



Published in final edited form as:

J Dent Educ. 2025 September ; 89(9): 1310–1318. doi:10.1002/jdd.13855.

Environmental factors increasing the risk of poor posture in dental hygiene students

Trisha M. Willie, OTD, OTR/L [occupational therapy doctorate resident],

Chan Division of Occupational Science and Occupational Therapy at the University of Southern California

Yiyang Fang, OTD, OTR/L [PhD candidate and research assistant],

Chan Division of Occupational Science and Occupational Therapy at the University of Southern California

Nancy A. Baker, ScD, MPH, OTR/L [tenured professor],

Department of Occupational Therapy at Tufts University

Jay M. Kapellusch, PhD [tenured professor, head, Associate Dean for Academic Affairs],

School of Rehabilitation Sciences & Technology, and College of Health Professions at the University of Wisconsin Milwaukee

Shawn C. Roll, PhD, OTR/L [tenured professor and director of research training and development]

Chan Division of Occupational Science and Occupational Therapy at the University of Southern California

Abstract

Purpose/Objectives: This study examined the relationship between environmental factors (e.g., working position, patient position, scaling instruments) and poor posture in dental hygiene students.

Methods: A longitudinal cohort study was conducted from 2017 to 2019 to observe dental hygiene students' clinical rotation performance at two undergraduate universities. Samples of video observations (n=1487) of dental hygiene students performing scaling activities during oral care sessions were evaluated using the Rapid Upper Limb Assessment (RULA). Descriptive analysis and exploratory prediction modeling were performed to assess clinical environmental factors that predicted higher risks of developing WMSDs.

Results: RULA scores (mean=4.8, median=5, range=2-7) indicate dental hygiene students are at high risk of developing upper extremity MSDs. The type of scaling instrument, clock positioning relative to the patient, and sitting versus standing had statistically significant associations ($p<0.001$) with the RULA outcome. In univariate analyses, clock positions 7 and 8 were the worst, having an increased risk of poor RULA outcomes (scores 5 to 7) by nearly 9 times over

Correspondence: Dr. Shawn C. Roll; 1640 Marengo Street, Suite 412, Los Angeles, CA, 90033; sroll@usc.edu.

Disclaimer: The content is solely the responsibility of the authors and does not necessarily represent the official views of the CDC/NIOSH.

working in clock position 12 (odd ratio [OR] 9.11, 95% CI 5.48-15.60). Multivariate predictive modeling indicated that the riskiest combination of factors is using a manual scaling instrument (OR 1.67, 95% CI 1.28-2.18), standing (OR 1.42, 95% CI 1.03-1.96), and working clock positions 7 and 8 (OR 8.4, 95% CI 5.02-14.50).

Conclusions: There is a need to consider the combined contribution of multiple environmental factors on working positions to optimize ergonomic training during dental hygiene and protect emerging dental health professionals from the negative health impacts of prolonged awkward postures.

Keywords

Dental Hygiene Education; Dental Education; Musculoskeletal Diseases; Ergonomics; Health Behavior; Environmental Factors

INTRODUCTION

Oral health professionals are at a high risk of developing work-related musculoskeletal disorders (WMSDs), with prevalence as high as 81% in dentists and 96% in dental hygienists.^{1,2} WMSDs are characterized by discomfort, disability, or pain in joints or muscles aggravated by the performance of work tasks and activities that involve sustaining demanding and problematic postures.^{3,4} The strenuous nature of clinical activities, repetitive movements of the hands, and prolonged static postures—particularly flexion and rotation of the neck and trunk—contribute to the high prevalence of work injuries and disorders.⁵ Persistent WMSD symptoms among dental professionals reduce working capacity, leading to workforce retention concerns, including career switching⁶ and premature retirement.^{7,8}

