Posture in dentists: Sitting vs. standing positions during dentistry work – An EMG study

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SUMMARY
Introduction Adequate working posture is important for overall health. Inappropriate posture may increase fatigue, decrease efficiency, and eventually lead to injuries.
Objective The purpose was to examine posture positions used during dentistry work.
Methods In order to quantify different posture positions, we recorded muscle activity and positions of body segments. The position (inclination) data of the back was used to assess two postures: sitting and standing during standard dental interventions.
Results During standard interventions, whether sitting or standing, a tilt of less than 20 degrees was most prevalent in the forward and lateral flexion directions.
Amplitude of electromyography signals corresponding to the level of muscle activity were higher in sitting compared with the electromyography in standing position for all muscle groups on the left and right side of the body. Significant difference between muscle activity in two working postures was evident in splenius capitis muscle on the left ($p = 0.032$), on the right side of the body ($p = 0.049$) and in muscle activity of mastoid muscle on the left side ($p = 0.029$).
Conclusion These findings show that risk for increased fatigue and possible injures can be reduced by combining the sitting and standing occupational postures.
Keywords: work posture; electromyography; inclinometers; ergonomics; occupational health

INTRODUCTION

Adequate working posture is of high importance for overall health. Inappropriate posture may increase fatigue and decrease efficiency, and eventually lead to injuries [1]. Analysis of working posture can implicate possible recommendations for better working performance.

During work, dentists are committed to their patients in order to provide professional care, while at the same time they often neglect their own body posture. Clinical intraoral examination as the most frequent dental procedure has always required a certain unnatural posture that could lead to the development of musculoskeletal disorders (MSDs) [2]. Literature suggests there is a high prevalence of musculoskeletal symptoms among dentists [3, 4]. According to earlier studies, prevalence of general musculoskeletal pain that affects dentists ranges between 64% and 93% [4]. The most prevalent pain regions in dentists are back, shoulders, and neck [5]. In order to access working area (patient's oral cavity), dentists have difficulties to find the optimal body posture during their work. Inadequate dentist's working posture is the highest risk factor for the development of an MSD [5]. Suggestions regarding the preferred position for dental work are changing together with the development of dentistry and dental equipment. Development of the sitting position in dentistry was an attempt to eliminate discomfort and fatigue. Unfortunately, the seated working position has not reduced MSDs, even though many specialized chairs which have been developed [6]. According to Ratzon et al. [3], dentists working in the standing position have less severe low back pain. However, optimal working positions are still topic of discussion.

During dental work, the dominant and non-dominant hand perform different tasks. The dominant hand is doing precise motor coordination, according to manipulative demands throughout the procedure, while at the same time the non-dominant hand is used mostly as a support [7]. Thus, asymmetry of body sides during dental work is one of the risks of the development of MSDs [3]. Jonker et al. [8], measured postures of the head and upper extremities using inclinometry. Åkesson et al. [7] measured inclinations of the head and wrists in female dentists. In that study, electromyography (EMG) was also used for recording the descending part of the upper trapezius muscle bilaterally, as well as the flexor and extensor muscles of the right forearm. EMG of neck and shoulders muscles and their movements by video recording were investigated by Finsen [9], and Finsen and Christensen [10]. In the

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study of Milerad et al. [11], the muscular loads during work were studied from the shoulder and arm muscles. Postural data of the back were also video recorded in the study of Finsen et al. [12] and Marklin and Cherney [13]. These studies indicated a need for more detailed analysis of the back movements during dental work.

The goal of this study was to perform analysis of positions comprising muscle activities and back inclination of dentists during standard dental examination. We recorded activities of back, shoulder, and neck muscles, and inclination angles of the back in healthy dentists in sitting and standing working positions in order to provide possible recommendations for a more safe posture.

METHODS

Subjects

The study included ten right-handed dentists, with no known orthopedics or neurological disorder (two males, eight females, mean age 33 ± 3.4, mean height 173 ± 7.3, mean weight 70 ± 13.2), with a minimum of three years of work experience. Of investigated dentists, 60% preferably performed procedure in standing working position. All subjects signed informed consent approved by the Ethical Committee of the Faculty of Dentistry, University of Belgrade.

