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Evaluation of Ergonomic Risks during Dental Work

SUMMARY

***Aim*:** *The purpose was to assess ergonomic risk level in dentistry, which may contribute to manifestation of musculoskeletal disorders (MSD).*

***Methods and Materials*:** *The study included ten dentists, postgraduate students, mean age (33 ± 3.4). Participants were asked to perform typical dental examination in standing and sitting positions. The surface electromyography (EMG) was recorded during dental work from both left and right shoulder muscles: descendent trapezius muscle (T); back muscles: erector spinae muscle (ES); and neck muscles: sternocleidomastoid muscle (SCM) and splenius capitis muscle (SC).*

***Results*:** *High muscles forces, greater than 21% of the maximal voluntary contraction (MVC), which could be indicative of high risk, particularly occurred in muscles SC on both sides of the body in the sitting position. The medium risk level occurred in the same muscles on both sides in standing position. Left and right T muscles were under medium ergonomic risk level in both, sitting and standing working positions. SCM muscles on the left and right side of the body in both working positions were under low risk level, lower than 10% of the MVC. In sitting position, medium risk level occurred in ES muscles on both body sides, while in standing position the risk was low.*

***Conclusion*:** *Dentists are exposed to ergonomic risk. By combining both sitting and standing position the risk can be reduced.*

Keywords: Musculoskeletal disorders; Dentistry; Electromyography; Ergonomic risk

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Introduction

Musculoskeletal disorders (MSD) is an injury of the human support system of muscles, tendons, ligaments, joints, cartilages, nerves, blood vessels, or spinal discs. It has been demonstrated that MSD can occur from a single event, or can develop gradually from repeated trauma[1]. The aim of the ergonomic science is prevention and reduction of MSD.

Pains in certain parts of the body and impaired function that affect dentists are the results of cumulative micro trauma, which results from frequent, repeated and prolonged unhealthy body positions during operations. Literature suggests that there is a higher prevalence of musculoskeletal symptoms among dentists comparing to other occupational groups[2-5]. According to the prevalence studies, general musculoskeletal pain that affects dentists ranges between 64% and 93% [6, 7]. MSD in dentistry can cause reduced productivity and even abandoning the profession[8]. The most prevalent regions for pain in dentists have been shown to be back (36.3-60.1%) and neck (19.8-85.0 %) areas[9]. Because of the narrow work area (patient's oral cavity), it is very hard for the dentist to find the optimal body posture during their work. Working posture is the highest risk factor for development of MSD[10]. Dentists' working posture has been an attractive topic for many researchers[11-13]. The appropriate posture should be functional, allowing the best way for dentists to perform their procedure[14].

Many factors influence dentists' working posture: working habit, attitude, anthropometric characteristics of dentists, working with or without dental assistant, type

of dental procedure, etc. Suggestions about preferable position for dental work are changing together with the development of dentistry and dental equipment[11].

Firstly, dentists usually used standing position during treatment. Since the development of four-handed dentistry in the 1960's, sitting position became the preferred one. Development of the sitting position in dentistry was an attempt to reduce discomfort and fatigue typical for dental work. However, the seated working position has not eliminated the risk for discomfort and musculoskeletal pain[12, 13]. Some dental procedures such as: taking impressions, register of occlusion and tooth extractions, frequently require standing position. Some authors still suggest standing as the most efficient position to reduce pressure in the back[15]. Optimal working positions are still disputable. In practice, dentists usually adopt whatever working position to access the oral cavity appropriately.

In order to determine ergonomic risk level, and to provide possible recommendations of more desirable posture in quantified manner, we recorded electromyography (EMG) signals of some back, shoulder and neck muscles.

Material and Method

Participants

Ten healthy right-handed dentists (mean age 33±3.4) attending postgraduate studies, with minimum three years of work experience, who signed an informed consent, were included in the study. The study was approved by the Ethical Committee of the School of Dental Medicine, University of Belgrade (number 36/9). The inclusion criteria were no known motor deficiencies in the upper and lower back, and no history of inflammatory and degenerative rheumatic diseases. Demographic characteristics of the participants are given in table 1.