To mitigate the impact of posture-related WMSD symptoms in oral health professionals, further investigation is needed to develop effective preventive and maintenance strategies such as ergonomic education.^{1,8-12} Preventative training and curriculum design in dental education settings are particularly crucial, as these are periods when dental professionals first develop their work habits.^{13,14} In dental hygiene, it is estimated that students spend three times longer with a patient during their clinical rotations than a typical dental hygiene appointment.¹⁵ The extended amount of time spent on clinical practice, combined with long hours working on computers makes students vulnerable to prolonged poor postures, causing musculoskeletal concerns early in their careers.^{13,16} Although ergonomics is frequently addressed during dental hygiene education,¹⁷ approximately three-fourths of participating dental hygiene students still develop musculoskeletal pain.⁵

The limited effect of dental education in mitigating WMSDs may be attributed to the complex interplay between individual and environmental factors in clinical settings⁷ that can lead to more frequent awkward, static postures and the development of WMSDs.^{1,16,18} In this study, we use the term environmental factors to represent a range of ergonomic risk factors in dental clinical environments, including but not limited to practitioners' working positions, patient positions, and dental tools and equipment (e.g., scaling instruments). Existing literature on risk factors contributing to WMSD development in dental hygienists and dental hygiene students has primarily focused on individual

associations between musculoskeletal pain with tools and equipment use,^{19,20} sitting versus standing protocols,^{18,21} or operator positioning.^{22,23} However, none of these aspects are performed in isolation, and there is a lack of literature investigating the combination of these risk factors in dental clinical or educational settings. To protect future and current entry-level dental professionals, a comprehensive assessment of these environmental factors can inform the design and development of effective environmental modifications, ergonomic training, and postural instructions in dental educational programs. As such, this study aimed to examine the relationship between environmental factors in dental training clinics and poor posture in emerging dental professionals.

METHODS

This observational study was approved by the institutional review boards of the University of Southern California and Loma Linda University. All participants provided informed consent before data collection, and all patients signed photo release forms before the video data collection. A convenience sample of thirty-six right-handed female students from undergraduate dental hygiene programs at two universities was recruited and video-recorded during patient visits in the educational clinic.

Data Collection and Instrumentation

Patient visits were recorded using three cameras arranged at the front, side, and overhead of the patient's chair,²⁴ and each participant was recorded at least once per semester across three consecutive semesters of their dental hygiene clinical training. To minimize observer effects, cameras were positioned in a manner that would not obstruct the students' performance and intended to become part of the general environmental background over time; that is, when unobtrusive, awareness of being observed tends to wane over time. We further minimized observer effects by initiating recording at the outset of the patient visit with no additional interaction, engagement, or physical interruption by the researcher at any point throughout the visit, which lasted 2-3 hours on average.¹⁵

A team of three coders independently completed video observations using Observer XT software (Noldus, Inc.; Wageningen, Netherlands, Version 14.1). A standardized observational coding protocol characterized dental hygiene student activities (e.g., assessment, instrumentation, patient education) and environmental factors. We have previously reported on the methods for establishing this robust coding protocol, including detailed definitions and descriptions of each activity and environmental factor, the coder training process, and results of inter-rater reliability testing for each factor (e.g., overall Kappas 0.81 to 0.86).²⁴ For the analyses reported in this paper, we only examined components of the videos identified as instrumentation, excluding video segments involving other tasks (e.g., assessment, patient education).

We administered the Rapid Upper Limb Assessment (RULA) to evaluate students' postures during instrumentation. RULA is a reliable assessment²⁵⁻²⁹ that has demonstrated statistically significant associations with pain,³⁰ discomfort,^{31,32} and prevalence of upper extremity MSDs.^{33,34} RULA uses diagrams of body postures and three scoring tables to evaluate the risk of developing WMSDs. This ergonomic assessment tool accounts for

postures, muscle use, and force by observing posture and body part positioning during work tasks. In this study, we focused solely on the postural component of RULA by holding muscle use and force/load scores constant when administering the assessment. The RULA scoring involves analysis of two sections— arm and wrist in section A, and neck, trunk, and legs in section B— with an aggregate RULA score representing the overall risk of developing WMSDs. The aggregate RULA scores range from 1 to 7, with scores 1 and 2 being acceptable postures, scores of 3 and 4 indicating moderate risk such that further investigation may be needed, and scores 5, 6, and 7 indicating high-risk postures that need immediate change. Our raters demonstrated good to excellent overall inter-rater reliability, with ICCs ranging from 0.77 to 0.89 across the overall and section scores.²⁴

