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CLINICAL RESEARCH:

Application of Ergonomic Principles in Clinical Practice: An Observational Study Among Dental Students

Aplicación de los principios ergonómicos en la práctica clínica: un estudio observacional entre estudiantes de odontología

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ABSTRACT: The objective of the present study was to assess the application of ergonomics among undergraduate dental students at the University Dental Hospital Sharjah. The study also intended to compare application of ergonomic principles among fourth and fifth year dental students, and predict the risk of musculo-skeletal disorders for each group based on the RULA (Rapid Upper Limb Assessment) method. Eighty-four participants of this observational study were evaluated for ergonomic risk factors by obtaining data in the form of static photographs of dental students in their fourth and fifth years at UDHS. These images were then analyzed by the observers to determine musculo-skeletal risk using the Rapid Upper Limb Assessment (RULA) worksheet. The dependent variables were the risk scores obtained from the RULA worksheet, which evaluated the risk of WMS and/or WMSD for the dental students. Conversely, the students' work postures, movement repetition, static muscle work, and associated loads, were considered the independent variables. The Mann-Whitney U test was used to compare the statistical significance between both year groups. The overall final RULA scores showed that fourth year dental students had a higher mean ranking (score =1980.5) than fifth year dental students (score=1589.5), which was statistically significant (P=0.009), thereby placing them at a higher risk of developing musculo-skeletal diseases due to their ergonomics. The overall RULA scores of both groups portrayed that the 4th year participants were in the medium-risk category of developing WMSDs as a result of their working postures, whereas the 5th year participants were in the low-risk category.

KEYWORDS: Ergonomics; Dental students; Clinical training; Education.

RESUMEN: El objetivo del presente estudio fue evaluar la aplicación de los principios de ergonomía entre los estudiantes de odontología de pregrado en el Hospital Odontológico Universitario de Sharjah. Además, se buscó comparar la aplicación de dichos principios entre los estudiantes de cuarto y quinto año, y predecir el riesgo de trastornos musculoesqueléticos en cada grupo mediante el método RULA (Evaluación Rápida de las Extremidades Superiores, por sus siglas en inglés). Ochenta y cuatro participantes de este estudio observacional fueron evaluados en cuanto a factores de riesgo ergonómico mediante la obtención de fotografías estáticas de los estudiantes de cuarto y quinto año en UDHS. Estas imágenes fueron analizadas por los observadores para determinar el riesgo musculoesquelético utilizando la hoja de evaluación RULA. Las variables dependientes fueron las puntuaciones de riesgo obtenidas con RULA, las cuales evalúan el riesgo de presentar trastornos musculoesqueléticos (TME) y/o trastornos musculoesqueléticos relacionados con el trabajo (TMERT). Por otro lado, las posturas laborales, la repetición de movimientos, el trabajo muscular estático y las cargas asociadas fueron consideradas como variables independientes. Se utilizó la prueba U de Mann-Whitney para comparar la significancia estadística entre ambos grupos. Las puntuaciones finales generales de RULA mostraron que los estudiantes de cuarto año obtuvieron un promedio de rango superior (puntuación=1980.5) en comparación con los estudiantes de quinto año (puntuación=1589.5), siendo esta diferencia estadísticamente significativa (P=0.009), lo que indica un mayor riesgo de desarrollar trastornos musculoesqueléticos debido a sus condiciones ergonómicas. Las puntuaciones generales de RULA indicaron que los participantes de cuarto año se encontraban en una categoría de riesgo medio de desarrollar TMERT debido a sus posturas de trabajo, mientras que los de quinto año estaban en una categoría de riesgo bajo.

PALABRAS CLAVE: Ergonomía; Estudiantes de odontología; Entrenamiento clínico; Educación.

INTRODUCTION

Among the many occupational health hazards that may pose a threat to dental practitioners and students alike, fall under the spectrum of work related musculo-skeletal disorders (WMSDs). Examples of MSDs include de Quervain's disease, carpal tunnel syndrome, Raynaud's syndrome, Guyon's syndrome, bursitis, sciatica, trigger finger, and rotator cuff impingement (1). Such degenerative and inflammatory conditions target a variety of anatomical structures. They take both a physical and financial toll on medical professionals. This would subsequently lead to multiple symptoms of discomfort, some of which are muscle weakness and pain (2).