Instrumentation

We recorded the surface EMG from back muscle [erector spinae (ES)], shoulder muscle [trapezius descendens (T)], and neck muscles [sternocleidomastoideus (SCM), and splenius capitis (SC)], as shown in Figure 1.

EMG electrodes were placed on the left and right sides of the body, following the recommendations of the SENIAM (surface EMG for non-invasive assessment of muscles) protocol [14]. We used disposable pregelled EMG Ag/AgCl electrodes with 10 mm flat pellets (GS26, Bio-Medical Inc, Warren, MI, USA). Signals were amplified with Biovision preamplifiers (Biovision Inc, Wehrheim, Germany). The gain of the preamplifiers was set to 1,000. Reference electrode was placed over the spine, on the processus spinosus of C7. The signals were acquired with AceLAB setup that includes NI USB 6212 AD card (National Instruments Inc., Austin, TX, USA) with AD resolution of 16 bits [15]. We used custom-made acquisition software application made in LabVIEW (National Instruments Inc.). The sample rate was set to 1,000 samples per second.

We also analyzed posture of the dentists while performing the given tasks. Posture acquisition was performed by using wireless sensor system with light (30 g) and small wireless sensor units which acquire sensor data and send it to a remote PC, as described in the study by Jovičić et al. [16]. High performance 12-bit digital triaxial accelerometers LIS3LV02 (STMicroelectronics, Geneva, Switzerland) were used, with the 2/6 g range of sensors. Orientations of the axes are shown in Figure 1. This system was modified by displacing two triaxial accelerometers from a compact wireless sensor unit and connecting them to it through wires in order to minimize sensor dimensions and weight, and to provide more secure mounting to the surface of the back. The sensors were placed on a horizontal line at the level of the seventh thoracic vertebra, on the point one-quarter length from the spine, symmetrically on both sides of the back.

Experimental procedure

Recording sessions were performed in the morning in order to minimize differences that can occur due to fatigue after daily activities. The subjects performed the procedure in specially prepared clothes that do not cover the electrodes, and the skin was adequately prepared for electrode placement. Subjects did not take strenuous physical activity 24 hours before the recording session. Subjects were asked to perform a typical dental examination of patients in standing and sitting positions.

Before starting the dental examination, maximal voluntary contraction (MVC) was determined for each investigated muscle according to the SENIAM protocol [14]. After the MVC test, subjects rested for 10 minutes and then commenced the dental procedure. After recording their MVCs, their neutral standing positions were recorded in order to assess their typical back inclination and muscle activities.

The dentists were asked to take their typical working position during recording. In parallel with experimental measurements, the dentists were also video recorded using two cameras recording back and body profile.

Signal processing

Post-processing of recorded EMG signals included notch filter (50 Hz) and first-order modified differential infinite impulse response filter to remove baseline offset. Filtered EMG signals were rectified, followed by calculation of root mean square values for 0.5 seconds long intervals. The signals were further normalized to previously recorded MVCs. The obtained signals (EMG_N) are expressed in percentages of MVC values. In order to quantify EMG activities, we further averaged complete recorded sequence of dental examination, and calculated standard deviations for each muscle. The data analysis was performed in Matlab (Mathworks, Natick, MA, USA).

Angle estimation was performed by using accelerometers as inclinometers, which is a valid application for static measurements or slow ambulation and torso and trunk movements [17].

Angles were estimated according to $\theta_{ML} = \text{atan2}(\alpha_y,\alpha_x)$ for estimation of medial–lateral back flexion; and $\theta_{AP} = \text{atan2}(\alpha_y,\alpha_z)$ for anterior–posterior back flexion, where 'atan2' is the four-quadrant inverse tangent function defined in Matlab program. Angle definitions are shown in Figure 2.

