WORKING POSTURE EVALUATION OF CLINICAL STUDENT IN FACULTY OF DENTISTRY UNIVERSITY OF INDONESIA FOR THE SCALING TASK IN SITTING POSITION IN A VIRTUAL ENVIRONMENT

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Abstract

Musculoskeletal disorders (MSDs) are global issues in the dental profession. This research evaluated the MSDs risk caused by the sitting working posture of clinical students performing the task of scaling. The evaluation using the virtual environment approach shows risk of MSDs in the students' upper extremities such as neck, shoulder, and trunk. Further simulation based on the ideal sitting working posture shows that ergonomic scaling could be achieved when the patient sits at a 15° angle. When scaling the 1st and 4th quadrant of the teeth, the 9 o'clock position is used. Hence, the 11 o'clock position is used when scaling the 2nd and 3rd quadrant.

Abstrak

Evaluasi Postur Kerja Mahasiswa/i Tingkat Profesi Fakultas Kedokteran Gigi Universitas Indonesia pada Tindakan Pembersihan Karang Gigi dengan Posisi Duduk dalam *Virtual Environment*. Gangguan muskuloskeletal merupakan isu global dalam profesi kedokteran gigi. Penelitian ini mengevaluasi postur kerja para mahasiswa/i yang berisiko menimbulkan gangguan muskuloskeletal di masa datang pada tindakan pembersihan karang gigi dengan posisi duduk. Hasil evaluasi dengan pendekatan *virtual environment* menunjukkan bahwa kondisi aktual memiliki risiko muskuloskeletal untuk tubuh bagian atas, yaitu leher, bahu dan punggung. Simulasi *virtual environment* yang mengacu pada postur kerja duduk ideal menunjukkan tindakan pembersihan karang gigi yang ergonomis dapat dilakukan dengan sudut sandaran dental unit 15°. Dalam menangani kuadran 1 dan 4 digunakan posisi kerja jam 9, sedangkan pada kuadran 2 dan 3 digunakan posisi jam 11.

Keywords: dentist, musculoskeletal disorder, scaling, virtual environment, working posture

Introduction

According to Keputusan Menteri Kesehatan (Minister of Health Decree) No. 432/2007 published by Indonesia's Ministry of Health, there are potential ergonomic hazards that could risk workers' health such as manual handling, awkward posture, and repetitive tasks.[1] These issues are not only encountered by factory workers, but also by health workers in clinics and hospitals. Dentists are potentially exposed to such hazards since they work in a meticulous manner while treating a relatively small working area, namely the patient's mouth. Musculoskeletal disorders (MSDs) are common ergonomic hazards in the dental profession. World Health Organization (WHO) defined MSDs as disorders that occur in muscles, tendons, joints, invertebral discs, peripheral nerves, and vascular systems that develop gradually in a chronic manner. These disorders are usually caused by postural distortion, prolonged static postures, and also repetitive movement while working. Since those activities are recurrent in the dental profession, MSDs are considered as a common work-related disease in this profession.

MSDs in the dental profession is a global problem that occurs in several countries around the world. It is referred to in a scientific review conducted by Hayes *et al.* in eight countries from the United States of America to Thailand. Hayes *et al.* found out that from a group sample of dentists as many as 64-93% complained about the prevalence of MSDs within their professional routines.[2] Furthermore, MSDs definitely seriously impact the healthcare industries. Lehto *et al.* show that MSDs significantly relate to the loss of work hours caused by absenteeism.[3] Leggat *et al.* also found a relation to decreasing work productivity, even Crawford found that it could end a dentists' career.[4,5] Therefore, preventive action should be taken to decrease the prevalency of MSDs risk within the dental profession and also give risk education to young clinical students at universities' faculty of dentistry.

Early education for students in ergonomic dentist working posture is relevant to prevent unhealthy working postures in their prospective professional career and also to decrease the risk of MSDs in the future. Morse *et al.* found that MSDs symptoms and prevalence has presented ever since their practical work study in the university clinics.[6] Similar complaints of MSDs symptoms were also expressed by the students in the Faculty of Dentistry UI (Universitas Indonesia) which served as another source in this research.

