm by hand-held dynamometer JAMAR (model J00105, Lafayette Instrument Company, USA). The high reliability of measurements with this device has been shown by Roberts et al. (2011). Three measurements were performed for each hand with the pause of one minute and the best result was accepted for data analysis.

#### **Statistical analysis**

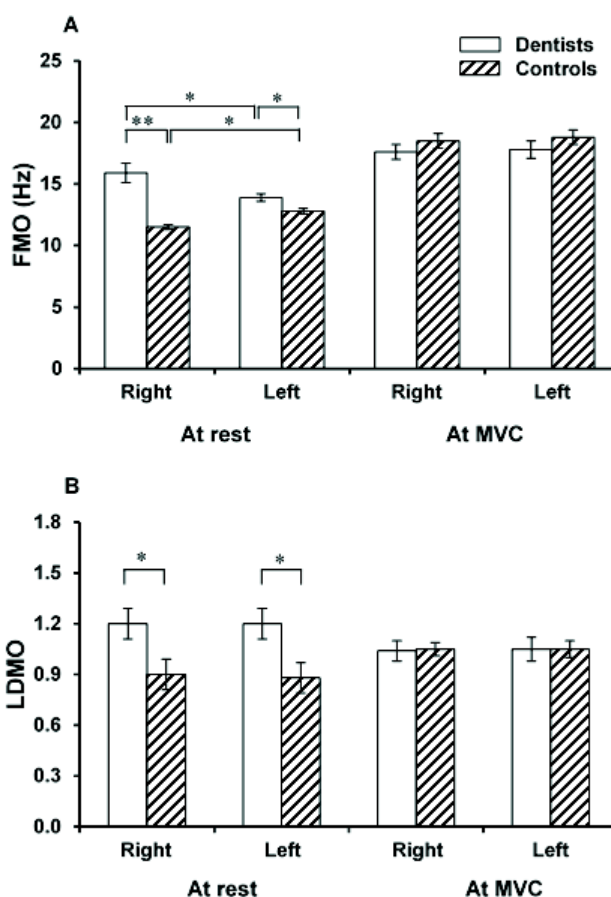
Data are means and standard errors of the mean ( $\pm$  SE). Descriptive statistics were calculated using Statistica v.13.0 software. Shapiro-Wilk test was used to analyse normality of data distribution. One-way analysis of variance (ANOVA) followed by Tukey's post hoc comparisons were used to test for differences between groups and between the right and left sides of the body of the all measured characteristics. A level of  $P < 0.05$  was selected to indicate statistical significance.

## RESULTS AND DISCUSSION

### Comparison of measured characteristics between two groups

Age and measured anthropometric characteristics (body mass, height and BMI) did not differ significantly between the groups of dentists and controls (Table 1). In dentists and controls the mean BMI was greater than  $25.0 \text{ kg m}^{-2}$  (overweight) by 0.4% and by 6.0%, respectively.

The tone characteristic – FMO of the *m. extensor carpi radialis* (Fig. 2, A) at rest was higher ( $P < 0.05$ ) in dentists compared to controls. This characteristic at rest differed ( $P < 0.05$ ) in both groups – dentists and controls – between the right and left side of the body, and in dentists the FMO of the right side was 11% higher than in the left side, whereas in controls it was 5%. Difference of the FMO at MVC was not statistically significant between body sides and between groups.