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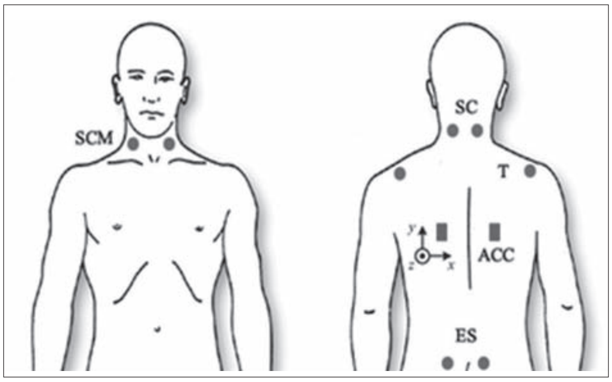

Figure 1. Electrode and sensor placements: round markers represent placements of the EMG electrodes for four muscle groups (SC – splenius capitis; T – trapezius descendens; ES – erector spinae; SCM – sternocleidomastoideus); rectangular markers show placements for accelerometers (ACC) together with orientation of their axes

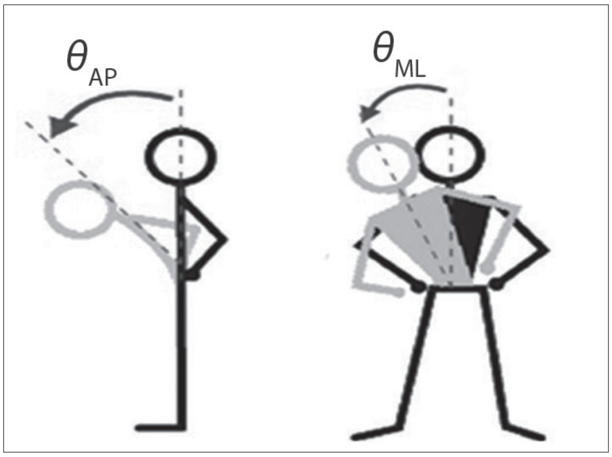

Figure 2. Flexion angles of the back; left: anterior–posterior flexion; right: medial–lateral flexion

Statistical analysis was performed using commercial statistical program SPSS version 18 (SPSS Inc., Chicago, IL, USA). The Student's t-test assesses the differences for sitting and standing positions. A probability level of $p < 0.05$ was accepted as statistically significant.

RESULTS

One example of recorded muscle activities and changes in postural inclinations are presented in Figure 3, referring to the first subject. Relations among averaged normalized muscle activities during standing and sitting working postures are given in Figure 4.

The average values of EMG_N for all subjects are calculated for sitting and standing positions and presented in Table 1. The established implications for ergonomic risk levels associated with muscle forces are marked in grey shades in Table 1, according to Astrand and Rodahl [18]. Their findings suggested MVC in the range 0–10% indicates "low risk," MVC 11–20% indicates "medium risk," and MVC of 21% or higher indicates "high risk." According to their suggestions, EMG_N with medium and high risk are shaded in light grey and dark grey in Table 1, respectively. Table 2 shows paired differences between

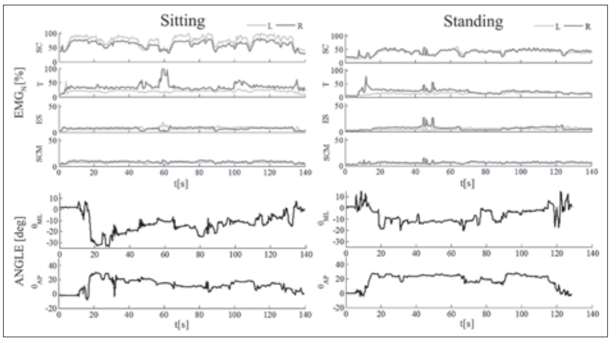

Figure 3. EMG_N for SC, T, ES, SCM comparing left and right body side during standing and sitting (upper row), and postural changes during examination for sitting and standing positions (lower row); examples are shown for the first subject

sitting and standing position for each muscles group on the left and right side of the body. Significant difference between muscle activity in the two working postures was evident only in SC muscle groups on the left ($p = 0.032$) as well as the right side of the body ($p = 0.049$), and in muscle activity of SCM muscle on the left side ($p = 0.029$).

The distribution of different medial–lateral and anterior–posterior angles ranges (in degrees) for standing and sitting positions are presented in Figures 5 and 6.

During their work, dentists were sitting with a back flexion of more than 20 degrees during 26% of the time, and standing 38% of the time with a back flexion of more than 20 degrees. Dentists worked with a back lateral flexion of more than 20 degrees in 35% of the time in standing and 50% in sitting position.