Ergonomics is an applied science which studies the work environment in order to make physical alterations and environmental changes to promote safety for employees. Applying ergonomic principles significantly reduces the risk of developing WMSD (2), minimizing discomfort on the practitioner once adopted (3, 4). Dentists particularly tend to be placed at a higher risk of developing WMSDs due to the high tendency of adapting to awkward postures while working on a confined space such as the patient's mouth under a limited field of view (5). This would lead to continuous muscle fatigue over a long period of time, resulting in musculoskeletal injury.

The uncomfortable nature of maintaining a static body posture to counter gravity, while also applying a non-dynamic force with the hands and wrists, exerts a lot of pressure on the supporting muscles. Adaptation of ergonomic protocols are applied in dental schools as early as preclinical

years to condition the students to maximize their work efficiency, without having to compromise their physical health. This observational study aims to compare the ergonomics of fourth and fifth year dental students to assess postures and predict the risk of developing musculo-skeletal disorders (6).

METHODOLOGY

Study Design: This observational study used a single blind cross-sectional design in order to assess how deviant dental students' ergonomics are from the ideal seating position and posture, as well as, to determine whether there is a significant difference between the ergonomics of fourth and fifth year dental students. This study was approved by the University of Sharjah Research Ethics Committee (REC-22-11-05-02-S). The process of acquiring ethical approval involved making sure the consent provided to the participant was clear and comprehensible. It also clarifies that the study does not involve any psychological risks of misusing the photos, as well as the necessary measures that would be taken to minimize these risks, and the freedom of withdrawal from the study whenever desired.

Study Population: To concentrate on the significance of ergonomics in dentistry, the target population of this study included fourth year and fifth year undergraduate dental students receiving clinical training on live patients. This study was conducted at the University Dental Hospital Sharjah. Cluster sampling was the most appropriate method for the selected sample, and it has an advantage of being feasible and requiring fewer resources. All participants who chose to take part in this study had fulfilled the inclusion criteria; this included being right-handed, undergraduate students who worked on patients above the age of 15 years. For the sake of consistency of assessment and standardization of the results, the discipline of observation was restricted to endodontics, as the ergonomics adapted differ with procedures among different disciplines. Pre-clinical level students, post-graduate students, and faculty members were excluded from this study, along with any left-handed students to minimize variability in hand positioning and instrument handling. Some left handed students resort to working on right handed stations. Despite being accustomed to these stations over several months of work, it is undeniable that a compromised seating position would have to be adapted for stations that are otherwise designed for right handed dentists. Furthermore, left-handed students may inherently use different ergonomic strategies than right-handed students, leading to the incorporation of confounding variables that may affect the analysis and interpretation of study results.

Measurements: The Rapid Upper Limb Assessment (RULA) worksheet, which is employed in order to measure and assess ergonomics and posture, and provide an overall risk score, was utilized in this study. RULA worksheet was developed by McAtamney as a single page document used to analyze body posture, forces applied, and motion repetition rates in workplaces where WMSDs are reported. RULA evaluates the ergonomics at the upper limb, neck, trunk, and legs, and provides an overall risk score for WMSD (7). The worksheet is divided into two sections: Section A assesses the wrist and arm positions and angulations, whereas Section B assesses that of the neck, trunk, and legs. The collected data from the tables pertaining

to sections A and B, along with the ergonomic risk factors, are combined to give a single score that depicts the overall level of WMSD risk (8) (Table 1).

Table 1. The level of MSD risk based on RULA worksheet scores.

Score	Level of MSD Risk
1-2	Negligible Risk, no action required
3-4	Low Risk, change may be needed
5-6	Medium risk, further investigation, change soon
6+	Very high risk, implement change now

These risk scores obtained from the RULA worksheet evaluated the risk for WMS and/or WMSD and were the dependent variables in this study. The independent variables included the students' work postures, movement repetition, static muscle work, and the associated loads.