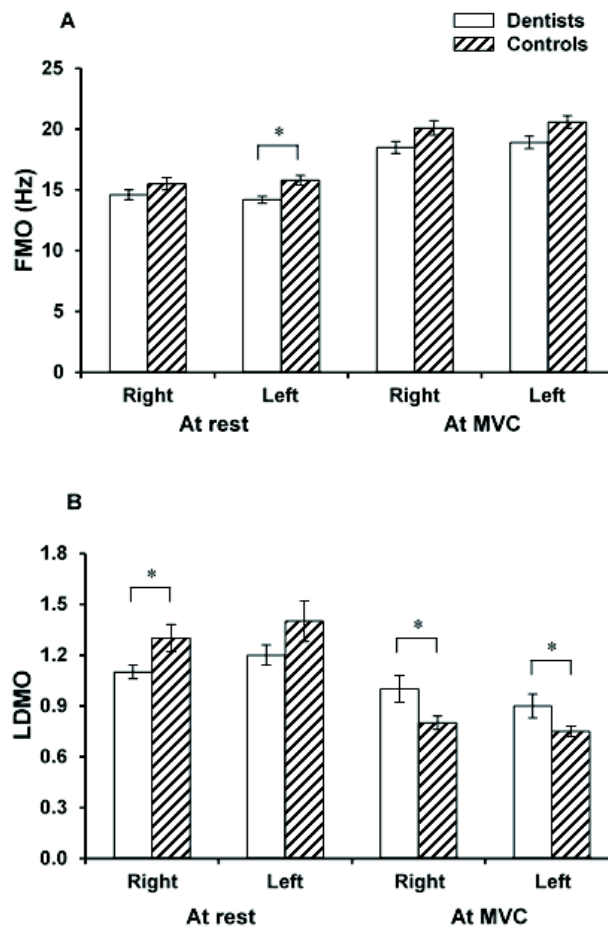


**Figure 2.** The muscle tone (frequency of muscle oscillation, FMO) (A) and elasticity (logarithmic decrement of the dampening of muscle oscillations, LDMO) (B) characteristics of *m. extensor carpi radialis* for right and left body sides at rest and maximal voluntary contraction (MVC) in dentists ( $n = 10$ ) and controls ( $n = 10$ ) (mean  $\pm$  SE); \*:  $P < 0.05$ .

The elasticity characteristic – LDMO of the *m. extensor carpi radialis* (Fig. 2, B) at rest was greater ( $P < 0.05$ ) on the average by 12% for both body sides in dentists compared to controls. This characteristic at MVC did not differ significantly between dentists and controls.

The FMO of the *m. trapezius* (Fig. 3, A) of the left body side at rest was lower in dentists ( $P < 0.05$ ) as compared to controls. Difference between body sides in FMO was not statistically significant in both groups of participants. This characteristic at MVC was lower in dentists as compared to controls for the right and left body side on the average by 6%, but this difference in controls was not statistically significant.

The LDMO of the *m. trapezius* (Fig. 3, B) at rest was lower in dentists compared to controls on the average by 14%, this difference for the right side of the body was significant ( $P < 0.05$ ). The LDMO at MVC was greater ( $P < 0.05$ ) on the average by 15% in dentists compared to controls.



**Figure 3.** The muscle tone (frequency of muscle oscillation, FMO) (A) and elasticity (logarithmic decrement of the dampening of muscle oscillations, LDMO) (B) characteristics of *m. trapezius* for right and left body sides at rest and maximal voluntary contraction (MVC) in dentists ( $n = 10$ ) and controls ( $n = 10$ ) (mean  $\pm$  SE);. \*:  $P < 0.05$ .

FMO and LDMO of the *m. trapezius* did not differ significantly between the right and left body side in both group participants.

The handgrip strength (Table 2) of the right hand was greater by 8% than in the left hand for both groups and handgrip strength was in dentists greater on the average by 5% as compared to controls, but the difference was not statistically significant. The values of CROM of flexion and rotation (both to the right and to the left) were lower ( $P < 0.01$ ) in dentists compared to controls. Data of CROM of extension and lateral flexion did not differ significantly between the two groups.

**Table 2.** The motor performance characteristics of dentists and controls

Characteristics	Dentists (n = 10)	Controls (n = 10)
HGS right (kg)	36.4 ± 2.5	31.1 ± 2.6
HGS left (kg)	32.4 ± 1.8	29.1 ± 2.1
CROM of flexion (°)	52.4 ± 3.1**	65.1 ± 3.3
CROM of extension (°)	62.4 ± 3.8	60.1 ± 3.1
CROM of flexion to the right (°)	49.4 ± 1.7	47.4 ± 1.9
CROM of flexion to the left (°)	49.9 ± 2.1	46.3 ± 2.2
CROM of rotation to the right (°)	55.1 ± 1.5**	62.9 ± 2.1
CROM of rotation to the left (°)	56.6 ± 1.4*	61.3 ± 1.6

Note: HGS – hand grip strength; CROM – active cervical range of motion. Data are mean ± SE; \*:  $P < 0.05$ ; \*\*:  $P < 0.01$  compared to controls. Difference between data of HGS and CROM for the right and left body side were not significant in both groups of participants ( $P > 0.05$ ).

### Comparison of data with previous studies' results

In the present study, the muscle tone characteristics of neck and shoulder region and motor performance characteristics were compared between dentists and control group participants. Participants in both groups were in average slightly overweight, this can be partly explained by prevalence of sitting time during work day. In the present study we did not record the length of time spent sitting and being physically active in participants' work day schedule. In a cross-sectional study of 300 health service providers (HSP) with the mean age of 39.3 years (Iwuala et al., 2015), where 47.7% were medical doctors and dentists, 43.3% were nurses and other categories of HSPs, the authors found that 27.3% of HSPs were obese, 44.7% overweight, and 49.7% had abdominal obesity. Another cross-sectional interview-based questionnaire study of 313 dentists with the mean age of 32.6 years and the prevalence of females (76.6%) revealed that 60.7% of participants were physically active, but professionals aged 41–50 years and those in the teaching field spent more time in sedentary behavior (Srilatha et al., 2016).