DISCUSSION

Results of our study show that EMG amplitude varied in relation to body posture. In muscle groups investigated, EMG amplitudes were higher in the sitting than in the standing position. In our study we investigated muscles important for the stabilization of body posture. These muscles were also selected because they provide an indication of muscle activity in body parts which are most affected by the musculoskeletal disorders in dentists (low back, neck, and shoulders) [5].

According to Finsen [9], mean RMS amplitude around 10% of maximal EMG may have an injurious effect on the muscle, if the activity level is sustained without rest periods. EMG amplitude greater than 10% of MVC during dental work was established in the sitting position on the left and right side in all muscle groups except in the muscles of anterior side of the neck (SCM) in both sides. In the standing position, EMG amplitude greater than 10% MVC was present in the muscles of posterior side of the neck (SC) and shoulder muscles (T) on both sides of the body, while the amplitude in the SCM muscles and in the ES muscles on both the left and the right side was less than 10% of MVC.

SCM muscles had low activity level in both working positions. SC muscles had significantly higher muscle activities in sitting position than in standing. Muscles from posterior side of neck were more loaded, especially in sitting

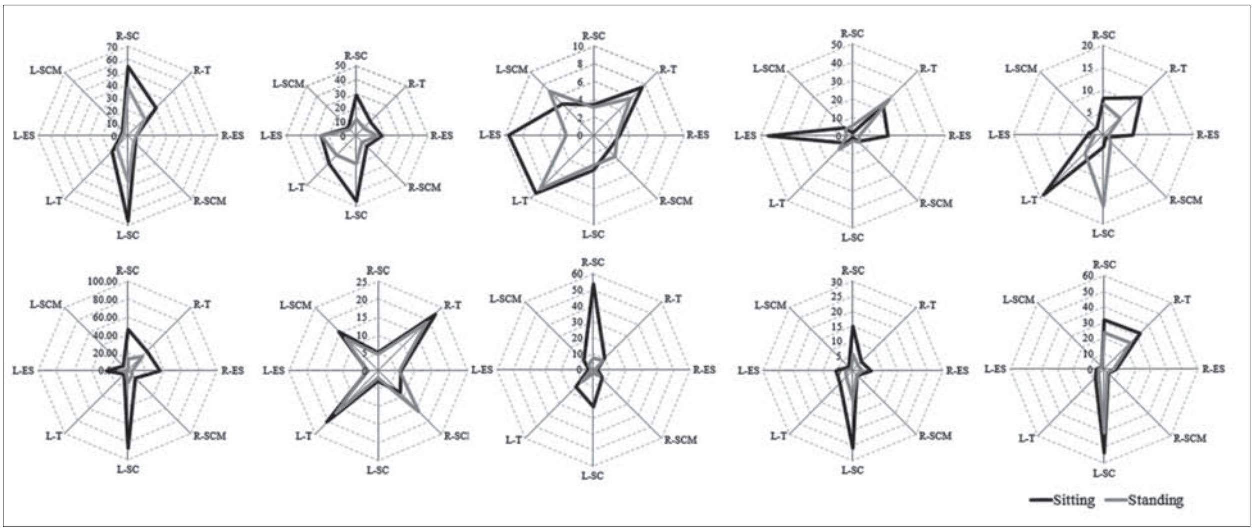

Figure 4. Radar charts showing relations among averaged normalized muscle activities, standing vs. sitting (grey and black lines, respectively). Each subject is represented with one radar chart, starting from top left towards right

Table 1. EMG_N for each muscle on both sides for sitting and standing position, with associated risk levels

	Side	Left				Right			
Standing	Muscles	SC	T	ES	SCM	SC	T	ES	SCM
	EMG_N [%] Av ± SD	13.1 ± 14.5	10.6 ± 5.7	5.9 ± 6.8	5.1 ± 3.6	11.8 ± 10.9	14.4 ± 9.2	5.3 ± 3.9	5.4 ± 4.2
Sitting	Side	Left				Right			
	Muscles	SC	T	ES	SCM	SC	T	ES	SCM
	EMG_N [%] Av ± SD	31.3 ± 30.7	13.4 ± 7.6	13.0 ± 14.2	6.3 ± 4.1	24.9 ± 21.0	18.7 ± 10.5	11.2 ± 10.3	5.9 ± 3.7