In this research we evaluated the sitting working posture while treating patients. Sitting posture will be the main focus in this research since most of the time, dentists treat their patients in a sitting posture. Furthermore, according to Anghel *et al.* dentists are also potentially exposed to MSDs risks even though they work in the sitting posture which is less stressful than standing.[7] Specifically, this research will evaluate the scaling task which is said to be the most physically demanding task of all clinical treatments.

The research objective is to evaluate the working posture of clinical students in UI's Faculty of Dentistry in the sitting posture, specifically performing the scaling task in order to assess the musculoskeletal risk that could occur in the future. The evaluation results are then used to develop a guideline (explained later on Results & Discussion) for ergonomic scaling for students in UI's Faculty of Dentistry. Preliminary research was done in order to define the problems and provide initial information on the research objects. The next step was data gathering and data processing with questionnaires and use of the virtual environment approach using Jack 6.1 and Vicon Nexus 1.5.1 software. Posture analysis was then taken using posture evaluation index (PEI) to assess future musculoskeletal risks. According to Caputo *et al.* PEI could find the optimum parameter of a certain workplace in respect of a worker's posture.[8] The development of an ergonomic scaling guidelines will be arranged by combining literature reviews with working posture configuration simulation within the virtual environment to find the proper combination of postural angle and also interaction with the working environment.

Methods

The research objects are clinical students from University of Indonesia's (UI) Faculty of Dentistry who worked in the 1st, 2nd, and 3rd Integration Clinic at RSGM-P (Dental Hospital) Salemba. They treat patients on weekdays (5 days) from 8.00-14.00 and are usually monitored by lecturers and clinic supervisors. This research began with data gathering which was then followed by data processing before the data were analyzed. The data include MSDs prevalence or symptoms, working area dimensions, anthropometric data, actual scaling movements, and literature review. This step will be followed by data processing that includes posture verification from literature review, postural index calculation, and configuration simulation within the virtual environment.

Identification of students' complaints related to MSDs. In order to identify the symptoms of MSDs among the students, we collected data using the Nordic Body Discomfort Questionnaire and additional questions targeting 92 samples which consisted of 72 women and 20 men. We found that 55.7% of the sample said that scaling is the most frequent task in the clinic (Figure 1). Besides that, according to 49.6% of the sample, scaling is considered as the most physically demanding task in the clinic (Figure 2). Based on these results, we are focusing the research on the scaling task.

In addition to the previous result, the Nordic Questionnaire gave us information about MSDs symptoms related to daily dental treatment practice. It is concluded that symptoms of MSDs such as muscle ache and discomfort are present in their upper extremities such as neck, shoulders, and back. Seventy four percent of respondents suffer neck ache, while 44% experience shoulder ache, 55% have upper back ache and 54% feel lower back ache. The respondents experienced aches

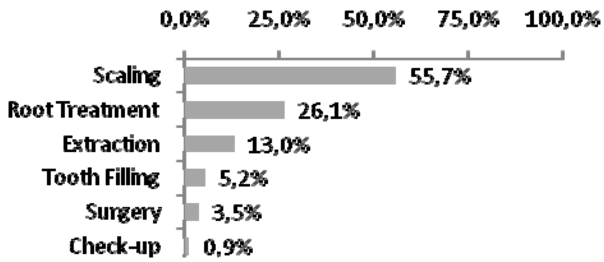

Figure 1. Frequent Dental Treatments

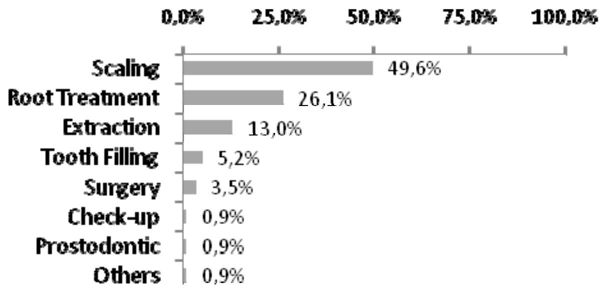

Figure 2. Physically Demanding Dental Treatments

and discomfort as often as 1 to 2 times a week. Fifty two percent of the respondents frequently experience discomfort at their necks, 44 % at their shoulders, 40% at their upper back and 31% at their lower back. From these results, it could be inferred that there are MSDs complaints from the respondents. Therefore, further evaluation for the scaling task which is considered as the most physically demanding task is needed.