Data Collection: The data collection process was conducted by four observers. To rule out any discrepancy and avoid any bias in the results, the participants' posture photographs were standardized to be taken from the right-side profile candidly without their awareness as they perform endodontic treatments. The photo taking process was standardized by standing on a marked position outside of each cubicle of the study participants, and all photographs were captured using the same camera to minimize inconsistencies. In addition to the necessary measures that were taken to ensure candidness, the nature of the work of the dental students indirectly allowed for a smoother data collection process, free of distraction to the students. They are in a state where the amount of focus required to deliver the treatment, eliminates the ease of being distracted by subtle external stimuli, therefore making our presence as observers negligible to their attention. Once the photo was captured, a consent form was immediately given to the participants' on the spot and on-site, informing them about the anonymity of their identities throughout the data analysis of this study. Multiple photos were shot (3-4 photos) for each participant and the most representative one taken at the most desirable angle to fit within the criteria was selected. Personal identities and confidentiality were maintained by the means of using an imaging program that instantly blurs out the participants' eyes, and by storing the collected photographs on an external password protected hard drive to further protect the participants privacy and prevent any cyber threat or leaks of the photographs (Figure 1).

Figure 1. Example of the standardized photo documentation process for a fourth year undergraduate dental student.

Following the transfer of the images onto the hard drive, all four observers analyzed and scored the participants' photos based on the RULA worksheet and then permanently deleted off of the drive they were saved on. An inter-rater reliability test was also done (Krippendorff's alpha=0.857) to measure the agreement among the observers. During the early stages of photo analysis, all four observers had discussed the common postures

and repetitive movements that dental professionals adopt during treatment, such that the observers' eyes would be trained to identify and standardize variations of an ideal posture. This was one crucial way to avoid skewed results and interpretations of the same visual. Each body segment was assessed separately and explained among the observers in terms of position, applied force, and their subsequent scoring.

RESULTS

Participants: This study included 84 dental students, comprised of 40 (36%) fourth year dental students and 44 (43%) fifth year dental students working at UDHS. Only right-handed individuals were included, the majority of whom were females (68%). To standardize assessments only students performing endodontic procedures were observed. In this study, few participants (3%) utilized peripheral tools like loupes, to enhance their visual ability. The reliability coefficient (Krippendorff's alpha) that was used to measure the agreement among the observers indicated that there was an 85% level of agreement (good agreement). Krippendorff's alpha (REF) measures the "variance", namely how much scatter is present between the observers. It provides a useful measure of how often ratings or labels from different observers agree in a manner that isolates observer skill and is comparable across datasets with varying proportions of positives. In this study, Krippendorff.s alpha was useful because it generalized to more than two observers, and more importantly, it can handle missing data in the cases where some data points (or images in this case) were not rated by all observers.

Descriptive Analysis of RULA score: The median wrist and arm scores were 5.00 (standard deviation [SD]=0.951), and 4.00 (SD=1.152) for fourth and fifth year students, respectively. The median Neck, Trunk and Leg scores were 4.00 (SD=1.202) for fourth year students, and 4.00 (SD=1.020) for fifth year students. The medians of the overall RULA scores, irrespective of the area of analysis (Arm/Wrist/Neck etc.), were 5.00 (SD=1.223) for fourth year students, and 4.00 (SD=1.146) for fifth year students (Tables 2-5).

Table 2. The frequency of each risk level based on the year group.

	Risk Level			
Year	**Negligible**	**Low**	**Medium**	**Very High**
Four (N=40)	0	15	22	3
Five (N=44)	0	30	13	1

Table 3. The frequency of each risk level based on the gender.

	Risk Level			
Year	**Negligible**	**Low**	**Medium**	**Very High**
Four (N=27)	0	14	11	2
Five (N=57)	0	21	24	2

Table 4. The frequency of Wrist and Arm RULA scores based on each year group.

	Wrist and Arm RULA Scores					
Year	**2**	**3**	**4**	**5**	**6**	**7**
Four (N=40)	1	6	8	23	1	1
Five (N=44)	8	9	12	14	1	0

Table 5. The frequency of Neck, Trunk and Leg RULA scores based on each year group.

	Neck, Leg and Trunk RULA scores					
Year	**2**	**3**	**4**	**5**	**6**	**7**
Four (N=40)	2	5	20	9	2	2
Five (N=44)	2	13	19	7	2	1

COMPARISON OF RULA SCORES BETWEEN FOURTH AND FIFTH YEAR DENTAL STUDENTS

The medians of both year scores were compared in order to identify the presence of a significant difference using the Mann-Whitney U test, which indicated that the Wrist and Arm RULA scores of fourth year dental students (rank = 2075.5) were higher (U=589.5, P=0.003) than that of the fifth year students (rank=1579.5) (Figure 2).