We investigated tone and elasticity characteristics of the *m. extensor carpi radialis* and *m. trapezius* using the myotonometry method (Vain et al., 2015). The results of the study showed that in rest both dentists and controls had asymmetry of tone and elasticity characteristics of the right and left body sides of *m. extensor carpi radialis*. Also dentists demonstrated higher muscle tone and lower elasticity (in case of bigger LDMO) of *m. extensor carpi radialis* at rest than controls. Manual asymmetric and mostly right-handed repetitive operations in dentists' work and taking into account the long period of practising – in the current study the average duration of work was fourteen years – lead to muscle fatigue and imbalance. These data are in line with conclusions presented

previously (Gupta et al., 2013). It was confirmed that greater muscular activity on one side of the trunk could reduce the right/left symmetry of respiratory kinematics and consequently the self-compensation of their disturbing effect in the coronal plane; it may also disturb the proprioceptive flow of the sensory input displayed by the muscles spindles, which have a prominent role in postural equilibrium maintenance (Roll & Roll, 1988).

In contrary, dentists had lower muscle tone and higher elasticity (in case of lower LDMO) of *m. trapezius* than controls. These results can be explained by the dentists having a repeated static load in a specific working position. Participants in the control group also worked in static position, but their working approaches differ significantly from dentists' techniques (Hagberg & Wegman, 1987; Ardahan & Simsek, 2016). Viir et al. (2007) studied muscle tone and elasticity of *m. trapezius* in 15 healthy right-handed female computer operators with the mean age of 27 years and BMI  $19.7 \text{ kg m}^{-2}$  in low load bearing (supine position on the examination table) and voluntary uncontracted state (sitting on chair with a back-rest and without armrests); the duration of work was not mentioned. They found that immediate decrease in the tone of the upper part of *m. trapezius* by 20% occurs with a change from a sitting position to a supine position and demonstrates that maintaining the sitting position requires greater tension (the values for FMO of *m. trapezius* of the right and left side decreased from (mean  $\pm$  SD)  $13.1 \pm 1.1 \text{ Hz}$  to  $10.8 \pm 0.6 \text{ Hz}$  and from  $12.9 \pm 1.1 \text{ Hz}$  to  $10.1 \pm 0.8 \text{ Hz}$ , respectively). Muscle tone values of our study participants for this muscle in sitting position are higher, but they are older and have been working for a long period. Working in sitting position could be one factor influencing muscular stress and postural control. Increased isometric push effort in a sitting position was associated with greater sway path and mean displacement of the center of pressure along the antero–posterior axis (Hamaoui et al., 2007). Moreover, it was suggested that increased muscular tension along the torso induces a more disturbing effect on posture when it is asymmetrical (Hamaoui & Bozec, 2014). Regular brief breaks of simple movements as well as being in the supine position to recover from prolonged sitting have been recommended (Viir et al., 2007).

When comparing the flexibility of the cervical spine between the two groups, we found that dentists had the deficit of neck extension and rotation range of motion compared to controls. This can be explained by the relatively static set of dentists' working postures that cause tension in neck and shoulder muscles and evoke a heavy burden on the flexion and rotation of neck muscles (Kanteshwari et al., 2011; Gaowgzeh et al., 2015; Man-Sig, 2015). In studies on office workers and computer users it has been noted that during long working hours muscles stiffen and the mobility of the neck decreases (Andersen et al., 2013; Ardahan & Simsek, 2016). The duration of work can be one factor influencing neck flexibility and development of postural disorders of the head and neck area. However, a recent study investigated the forward head posture (head is in front of the gravitational line) in 41 dentists (21 women and 20 men), and the mean values of cervical curve in dentists and the control group did not differ significantly. Besides, the authors did not find statistical differences in cervical curve values in dentists working for either 5–8 years or 8–12 years. The mean cervical curve values of men were longer than in women in the dentists' group (Mostamand et al., 2013).