Working area observation. The dental unit and its nearby surroundings are the main working area for dentists since they spend most of their time in this area treating patients. The students in Integration clinic use AL-398AA model dental units which are manufactured by Foshan Anie. The students can adjust the height of their dental units within the range of 44.2 cm at the lowest point and 66.8 cm at the highest point measured from the ground to the bottom side of the patient's seat. The seat itself has a certain inclination of 14° toward the ground making it unparallel with respect to the floor. The dentist chair is also a part of the dentist's working area that influences posture when working in a sitting position. The chair's height in the clinic could also be adjusted to 45.8 cm at the lowest point and 59 cm at the highest point.

Anthropometric data. In this research, we used the anthropometric data from Indonesian anthropometric database of Chuan *et al.*[9] research. The data covered samples with the age range of 18-45 years old and a total of 377 respondents comprising 245 men and 132 women. This data was used as a dimension baseline for motion capture and virtual environment processing using Jack 6.1. The dimensions consist of body height, arm length, distance between elbow to fingertip, distance between buttock to popliteal, arm rest height, and popliteal height (Table 1). Those dimensions were selected based on relevant input demands in Jack 6.1 software, working range calculations, and sitting posture dimensions which could be significant for chair designing in the future.

The research used design for an extreme approach with the broad range of body dimensions. Data were gathered from the 5th and 95th percentile of respondents to represent extreme body dimensions from a certain population. The 5th percentile is represented by a female sample, hence the 95th percentile is represented by a male sample. These inputs gave general results that will make the guideline viable to general Indonesians and not strictly limited to the dimensions of current clinical students in the Faculty of Dentistry UI. However, these anthropometric data do also represent those student's dimension since their values are within the range of the Indonesian anthropometric database between the 5th and 95th percentile.

Table 1. Specific Body Dimensions from Indonesian Anthropometric Data for the 5th and 95thPercentiles

BodyParts	Percentile	
	5	95
Body Height	150.9	183
Arm Length	62	84
Elbow to Finger	37	56
Buttock to Popliteal	37	54
Arm Rest Height	19	30
Popliteal Height	38	49

Actual motion capturing process. In this research, posture evaluation is conducted with a virtual environment approach using a motion capture method as the initial step in order to give real evaluation results that represent the actual scaling task in the clinic. Two respondents were selected based on previous anthropometric requirements. The respondents chosen have similar body dimensions within the 5th and 95th percentile data. The scaling posture is then captured and evaluated using Jack 6.1 software.

The motion capture process undergoes several steps initiated by the environmental preparation, system calibration, subject preparation, motion capture, and finally data editing. The capturing process was held in the motion capture facility at Ergonomic Center laboratory in the Department of Industrial Engineering, University of Indonesia. In attempts to simulate the actual scaling motion similar to the real treatment conditions at the clinic, we used a dental learning mannequin to replace the patient and the dental unit. Furthermore, scaling motions for all four mouth quadrants were captured in this simulation.

In dental terminology, the term quadrant is used to divide the mouth into four sections from the 1st, 2nd, 3rd, and 4th quadrant defined from the upper right side of the mouth to the lower right side in a clockwise manner (Figure 3). In addition to the term quadrant, there is also a specific term to tell the dentist's position while treating a patient using clock analogy. Assuming that the patient is the axis of the clock, therefore if the dentist is on the right hand side of the patient it is called the 9 o'clock position. While treating a patient from the position above the patient's head is called to be at the 12