EMG_N – EMG normalized to maximal voluntary contraction; SC – splenius capitis; T – trapezius descendens; ES – erector spinae; SCM – sternocleidomastoideus; Av – average values; SD – standard deviation

Table 2. Differences between corresponding muscle activities (EMG_N) for sitting and standing positions, shown separately for the left and right side

EMG_N (sitting – standing)		Differences					
		Av	SD	95% confidence interval of the difference		t	p-value
				Lower	Upper		
Left	SC sitting – SC standing	18.23	22.70	1.99	34.46	2.54	0.032*
	T sitting – T standing	11.10	25.65	-7.24	29.45	1.37	0.204
	ES sitting – ES standing	7.15	13.56	-2.55	16.85	1.67	0.130
	SCM sitting – SCM standing	1.41	1.94	0.023	2.80	2.30	0.047*
Right	SC sitting – SC standing	13.03	15.90	1.65	24.41	2.59	0.029*
	T sitting – T standing	-2.73	22.04	-18.49	13.04	-0.39	0.705
	ES sitting – ES standing	5.88	10.04	-1.31	13.06	1.85	0.097
	SCM sitting – SCM standing	0.51	3.50	-1.99	3.02	0.46	0.656

* statistically significant difference between the sitting and the standing group ($p < 0.05$ signifies Student's two-tailed t-test)
SC – splenius capitis; T – trapezius descendens; ES – erector spinae; SCM – sternocleidomastoideus

working position. Shoulder muscles and ES muscles also had higher activities in sitting position. These findings indicate that muscles maintaining body posture during dental work were more loaded in sitting position, reflecting that it can be harder for dentist to find adequate balance during fine, precise manipulative dental work while sitting.

Amplitude of all EMG signals showed large variations between subjects, probably caused by individual characteristics and adopted working habits.

For this study we recorded a short dental intervention which, accumulated, can cause workload. We chose a basic dental examination procedure because it is essential, the most important, and the most frequent dental procedure.

Maintaining static postures in dentistry requires sustained muscle contraction. When a muscle is contracted for a prolonged period of time, intramuscular pressure is at its highest, which means prolonged static muscle activity is a risk factor for MSDs [2, 5, 19].

Results of our study indicate that amplitudes of EMG signals from left and right side of the body are similar. A study by Finsen et al. [12] showed similar myoelectric activity on the right and left trapezius muscles. However, muscles from the left side of body have mostly stabilization function, as all the subjects in the study were right-handed. The right side is active and performing precision work, where a high level of visual and manipulative precision