Table 1. Subjects demographics. The preferable position refers to the position in which dentist preferably perform procedure. Years of work are presented as working experience of the dentists.

Subject ID	Age	Sex	Height [cm]	Weight [kg]	Preferable position	Dexterity	Work experience [years]
S1	29	Female	171	57	standing	Yes	3
S2	32	Female	165	59	standing	Yes	5
S3	32	Female	173	71	sitting	Yes	4
S4	29	Female	170	62	standing	Yes	4
S5	30	Male	185	90	standing	Yes	2
S6	32	Female	163	60	standing	Yes	5
S7	33	Male	183	95	sitting	Yes	6
S8	34	Female	178	70	standing	Yes	7
S9	40	Female	168	60	sitting	Yes	14
S10	37	Female	177	72	sitting	Yes	10

Instrumentation

The surface EMG were recorded from back muscle - *erector spinae* (ES), shoulder muscle - *descendent trapezius* (T), and neck muscles – *sternocleidomastoid muscle* (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 SENIAM protocol[16]. Signals were acquired with AceLAB setup that included NI USB 6212 AD card (National Instruments, Inc., Austin, USA) with AD resolution of 16 bits. We used custom made acquisition software application made in LabVIEW (National Instruments, Inc., Austin, USA). The sample rate was set to 1000 samples per second. Block diagram of the measurement system and data processing is summarized in figure 2.

Figure 1. Photo impression of the experimental setup during one recording session.

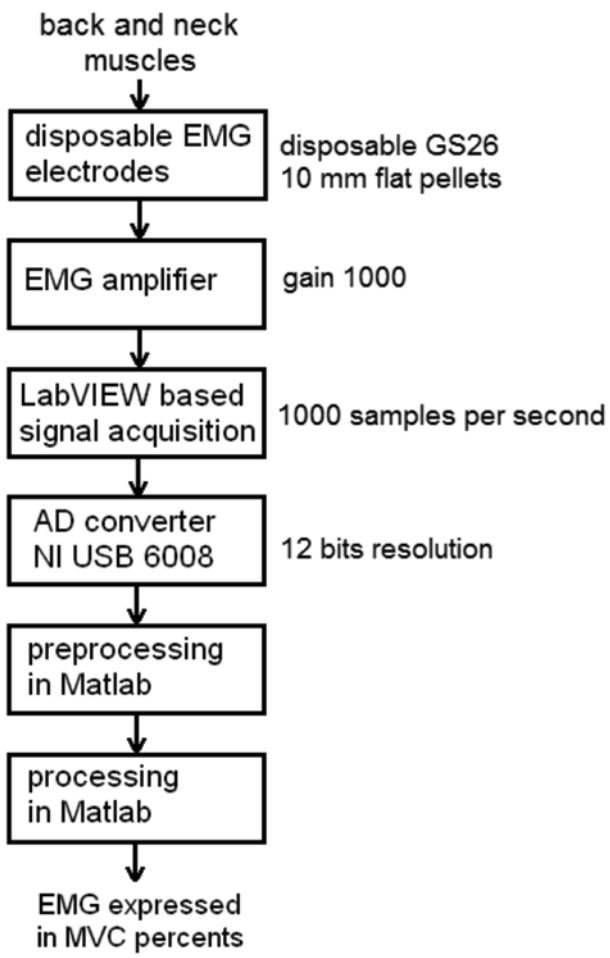

Figure 2: Block diagram of instrumentation and data processing steps

Data Processing

EMG data are normalized to Maximal Voluntary Contraction (MVC), and expressed in percents of MVC values.

In order to estimate MVC based parameters: $MVC_{index}^{i,s}$ (i =1, 2, 3, 4 for SC, T, ES, and SCM muscles, respectively, and s=1,…,10 for subjects with ID=1,…,10), we further averaged whole interval recorded during dental examination, and calculated standard deviations for each muscle $SD_{index}^{i,s}$ (i =1, 2, 3, 4 for SC, T, ES, and SCM muscles, respectively, and s=1,…,10 for subjects with ID=1,…,10). The values close to 0% indicate that muscle is not activated during discrete time interval compared to MVC, and values near 100% indicate that the muscle is completely activated when compared to MVC.