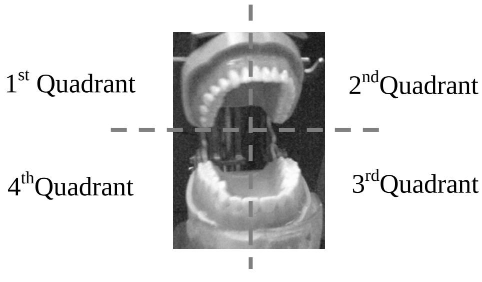

Figure 3. The Mouth Quadrant Concept

Table 2. Ideal Working Posture in Sitting Position

	Value Range	Ideal Angle	Remarks
Lower Arm Flexion	25°-30°	<10°	The angle could be achieved by P5 & P95 if the working area positioned with max height of 5 cm above the elbow
Upper Arm Abduction	max. 35°	<10°	The threshold value could exceed 10° if arm rest exist and used by the user. The arm should be as close as possible with respect to the body.
Upper Arm Flexion	max. 30°	<15°	The threshold value could exceed 15° if arm rest exist and used by the user. Take a brief rest at least every 20% from total working hour.
Wrist Abduction	max. 20°	<10°	Avoid wrist abduction to decrease musculo-skeletal risk
Wrist Flexion	max. 45°	< 15°	
Head Inclination	max. 30°	< 10°	Use eyeball movement to increase sight capabilities without neck bending
Neck Rotation	max. 45°	<5°	Avoid neck rotation to decrease musculo-skeletal risk.
Trunk Rotation	max. 15°	<10°	Avoid trunk rotation at least < 10% total working hour.
Bending Trunk	max. 15°	<10° or <20°	The ideal angle when standing is < 10° and while sitting < 20°. Make your trunk as straight as possible. Backrest could be helpful. Avoid bending > 60° more than 5% of working hour.
Trunk Sideward Inclination	max. 20°	<10°	
Knee Flexion	95°-135°	115°	Make your sole touch the floor
Leg Splay Angle	30°-45°	30°-40°	The shank has to be perpendicular with the floor.

o'clock position. Those terminologies will be used later in this research article.

Literature review related to ideal working posture in sitting position. A virtual environment approach was used in this research to evaluate the student's working posture. In addition to that approach, literature review from several references was also used to gain information about the ideal working posture in context with the scaling task. It is also needed to give inputs for developing the ergonomic scaling guideline which will be used to educate clinical students in the Faculty of Dentistry University of Indonesia.

The ideal working posture in a sitting position is synthetized by comparing several results from previous research done by other scientists. The goal of this comparison is to identify the minimum angle and value range of a certain body segment having minimum risk of MSDs development. The review refers to several researches and publications from ISO 1126 standards, Henry Dreyfuss Associates researches, Grandjaen (1988) and Pheasant (1987, 1991), Aarås *et al.* (1988), Keir *et al.* (1996), Kee and Karwowski (2001), Karwowski (2002), RULA standards developed by McAttarney and Corlett, Hünting *et al.* (1981), Paquet *et al.* (2001), and McGill *et al.* (1999).[7,10-12] Finally, we combined the information gathered from those researches and synthetized it as shown in Table 2.

Besides the body segment angles, the proper posture has to be followed with proper sitting behavior. In order to distribute the weight in the area around the hip, it is suggested that dentists implement dynamic sitting behavior. It means that the dentist has to frequently change sitting positions within the range of proper body segment angles.

Results and Discussion

Actual posture evaluation. The result from actual motion capture for the 5th and 95th percentile indicates a match between students' complaints with the musculoskeletal risk shown by the postural index value. It is found that the actual condition created musculoskeletal risk to the upper extremities such as neck, back, and arms which is related to shoulder problems.

Table 3 shows the actual postural index for the 5th percentile. Based on the calculation, the 5th percentile has a relatively similar index among all quadrants. The greatest value lies in the 2nd and 3rd quadrant which is located at the opposite site of the dentist's sitting position on the left side of the mouth. There is a consistent high risk of trunk MSDs development in all four quadrants. Insignificant differences of postural index between quadrants in the 5th percentile shows that the dentist did not change positions significantly during the simulation of different quadrant treatments. When the motion capture was conducted, the 5th percentile seems to sit uncomfortably so that the weight was distributed unevenly resulting in an awkward sitting posture. Shoulder and neck complaints by the 5th percentile are certainly in line with the high musculoskeletal risk of the upper arm and neck shown in the virtual environment.

Table 4 shows us the actual postural index for the 95th percentile. Generally, the index shows relatively smaller value than the 5th percentile's index. The 95th percentile has greater LBA value than the 5th percentile since they have greater weight and body dimension. The greatest postural index for the 95th percentile lies in the third quadrant. Even though there is an increase in the number of The Ovako Working posture Analysis System (OWAS) value between different quadrants in the 95th percentile. However, Rapid Upper Limb Assessment (RULA) points shows a relatively stable value. The decreasing musculoskeletal risk of the 95th percentile relative to the 5th percentile is influenced by their greater range of motion. It indicates that the working area doesn't accommodate the anthropometric dimension of the 5th percentile.