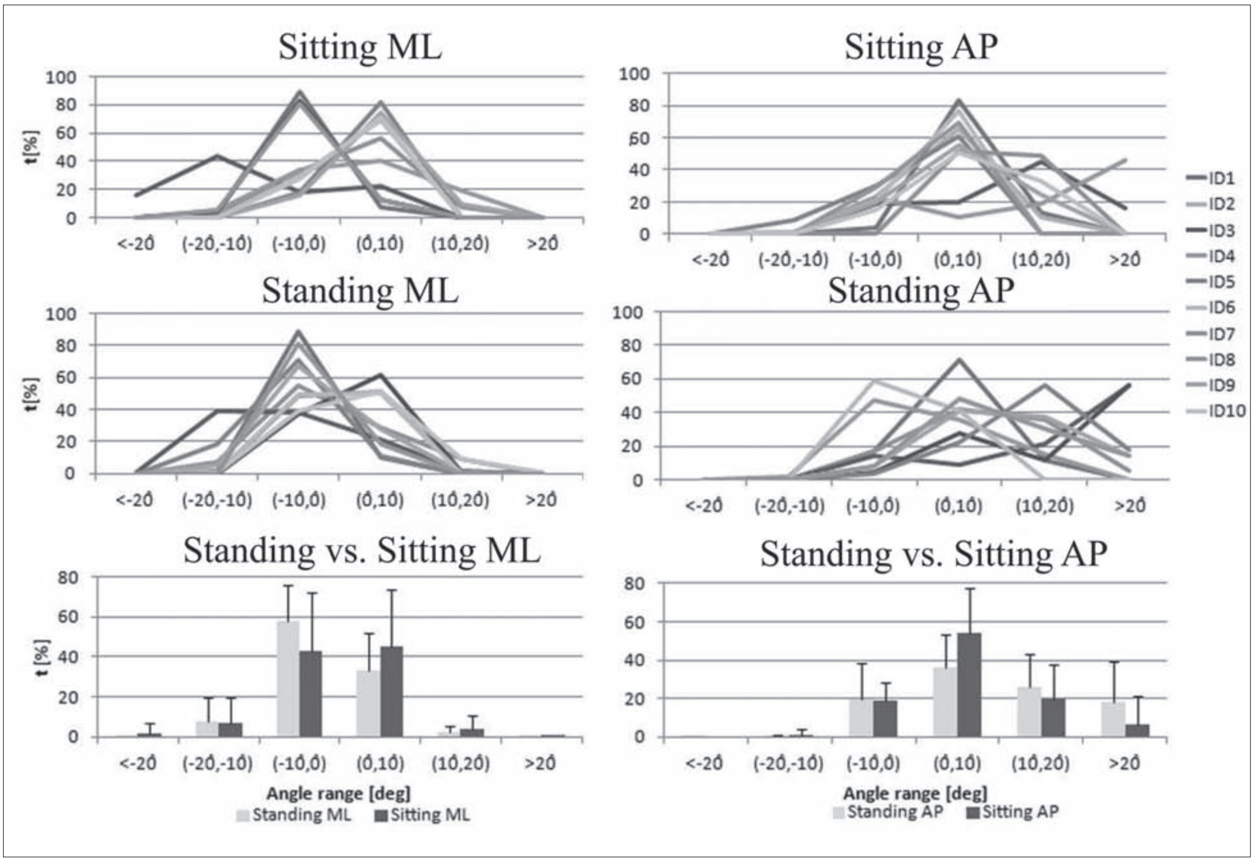

Figure 5. Percentage (%) of time in which dentists worked in different medial–lateral (ML) and anterior–posterior (AP) angle ranges (in degrees) in standing and sitting position for each subject; the two graphs below show average percentage of time

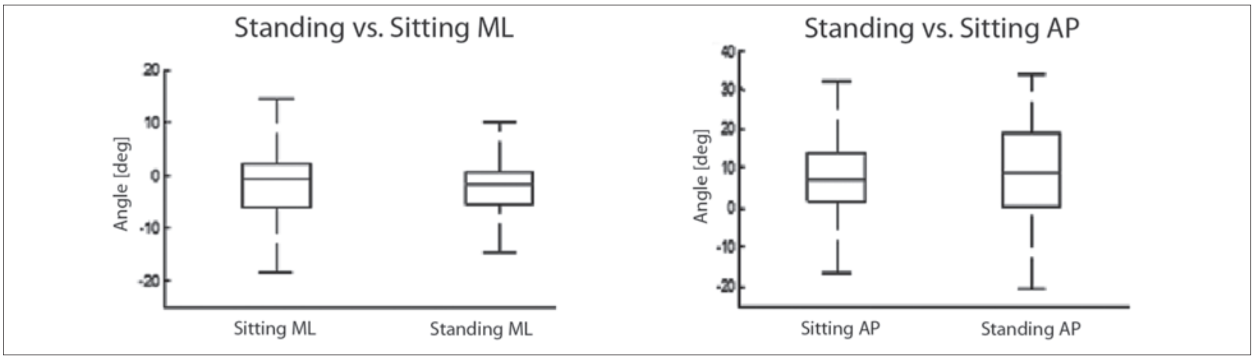

Figure 6. Box-and-whisker plots showing the distribution of different medial–lateral (ML) and anterior–posterior (AP) angle ranges (in degrees) for standing and sitting positions

is important and influences work postures including the head, neck, arms, and back muscles [20]. Unnatural work posture among dentists is often necessary to gain good manual and visual access to some parts of the mouth and tooth surface [21].