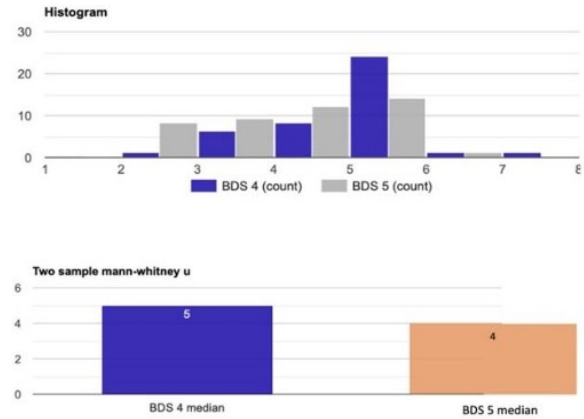

Figure 2. Mann Whitney U- test was used to compare the scores in the Wrist and Arm category between fourth and fifth year undergraduate dental students.

The Neck, Trunk and Leg scores on the other hand, showed that there was no significant difference between either of the group rankings (Fourth year=1865, Fifth year=1705) (U=715, P=0.116) (Figure 3).

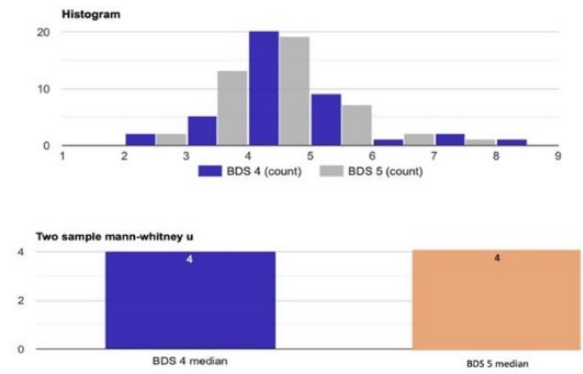

Figure 3. Mann-Whitney U test was used to compare the scores in the Neck, Trunk and Leg category between fourth and fifth year undergraduate dental students.

The overall final RULA Scores showed that fourth year students had higher mean ranking (Fourth year=1980.5, Fifth year=1589.5) than fifth year students, which was statistically significant. (U=599.5, P=0.009) (Figure 4).

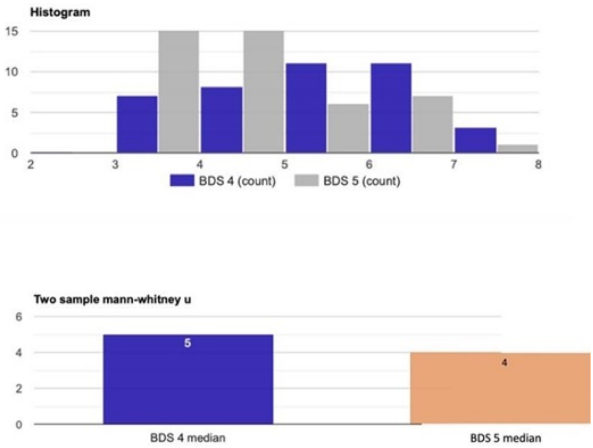

Figure 4. Mann-Whitney U test was used to compare the overall scores between fourth and fifth year undergraduate dental students.

DISCUSSION

Whether the ergonomic risk assessment of the endodontic discipline directly corresponds to the prevalence of WMSD is inconclusive. In the literature, there is controversy surrounding the concept of RULA values being directly correlated to WMSD (9). In this study, the observed group of fourth year students performing endodontic treatments had a median RULA score of 5 in the Arm and Wrist sub score, as well as the overall score category, which implies that this group is at a higher risk of developing work- related musculoskeletal disorders than fifth year dental students (Median of 4) performing the same treatments. According to the worksheet recommendations, people who fall under the medium risk (5-6) class require ergonomic intervention soon with some further investigation.