Table 3. Actual Postural Index for the 5th Percentile

Postural Analysis	SSP LBA	Quadrant 1	2	3	4
		OK	OK	OK	OK
		587	710	692	637
OWAS	Code	4121	4121	4121	4121
	Value	2	2	2	2
RULA	Upper Arm	2	4	4	2
	Lower Arm	3	2	3	3
	Wrist	3	3	3	2
	Wrist Twist	1	1	1	1
	Neck	5	1	5	5
	Trunk	5	5	5	5
	Total Score	7	7	7	7
Posture Evaluation Index (PEI)		2.09	2.13	2.12	2.11

Note: SSP = Static Strength Prediction
LBA = Lower Back Analysis

Table 4. Actual Postural Index for the 95th Percentile

Postural Analysis	SSP LBA	Quadrant 1	2	3	4
		OK	OK	OK	OK
		1166	1266	1692	1609
OWAS	Code	1141	1141	2141	2141
	Value	2	2	3	3
RULA	Upper Arm	3	3	3	3
	Lower Arm	3	3	3	3
	Wrist	3	2	2	2
	Wrist Twist	1	1	1	1
	Neck	2	1	1	1
	Trunk	1	1	2	2
	Total Score	4	4	4	4
Posture Evaluation Index (PEI)		1.65	1.68	2.06	2.03

Note: SSP = Static Strength Prediction
LBA = Lower Back Analysis

The result from PEI calculation shows us that the actual posture potentially creates future musculoskeletal risks. The implementation of ideal posture alone is not enough to create an ergonomic scaling posture. In order to make an ergonomic task become a reality, there are two things needed which are ergonomic working posture and proper interaction with the working environment. The working area includes the workstation and also human-machine interaction. Therefore, a proper strategy to position dentists with respect to their dental units is as necessary as implementing the ideal posture while treating the patient.

Ergonomic interaction with the working area. In order to identify the best working configuration related to human-machine interaction, further simulation in Jack 6.1 virtual environment was conducted.The configuration was made based on the ability of the dental unit, the ideal working posture in a sitting position, and other sources of literature. There are four variables that would be used in this simulation; percentiles, inclination angle of the dental unit, working position of dentists using clock analogy, and the mouth quadrants. The height variable of both the dental unit and the dentist's chair is not used directly in the simulation since we are using the ideal working posture as the main variable therefore the height will adjust to the working posture of the dentist in the virtual environment.

In terms of the inclination angle of the dental unit we are using two angles which are 15° and 30°. The 30° angle is based on the recommendation given by Hokwerda *et al.* as the usual inclination implemented in treating patients with sitting dentists in Europe.[13] Hence, the 15° angle is a position where the patient is particularly laying down on the dental unit. This angle causes the patient's nose to be positioned below the knee making it a comfortable position.

The patient using the dental unit model in the clinic. Hopefully, this position will give dentists better vision of the patient's mouth area. In terms of working position, we use both 9 o'clock and 11 o'clock position in this simulation. Both positions are commonly used by dentists when treating patients and have also been recommended by Cohen and Sherwood (1990) for proper scaling positions.[14]

The combination of those variables result in 32 configurations (2 percentiles x [2 position ^ 4 inclination attempts]) that have to be simulated in order to identify the best interaction between dentists and their working environment (Table 5). From those configurations, the postural index will be observed and compared with each other. The smallest postural index means less musculoskeletal risk for the dentist making it a better interaction between dentists and their working environment. The simulation is conducted within the virtual environment built in Jack 6.1 software.

Virtual environment simulation indicated that the interaction strategy between dentists and their working environment could be classified by the quadrant being treated. Similar results were found for both percentiles where ergonomic scaling could be accomplished if the treatment in the 1st and 4th quadrants are conducted with 15° dental unit inclination and 9 o'clock working position. Hence, the 15° dental unit inclination and 11 o'clock working position is used for treating both the 2nd and 3rd quadrants. The body segment that made these differences between configurations is the arm. The postural index for 16 simulated configurations by the 5th percentile is shown at Table 6.

Yet, the other 16 configurations simulated by the 95th percentile in the virtual environment could be seen in Table 7. The virtual environment approach also indicates that scaling by implementing the ideal segment angle could be implemented by dentists. However, those postures should be supported with proper interaction with the working environment. Further technical adjustment of the working environment that includes the adjustment of the dental unit and the dentist's chair height are explained in the next part of this research article.