The data analysis was performed in Matlab (The Mathworks, Natick, MA, USA). In order to assess changes between left and right side of the body, we calculated the ratio of $MVC_{index}^{i,s}$ for muscles on the left and right side of the body. The results of left/right MVC ratio were averaged for all subjects and presented.

Procedure

Subjects were asked to perform typical dental examination on the patients in standing and sitting positions. Dental examination started from the upper right part of the patient's mouth, then upper left, down left and finished at the down right side. All participants worked on the same dental chair (Jugodent Elektra 2000 G, Serbia). During work the dentists were positioned between the 9 and 12 o'clock position relative to the patient. In standing position the dentists adopted symmetrical posture upright. In sitting position participants were placed on the ordinary therapeutical chair with lumbar support and horizontally placed seat. They were allowed to adjust the seat to suit the preference. During dental procedure the dentists were video recorded using two cameras simultaneously.

Before starting dental examination, the MVC was determined for each investigated muscle according to the SENIAM protocol[16]. After the MVC test, participants were resting for 10 minutes, and then started dental procedure.

Assessment of Risk Levels

The established ranges from[17] for ergonomics risk levels associated with muscle forces were:

- from 0 to 10% of the MVC indicated "low risk";
- from 11 to 20% of the MVC indicated "medium risk";
- 21% or more of the MVC indicated "high risk".

Results

One example of EMG signals recorded on 8 muscles on left and right sides during sitting and standing positions are given in figure 3.

Filtered and rectified EMG signals recorded on 8 muscles on left and right side during sitting and standing positions are given in figure 4.

The average values of EMG amplitude normalized to MVC for all of the participants are calculated for sitting and standing positions and presented in table 2 and table 3, respectively.

The results of left/right MVC ratio are averaged for all participants and presented in figure 5. The values of left/right ratio close to 1 indicated that the posture was ideally symmetrical; values higher or lower than 1 indicated that one side of the body was more active during the examination. There were no significant differences between muscle activity of the left and right side of body.