Both fourth and fifth year groups had a median RULA score of 4 for the Neck, Trunk and Leg subscore which indicates that there is a low risk of

developing any WMSDs in those regions and therefore intervention may be required. A suggestion for the relatively low RULA scores in this category is the presence and use of ergonomic dental stools in place of traditional chairs at UDHS, which has a significant impact on the position of the trunk and may explain the lack of statistical significance in Neck, Trunk, and Leg scores between the groups. Given that all these students utilize the same chairs, their seating postures are mostly standardized and nearly identical, with the exception of their neck positions, which vary to a higher extent than their trunk positions. In a similar study by Gandolfi (10), it was stated that the cervical spine is the most exposed area prone to developing WMSD, and it is mainly due to the posture of the operators working with their heads tilted forward beyond 15-20°, resulting in the overload of muscles on the neck and the joints of the cervical spine. An ergonomic stool with a forward sloping seat allows the hamstring muscles to be relieved and the pelvis pulled forward, resulting in an anterior pelvic tilt, or lordosis of the lumbar spine; this is a desirable position (versus kyphosis) (11). Recent studies that utilized the RULA worksheet for analysis, showed that neck pain was the most common and the most varied among participants, followed by upper back, wrist, and shoulder pain, placing the practitioners at an increased risk of WMSD (12, 13). Due to the poor visibility in patients' mouths, an awkward and unnatural rotation of the neck is usually performed to achieve proper vision of the site (14).

Not enough participants used magnifying loupes in this study (3 of 84) and therefore its impact could not be assessed in this study, despite it providing slight improvement in neck and trunk rotations.

Comparison of the Ergonomic Risk Factors between Fourth and Fifth Year Dental Students: The results of this study were mixed, but mostly skewed towards higher RULA scores among fifth year students, indicating a higher risk of developing MSDs among students of that group in comparison with fifth year students. This was evident with the Wrist and Arm RULA scores, as well as the final RULA scores between the two groups ($U=599.5$, $P=0.009$). Conversely, the Neck, Trunk and Leg scores showed no significant difference between fourth and fifth year dental students. In contrast, a similar study conducted by Ting Chong 2 reported a lack of statistical significance between the overall RULA scores between fourth and fifth year dental students. This may suggest that at the University Dental Hospital Sharjah, instructors may enforce ergonomic principles among the undergraduate students during their clinical years, leading to a gradual improvement in working posture over the course of clinical education. It is suggested that regular resistance training can greatly increase trunk strength (as well as neck and shoulders) and therefore lead to an effective decrease in pain in those sites (15). Studies regarding the awareness of ergonomics principles have been conducted in several countries across the world (16-20).

Limitations of this study includes the relatively small sample size, because several participants did not consent to their photographs being used in the study. Participants wearing headscarves might not be accurately assessed due to the observers' inability to visualize the neck. The RULA assessment worksheet is a generalized assessment, which has not been modified for dental students/dentists leading to a multitude of problems including the inability of the observers to standardize the dental arch being worked on, the stage in the endodontic procedure being carried out, difference in chair types being used by the participants, inability to record both profiles of the participants, as well as, the length of the procedure(8, 9, 12). Since static images of working postures were used to derive the results of this study, no documentation of any dynamic variables was made, such as pre-existing MSDs, application of loads of a certain magnitude, or frequency of positional changes. A supplemental question-

naire would have been useful to further assess the impact and severity of WMSDs, such as the Nordic musculoskeletal questionnaire (10, 21) Environmental factors such as stress, workload, lighting and temperature were also not taken into account.

CONCLUSION

Fourth-year dental students are at a medium risk for developing WMSDs, while fifth-year students are at low risk. This study highlights the importance of ergonomic training and interventions in dental education. Future research should include a larger sample size and consider other factors affecting ergonomic practices.

ETHICS APPROVAL AND CONSENT TO PARTICIPATE: All methods were carried out in accordance with relevant guidelines and regulations. All experimental protocols were approved by the Research ethics committee Ref. no. REC-22-11-05-02-S (University of Sharjah). Informed written consent was obtained from all subjects involved in the study."

AVAILABILITY OF DATA AND MATERIALS: The data can also be obtained by contacting the corresponding author vis email.

COMPETING INTERESTS: The authors have no competing interests to declare.

AUTHOR CONTRIBUTION STATEMENT

Collected the data and wrote the manuscript: R.M., N.A.K.,R.K. and H.S.
Analyzed data and edited the manuscript: M.A. and S.S.

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