Ergonomic scaling guideline. Ergonomic scaling could be achieved if the dentists implement both an ideal working posture and proper working interaction with their environment. Sitting behavior also gave influences in addition to the design aspects of working area. As one of the outputs of this research, this paper would give information about ergonomic scaling guidelines gathered from literature reviews and previous virtual environment simulations in an attempt to reduce the risk of MSDs development for the clinical students of Faculty of Dentistry UI. The guidelines could be found at the Appendix.

Table 5. Simulated Configuration in the Virtual Environment

5th Percentile				95th Percentile			
No.	Work Pstn	D.U. Incl	Mouth Quadrt	No.	Work Pstn	D.U. Incl	Mouth Quadrt
1	9	15°	1	17	9	15°	1
2	11	30°		18	11	30°	
3	9	30°		19	9	30°	
4	11	15°		20	11	15°	
5	9	15°	2	21	9	15°	2
6	11	30°		22	11	30°	
7	9	30°		23	9	30°	
8	11	15°		24	11	15°	
9	9	15°	3	25	9	15°	3
10	11	30°		26	11	30°	
11	9	30°		27	9	30°	
12	11	15°		28	11	15°	
13	9	15°	4	29	9	15°	4
14	11	30°		30	11	30°	
15	9	30°		31	9	30°	
16	11	15°		32	11	15°	

Table 6. Postural Index for the 5th Percentile's Configuration

Postural Analysis		Configuration															
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
	SSP	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK
	LBA	402	263	270	407	412	393	416	411	390	331	379	344	375	250	251	357
OWAS	Code	1111	1111	1111	1111	1111	1111	1111	1111	1111	1111	1211	1111	1111	1111	1111	1111
	Value	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
RULA	Upper Arm	1	2	1	1	1	1	4	1	1	2	4	1	1	1	1	1
	Lower Arm	1	3	2	2	2	3	2	1	2	2	2	1	1	3	3	2
	Wrist	1	1	1	1	1	3	1	1	1	2	1	1	1	2	1	2
	Wrist Twist	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
	Neck	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
	Trunk	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
	Total Score	2	3	3	3	3	3	4	2	3	3	4	2	2	3	3	3
	PEI	0.77	0.94	0.94	0.98	0.98	0.97	1.18	0.78	0.97	0.96	1.17	0.76	0.79	0.93	0.93	0.96

Note: SSP = Static Strength Prediction
LBA = Lower Back Analysis

Table 7. Postural Index for the 95th Percentile's Configuration

Postural Analysis		Configuration															
		17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32
	SSP	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK	OK
	LBA	669	666	573	627	992	960	993	939	980	960	1236	850	626	615	574	624
OWAS	Code	1111	1111	1111	1111	1111	1111	1111	1111	1111	1111	1111	1111	1111	1111	1111	1111
	Value	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
RULA	Upper Arm	1	1	1	1	1	1	1	1	1	1	2	1	1	1	1	1
	Lower Arm	1	1	3	2	2	3	3	1	2	2	3	1	1	3	1	2
	Wrist	1	2	1	1	1	1	2	1	1	1	1	1	1	1	2	1
	Wrist Twist	1	1	2	1	1	1	1	1	1	1	2	1	1	2	1	1
	Neck	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
	Trunk	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
	Total Score	2	3	3	3	3	3	3	2	3	3	4	2	2	3	3	3
	PEI	0.85	1.05	1.03	1.04	1.15	1.15	1.15	0.93	1.15	1.14	1.42	0.91	0.84	1.04	1.03	1.04

Note: SSP = Static Strength Prediction
LBA = Lower Back Analysis

Conclusion

Based on the the Nordic Questionnaire that we gathered from dental students in Faculty of Dentistry UI Integration clinic at RSGM-P Salemba, there is a prevalence of MSDs and symptoms experienced by students at the neck, shoulder, lower back, and upper back. Postural analysis result shows potential musculoskeletal risk when treating patients while scaling the quadrants. It is caused by awkward posture that occurred when students tried to reach those quadrants. Therefore, virtual environment simulation is conducted in order to create a strategy to decrease the musculoskeletal risk caused by awkward posture when scaling patients.