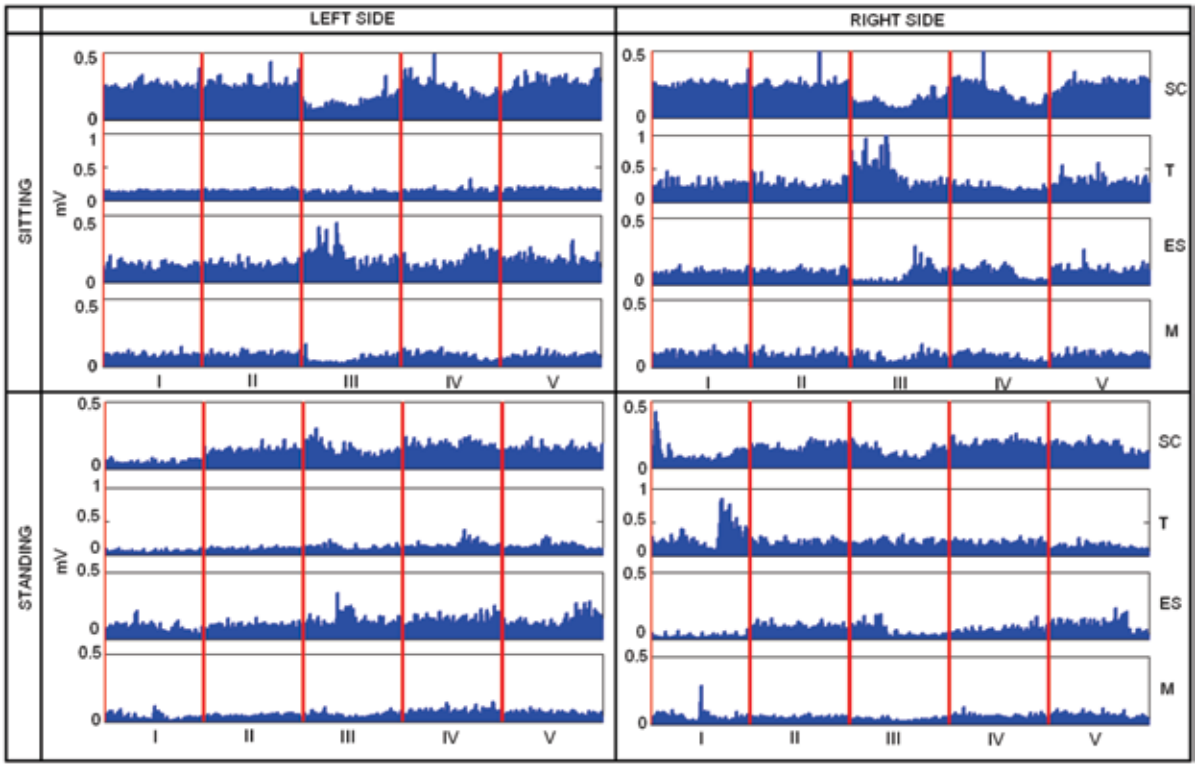

Figure3. EMG signals recorded on subject with ID=1. The amplitude is presented in mV. Muscles shown are splenius capitis (SC), descendent trapezius (T), erector spinae (ES), and sternocleidomastoid muscle (M). EMG signals are shown from left, and right side and in sitting and standing positions. The time windows are referred with I, II, III, IV, and V. All time windows are 5 seconds long and present: I: 25-30s, II: 50-55s, III: 75-80s, IV: 100-105, V: 125-130s of overall recordings session.