The dentists' handgrip strength of the right and left hand was similar to the related characteristics in the control group. These data are comparable with the study of Fayez (2014), where handgrip strength in dentists with the mean age of  $31.3 \pm 4.9$  years was



33.4 ± 13.1 kg (measured by JAMAR device as in the present study). The results of our study can be explained by the measured groups being comparable in regard to the static and dynamic activities of the working day and, consequently, similar handgrip strength.

The limitation of the present study is that participants were not asked about the intensity of pain in the cervical, thoracic and lumbar parts of spine and in shoulder girdle region. Fayed (2014) study showed high correlation between neck pain intensity and handgrip strength in 25 dentists with chronic neck pain. Also, the work place comfort and ergonomics were not studied. The ergonomic aspects of working place could be the major factor influencing muscle tone and motor performance characteristics in dentists. In the study of 231 dental students the knowledge, practice, and condition of work place regarding ergonomic posture were determined (Munaga et al., 2013). Authors found that 70% of dental students perform torsion of the body and cervical flexion to improve vision and prefer direct vision when working. Only 59% of students reported that they are working with ergonomically designed dental unit and instruments. Most of them reported that the work stool is not comfortable. The knowledge of ergonomic postural requirements and their clinical application among the dental students surveyed were not satisfactory. On base of this study it was suggested that a multifactorial approach that includes preventive education, postural and positioning strategies, proper selection, and use of ergonomic equipment should be employed.

## CONCLUSIONS

Significantly higher tone and elasticity characteristics of *m. extensor carpi radialis* and lower tone and elasticity characteristics of *m. trapezius* at rest were noted in dentists compared to controls. Dentists also demonstrated significant differences in the characteristics of muscle tone and elasticity of *m. extensor carpi radialis* between the right and left body side; that can be explained by specific work position and prevalence of right-handed manipulation with dentistry instruments. At maximal voluntary contraction, lower elasticity of *m. trapezius* was noted in dentists as compared to controls.

The active range of motion in neck flexion and rotation of dentists were lower compared to controls. The long (at present case more than ten years) duration of work can influence neck flexibility.

In dentists, handgrip strength of the right and left hand was similar to the respective characteristics of the control group.

Future studies could investigate the immediate influence of 8-hour work and the effect of a long period of employment on muscle tone and motor performance characteristics on dentists with comparison of different ergonomic environments. Additionally, the role of physical activity and occupational physiotherapy in the reduction of asymmetry in muscle function characteristics could be studied. It is recommended that during the work day dentists and office workers have short breaks (5–10 minutes) every hour with performing the set of therapeutic exercises to reduce the load of musculo-skeletal system due to prolonged sitting and fatigue.