The literature suggests most of the dentists have been working in the sitting position during work [8, 12, 21]. Although their findings differ, the percentage of sitting dentists is above 78% in all studies. In the study of Chaikumarn [22] all dentists chose sitting as their main working posture, and no dentists alternated their posture between sitting and standing, which lead to static work, as an important risk factor for the development of MSDs. Six out of ten dentists who participated in our study preferred standing position. This can be explained by the fact that they mostly had to work without an assistant. However, it was reported that dentists who work in the sitting position had more severe lower back pain [3]. We found higher muscular load in the sitting position. Most dentists who participated in our study preferred standing position during work.

This indicates that sitting is not always better than standing [23]. During work, different muscle groups were used in the standing than in the sitting position [24]. In the standing position fatigue can occur in lower extremity muscles. However, the main parts of the body which are affected by pain during dental work are back, shoulder and neck muscles. Etiology of MSDs is multifactorial and long sitting position in combination with static work can be one of the most important etiological factors for the development of MSDs [25, 26]. Optimal working positions are still disputable and alternating between sitting and standing could be suggested. Static muscle activity during dental work is the factor with most influence on development of MSDs [27]. A study by Jonker et al. [8] showed a lack of variation in postures and movements, and suggested altering between sitting and standing as an attempt to achieve variation in physical workload in upper extremities. By combining sitting and standing positions, dynamic work can be achieved. Dynamic work is less tiring and more efficient than static work [28].

The degree of back flexion in the two working postures during dental work was investigated by wireless tri-axial accelerometers. This type of accelerometer has been widely used in investigation of body posture [29]. In our study, we measured back flexion, and we found that a tilt of less than 20 degrees is most prevalent in forward, as well in lateral flexion, whether sitting or standing. It has been suggested that lateral flexion should be avoided, while anterior tilt of less than 20 degrees can be considered acceptable, but only when there is no additional lateral flexion [30]. Marklin and Cherney [13] found a trunk flexion of approximately 30 degrees as most prevalent during dental work, which may explain why back pain is often reported [2, 5]. Further, dentists were sitting with a back flexion of less than 20 degrees during 99% of the time, and with a back rotation and lateral flexion of less than 15 degrees for 99% and 95% of the time, respectively [12]. This data is consistent with ours, although a direct comparison is not possible due to methodological differences – in our study we used inclinometers, while they used video-recording as the method of obtaining the data.

CONCLUSION

In everyday practice, dentists are fully committed to their patients in order to provide them with adequate treatment. During dental work potential fatigue can occur. It is hard for dentists to be concentrated to fine, controlled dental work, and to maintain good balance and adequate working posture at the same time. That indicates that it is important for dentists to pay more attention to potential fatigue during work, and to alternate their postures in order to prevent an MSD.

This study indicates that there is also a great opportunity for further research and improvement in this area. This is a posture study, and its results indicate a need for creation of a Holter system for dentists, which they can wear during work, with the ability for warning when the same risk position is assumed for too long. The Holter system could also be able to detect muscular loads during different dental procedures.

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Електромиографска студија постуралног положаја тела током рада код стоматолога: поређење седећег и стајаћег положаја током стоматолошког рада

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КРАТАК САДРЖАЈ

Увод Неадекватан радни положај током рада стоматолога доводи до повећаног замора, смањује ефикасност и један је од водећих фактора за развој повреда на раду међу стоматолозима.

Циљеви рада Циљ рада је био испитати различите положаје стоматолога током клиничког рада и дати препоруке за побољшање радне позиције.

Методе рада Површинском електромиографијом (ЕМГ) регистрована је мишићна активност, као и степен нагиба тела током уобичајног стоматолошког рада приликом рада на терапеутској столици и у стајаћем положају.

Резултати Нагиб мањи од 20 степени био је измерен током већег дела клиничког рада стоматолога у обе радне позиције. Повећање мишићне активности уочено је приликом рада у седећем положају код свих испитиваних мишића. Статистички значајна разлика уочена је код *M. splenius capitisa* са леве ($p = 0{,}032$) и са десне стране ($p = 0{,}049$), док је код *M. sternocleidomastoideusa* постојала само на левој страни тела ($p = 0{,}029$).

Закључак Да би се смањио замор и ризик за настанак мишићно-скелетних обољења, препоручује се да стоматолози током клиничког рада комбинују седећи и стајаћи радни положај.

Кључне речи: радна позиција; електромиографија; инклинометри; ергономија; медицина рада

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