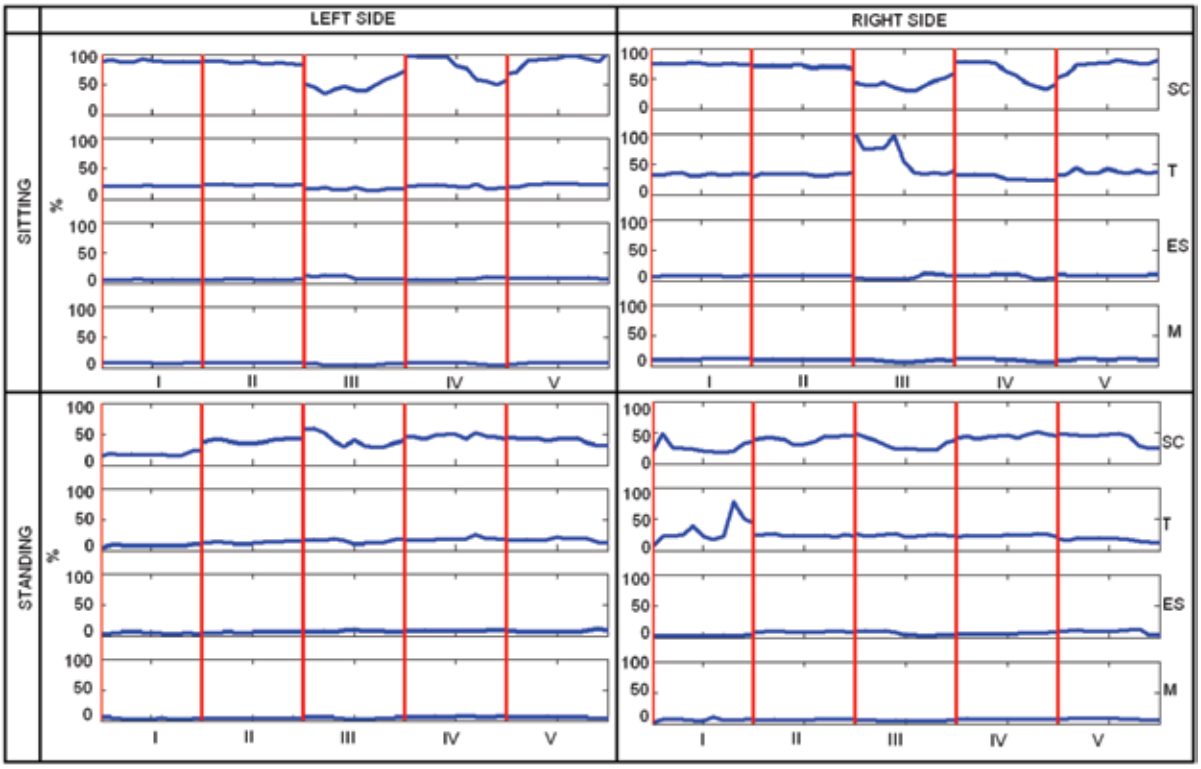

Figure 4. Normalized RMS values calculated on filtered and rectified EMG data for 0.5 seconds long intervals. The amplitude is presented in percents of MVC. Muscles shown are splenius capitis (SC), trapezius descedens (T), erector spinae (ES), and sternocleidomastoideus (M). EMG signals are shown from left, and right side and in sitting and standing positions. The time windows are refered with I, II, III, IV, and V. All time windows are 5 seconds long and present: I:25-30s, II:50-55s, III:75-80s, IV:100-105, V:125-130s of overall recordings session.

Table 2. Averaged RMS parameters expressed in percents of MVC from left and right side in sitting position, and associated risk levels

	SITTING POSITION							
Side	Left				Right			
Muscles	SC	T	ES	SCM	SC	T	ES	SCM
MVC (%)	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
Risk level	High	Medium	Medium	Low	High	Medium	Medium	Low

MVC: Maximal voluntary contraction
SD: Standard deviation

Table 3. Averaged RMS parameters expressed in percents of MVC from left and right side in standing position, and associated risk levels

	STANDING POSITION							
Side	Left				Right			
Muscles	SC	T	ES	SCM	SC	T	ES	SCM
MVC (%)	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
Risk level	Medium	Medium	Low	Low	Medium	Medium	Low	Low

MVC: Maximal voluntary contraction
SD: Standard deviation

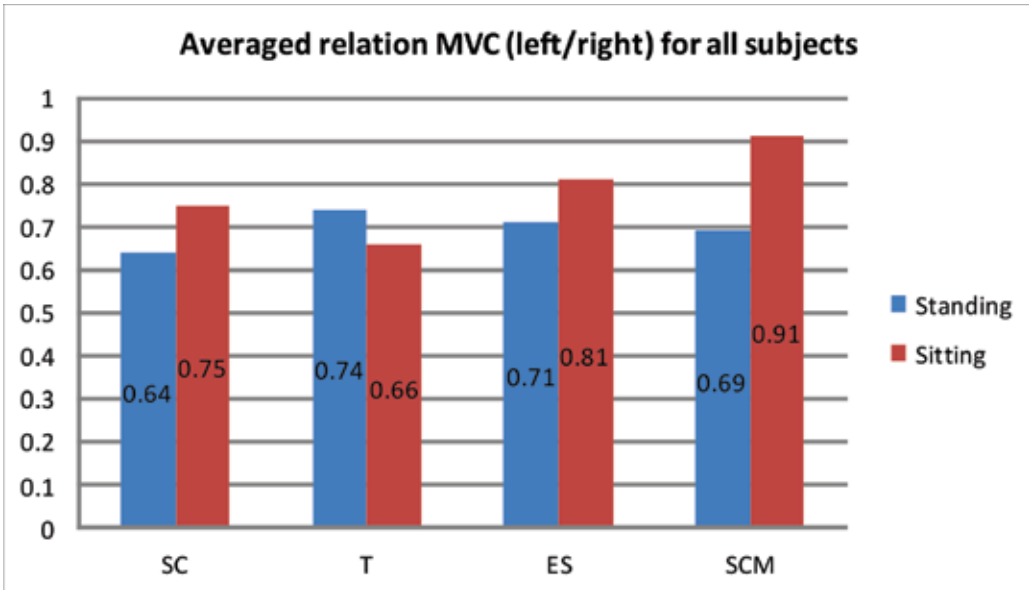

Figure 5. Bar plots for MVC relations of left and right muscles in all subjects in 2 positions (sitting and standing).

Discussion

Muscles chosen for the study are muscles from the anterior (SCM) and posterior sides (SC) of the neck, muscles from the lower back (ES) and shoulders (T). These muscles were selected because they provide an indication of muscle activity in the body parts that are most affected by the dentists' MSD (low back, neck and shoulders)[18]. Back pain is a primary cause of occupational disability[19]. Since dental work has a direct impact on back posture, activities of ES muscles (back extensor muscles, which help maintain lumbar curve[20]) were measured in this study as well.