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## REFERENCES

- Andersen, H., Andersen, L., Pedersen, T., Mortensen, P., Karstad, K., Mortensen, S., Zebis, K. & Sjøgaard, G. 2013. Dose-response of strengthening exercise for treatment of severe neck pain in women. *J. Strength Cond. Res.* **27**(12), 3322–3328.
- Ardahan, M. & Simsek, H. 2016. Analyzing musculoskeletal system discomforts and risk factors in computer-using controls. *Pak. J. Med. Sci.* **32**(6), 1425–1429.
- Bizzini, M. & Mannion, A.F. 2003. Reliability of a new, hand-held device for assessing skeletal muscle stiffness. *Clinical Biomech.* **18**(5), 459–461.
- Fayez, E.S. 2014. Neck pain and hand grip strength in dentists of Saudi Arabia. *Int. J. Innovation Appl. Stud.* **9** (2), 655–661.
- Gaowgzeh, R.A., Chevidikunnan, M.F., Al Saif, A., El-Gendy, S., Karrouf, G. & Al Senany, S. 2015. Prevalence of and risk factors for low back pain among dentists. *J. Phys. Ther. Sci.* **27**(9), 2803–2806.
- Gupta, A., Ankola, V. & Hebbal, M. 2013. Dental ergonomics to combat musculoskeletal disorders. A review. *Int. J. Occup. Safety Ergon.* **19**, 561–571.
- Hagberg, M. & Wegman, D.H. 1987. Prevalence rates and odds ratios of shoulder neck diseases in different occupational groups. *Br. J. Ind. Med.* **44**, 602–610.
- Hamaoui, A., Poupard, L. & Bouisset, S. 2007. Does postural chain muscular stiffness reduce postural steadiness in relation to respiratory disturbance? *Gait Posture* **25**(2), 199–204.
- Hamaoui, A. & Le Bozec, S. 2014. Does increased muscular tension along the torso disturb postural equilibrium more when it is asymmetrical? *Gait Posture* **39**(1), 333–338.
- Hope-Ross, A. & Corcoran, D. 1985. A survey of dentists' working posture. *J. Ir. Dent. Assoc.* **31**(3), 13–20.
- Iwuala, S.O., Ayankogbe, O.O., Olatona, F.A., Olamoyegun, M.A., OkparaIgwe, U., Sabir, A.A. & Fasanmade, O.A. 2015. Obesity among health service providers in Nigeria: danger to long term health worker retention? *J. Pan Afr. Med.* **22**, 1.
- Kanteshwari, K., Sridhar, R., Mishra, A.K., Shirahatti, R., Maru, R. & Bhusari, P. 2011. Correlation of awareness and practice of working postures with prevalence of musculoskeletal disorders among dental professionals. *Gen. Dent.* **59**(6), 476–483.
- Man-Sig, K. 2015. Influence of neck pain on cervical movement in the sagittal plane during smartphone use. *J. Phys. Ther. Sci.* **27**, 15–17.
- Micholt, F. 1990. Ergonomics and health risks for the dentists: overview. *Rev. Belge Med. Dent.* (1984) **45**(2), 17–33.
- Mostamand, J., Lotfi, H. & Safi, N. 2013. Evaluating the head posture of dentists with no neck pain. *J. Bodyw. Mov. Ther.* **17**(4), 430–433.
- Munaga, S., Rawtiya, M., Khan, S., Chitumalla, R., Kubagiri, S.R. & Sajjan, P. 2013. Assessment of knowledge, practices, and work place condition related to ergonomics among dental students of Bhopal city – A questionnaire study. *J. Orofac. Sci.* **5**, 109–113.
- Ohlendorf, D., Erbe, C., Hauck, I., Nowak, J., Hermanns, I., Ditchen, D., Ellegast, R. & Groneberg, D.A. 2016. Kinematic analysis of work-related musculoskeletal loading of trunk among dentists in Germany. *BMC Musculoskelet. Disord.* **17**(1), 427.
- Olorunschola, K.V. & Achie, L.N. 2011. Caffeine alters skeletal muscle contraction by opening of calcium ion channels. *Curr. Res. J. Biol. Sci.* **3**, 521–525.
- Park, H.S., Kim, J., Roh, H.L. & Namkoong, S. 2015. Analysis of the risk factors of musculoskeletal disease among dentists induced by work posture. *J. Phys. Ther. Sci.* **27**(12), 3651–3654.
- Peolsson, A., Hedlund, R., Ertzgaard, S. & Öberg, B. 2000. Intra- and inter-tester reliability and range of motion of the neck. *Physiother. Can.* **52**, 233–245.
- Pope-Ford, R. & Jiang, Z. 2015. Neck and shoulder muscle activation patterns among dentists during common dental procedures. *Work* **51**(3), 391–399.

- Roberts, H., Denison, H., Martin, H., Patel, H., Syddall, H., Cooper, C. & Sayer, A. 2011. A review of the measurement of grip strength in clinical and epidemiological studies: towards a standardised approach. *Age Ageing* **40** (4), 423–429.
- Roll, J.P. & Roll, R. 1988. From eye to foot: a proprioceptive chain involve in postural control. In Amblard, B., Berthoz, A. & Clarac, F. (eds): *Posture and gait: development, adaptation and modulation*. Elsevier. Amsterdam, Netherlands, pp. 155–164.
- Srilatha, A., Doshi, D., Reddy, M.P., Kulkarni, S., Reddy, B.S. & Reddy, S. 2016. Physical activity among dental health professionals in Hyderabad City: A questionnaire survey. *Dent. Res. J. (Isfahan)* **13**(6), 544–551.
- Tarnopolsky, M.A. 2008. Effect of caffeine on the neuromuscular system – potential as an ergogenic aid. *Appl. Physiol. Nutr. Metab.* **33**, 1284–1289.
- Vain, A., Kums, T., Ereline, J., Pääsuke, M. & Gapeyeva, H. 2015. Gastrocnemius muscle tone, elasticity and stiffness in association with postural control characteristics in young men. *P. Est. Acad. Sci.* **64** (4), 525–534.
- Viir, R., Laiho, K., Kramarenko, J. & Mikkelson, M. 2006. Repeatability of trapezius muscle tone assessment by a myometric method. *J. Mechanics in Med. Biol.* **6**(2), 215–228.
- Viir, R., Virkus, A., Laiho, K., Rajaleid, K., Selart, A. & Mikkelson, M. 2007. Trapezius muscle tone and viscoelastic properties in sitting and supine positions. *Scand. J. Work Environ. Health Suppl.* **3**, 76–80.