Virtual environment simulation shows that the 15° dental unit inclination with 9 o'clock working position creates ergonomic treatment at the 1st and 4th quadrant. In addition, for the 5th percentile the height of the dental unit is adjusted to 44.8 cm and the dentist's chair is adjusted at 58.97 cm. For the 95th percentile the height of the dental unit is adjusted at 46.75 cm while the height of the dentist's chair is adjusted at 46.7 cm.

Furthermore, scaling treatment for the 2nd and 3rd quadrant should be worked on from the 11 o'clock working position with 15° inclination of dental unit. For the 5th percentile the height of the dental unit is adjusted at 45.69 cm and the dentist's chair is adjusted at 55.83 cm. Yet, for the 95th percentile the height of the dental unit is adjusted at 51.02 cm while the dentist's chair height is adjusted at 48.9 cm. The adjustment is implemented to avoid arm abduction and flexion to reach specific mouth area. If it is possible, a magnifying glass could help dentists to increase dental work in a meticulous way and avoid awkward postures.

Appendix

Ergonomic Scaling Working Position Guidelines

a. Prepare the dental unit and instruments to support the scaling task based on clinical procedures.
b. Adjust the dental unit with respect to the treated quadrant for scaling using the guidelines below,
   i. For the 1st and 4th quadrant use the 9 o'clock working position with the specifications below,
      5th percentile: 15° dental unit inclination, 44.8 cm dental unit height (close to its lowest point), and 58.97 cm dentist's chair height (close to its highest point).
      95th percentile: 15° dental unit inclination, 46.75 cm dental unit height (close to its highest point), 46.7 cm dentist's chair height (close to its lowest point).
   ii. For the 2ndand 3rd quadrant use the 11 o'clock working position with the specifications below,
      5th percentile: 15° dental unit inclination, 45.69 cm dental unit height (close to its lowest point), 55.83 cm dentist's chair height (±4 cm before the highest point).
      95th percentile: 15° dental unit inclination, 51.02 cm dental unit height (±9 cm above its lowest point), 48.9 cm dentist's chair height (±4 cm above the lowest point).
c. Ensure the dental unit's tray is positioned within arm's reach to minimize movement when reaching for dental instruments.

Ergonomic Dentist's Working Posture

a. Implement symmetrical working posture (Figure 4).
b. Avoid movement that will cause the lower arm to cross over the body's midline (body's vertical axis).

c. Sit in a comfortable position with the mouth located midline of the body's axis (body's vertical axis).
d. Create a leg splay within the range of 30-45°
e. Conduct scaling with a straight back posture as possible
   i. Use the backrest to support the back upright
   ii. Avoid bending your back over 20° from its vertical axis
   iii. In order to decrease MSDs risk in the back, it is not recommended to bend over 60° for more than 5% of your total working hours
   iv. Avoid lateral back bending of more than 10° while working. If back twisting posture above 10° is present, then avoid doing it for more than 10% of total working hours.
f. Avoid neck twisting and bending more than 10° with eyeball movement strategies
g. Keep the arm close to the body
   i. Avoid upper arm abduction more than 10°
   ii. Avoid upper arm flexion more than 15°
   iii. Use the arm support to decrease musculoskeletal risk at shoulders when the arm exceeds the tolerable range of segment angle stated at point e (i) and e (ii).
h. Keep the lower arm in a horizontal position
   i. It is recommended to work with an elbow angle less than 10° where the working area is located ± 5 cm above the elbow normal position (with 0° stated at 90° angle between upper and lower arm).
   ii. A maximal angle of 25° is recommended as the maximum tolerable point range (figure 5)
   iii. Avoid wrist abduction when reaching for instruments with an awkward posture of more than 10°.
i. Create a knee angle between the shank and thigh within a range of 95°-135° and an ideal angle of 115° (figure 5)
j. The feet soles have to touch the floor to evenly distribute the body weight.

Sitting Behavior

a. Take a break with a minimal amount of 20% total working posture in order to rest the arm which is exposed to prolonged static posture and repetitive motion while scaling.

Figure 1. Symmetrical Working Posture

Figure 2. Maximal Elbow Angle and Recommended Knee Angle

b. Change the working position frequently at intervals within the tolerable angle range in order to evenly distribute the weight in specific areas of the body especially the hip and thighs.

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