This study was the first one, according to author's knowledge, were investigation of SCM muscles during dental work is done. Dental work requires high visual concentration, in that occasion function of SCM muscles have important role. SCM muscles contractions, lead to contraction of T muscles on the same side. Dental work has previously been shown to generate a relatively high mean load in the T muscles[21], and the T muscles were selected because of its pathophysiological importance and its frequent use in evaluation of occupational loads[22].

The SC muscles were chosen for the study, because these are superficial muscles, which are not directly influenced by the movements of the scapula, and, as well as the T muscles, are a common site of neck pain symptoms in dentists[23].

High muscles forces in this research, greater than 21 percent of MVC, which were accepted to be indicative of high risk, particularly occurred in muscles SC on both sides of the body in sitting position. The medium risk level occurred in the same muscles on both sides in standing position. Left and right T muscles in both, sitting and standing, working positions were under medium ergonomic risk level. SCM muscles on the left and right side of body in both working positions were under low risk level, lower than 10% of the MVC. In sitting position, medium risk level occurred in muscles ES on both body sides, while in standing position low risk level occurred in the same muscles. Amplitude of all EMG signals showed large variations between participants, which is probably individually determined by the adopted working habit.

Amplitudes of EMG signals from left and right side of body were quite similar. However, muscles from the left side of the body have mostly stabilization function, as all the participants in the study were right-handed. During the procedure, left hand is used as a support and for using the dental mirror to get an adequate view of the investigated regions of the mouth. The right side is active, performing precision tasks. Hsaio and Keyserling[24] suggested that the visual or manual target position has an influence on the posture of different body segments during work and that the persons adjust their posture in an effort to keep all parts of the body as close as possible to its neutral position.

Dentists often work in a non-neutral manner as a result of narrow work area (the oral cavity of the patient). Unnatural work posture among dentists is often necessary to gain good manual and visual access to part of the mouth and tooth surface[12].

In the study of Milerad et al[20], the muscular loads during work were studied in the descending part of trapezius muscle, as in our study, and also the infraspinatus muscle and the extensor-carpi-radialis muscle. All muscles were recorded from both sides. According to the results in that study, the trapezius muscles showed similar myoelectric activity on the right and left side, probably because of similar muscular static load on the both sides. The right extensor carpi radialis muscle had a significantly higher muscular load level than the left one, possibly due to stabilization demands on the dominant wrist during demanding precision work. The infraspinatus muscle had low activity level on both sides, reflecting that the dentists worked with a small degree of arm elevation and external rotation[20].

Finsen et al[11] recorded trapezius and splenius muscles bilaterally. Study showed that muscle activity in the neck was also high, and that no significant differences were found in muscle activity, either between work operations or between right and left side. The lack of difference between the right and left side indicated that the work only includes very slight variation in work postures.

In the study of Akesson et al[25], EMG was used for recording the descending part of the upper trapezius muscle bilaterally, as well as, for recording the flexor and extensor muscles of the right forearm. They found higher load for the right trapezius, as compared with the left one, but the differences between the right and left trapezius were small during dental work.

It was found that dentists who worked in the sitting posture had more severe low back pain than those who alternated between sitting and standing[5]. We found higher muscular load in sitting position.

Non-physiological prolonged static postures reduce nutrition of disks and nuclei[26]. Static muscle activity during dental work is factor with the most influence on development of MSD. During dynamic work a muscle contracts and relaxes rhythmically, which makes it act like a pump for the flow of blood in the blood vessels, allowing the blood to supply more oxygen and take away more lactic acid than during static work[27].

Conclusion

The postures of the back, shoulders and neck were primarily static. Dynamics working environment could be enabled by combining sitting and standing working posture. Recommendation for optimal working posture

should be given to dentists. It is important to recommend dentists to alternate their postures in order to prevent MSD. Dental ergonomics should be implemented in the educational system of dentists, what is consistent with other studies[28-30].

Recommendations for future investigations are to measure muscular load during different dental procedures, to find out which specialists require highest muscular load, and to measure muscular load between different age groups of dentists.

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