Environmental Factors

We extracted data during all instrumentation segments of our videos for the following environmental factors: (1) hygienist clock position; (2) hygienist sit/stand position; (3) scaling method; (4) patient chair position; (5) patient head position; and (6) patient mouth quadrant. Clock position refers to the location of the dental hygienist's hips in relation to the patient's mouth. Scaling method refers to whether or not the dental hygiene student used a manual hand scaling tool or ultrasonic scaling tool. We coded patient chair position as semi-supine if the angle between the floor and the back of the patient chair was between 25 and 55 degrees and supine if the angle was less than 25 degrees. Patient's head position was coded as left or right if the angle between the bridge of the patient's nose and the jugular notch on the sternum was greater than fifteen degrees. Otherwise, the patient's head position was coded as neutral. Mouth quadrant refers to the area of the patient's mouth in which the dental hygiene student was working: upper left, upper right, lower left, or lower right.

Postural Assessment

RULA assessments were conducted for ten randomly selected instrumentation segments of each video recording. The segments ranged from 15 seconds to 1 minute in length. The random selection of the ten samples was weighted by clock position such that the number of sample counts of any clock position was relative to the percentage of time the participant spent in that clock position. Detailed descriptions of the testing and validation procedures of the time-weighted sampling method can be found in a separate paper.³⁵ After samples were selected through this time-weighted average sampling process, coders used the RULA assessment to score the predominant posture of each video clip using a user interface application created through MATLAB (MATLAB R2019b, version 9.7). This application enabled automatic calculations of RULA aggregate and subcomponent scores based on the RULA assessment tool's scoring system.

Data Cleaning

We paired clock positions together based on relative similarity and frequency of distribution (i.e., 7-8, 10-11, 1-2, and 3-4). Since all participants were right-handed, clock positions 9 and 12, perpendicular to the patient's mouth on their right side, were the most frequently observed positions. Therefore, these two categories were considered standalone positions for data analysis. Due to the physical layout and positioning of patients during the sessions, positions 5 and 6 were never observed. Initially, we aimed to analyze RULA scores based on

the tool's three interpretative categories of acceptable posture (1-2), moderate-risk posture (3-4), and high-risk posture (5-7). Because fewer than 3% of the sample had acceptable scores, we used a binary RULA outcome that separated the high-risk postures with RULA scores from 5 to 7 from lower-risk postures, that is, those postures with RULA scores of 1 to 4.

Data Analysis

Descriptive statistics, including mean, median, and interquartile range, were calculated for aggregate RULA scores and sub-component scores (i.e., section A and section B). We also performed descriptive analysis for each environmental factor and compared the distribution of all environmental variables between low-risk and high-risk RULA using Chi-square tests. Lastly, exploratory prediction modeling was performed to determine a combination of environmental factors that best predicts high-risk RULA outcomes.³⁶ First, univariate analyses were completed to assess the associations between each environmental factor and the binary RULA outcome. To determine the comparison level for each categorical environmental factor, we calculated the mean RULA scores for each category; the category with the smallest mean RULA score was selected as the reference level. Next, a stepwise selection method was used to perform the multivariate logistic regression analysis. The significance level to enter the model was p-value less than 0.25, and the significance level to exit the model was a p-value greater than 0.15. We used more liberal cutoff significance levels of 0.25 and 0.15 instead of the traditional 0.05 to avoid eliminating important environmental factors.³⁷ The strength of the association between each environmental factor and the RULA outcome determined the sequence of entering the regression model. In other words, the environmental factor with the smallest p-value and largest odds ratio value entered the model first. The final multivariate model was determined based on the smallest Akaike information criterion (AIC)³⁶ goodness of fit value. The tidyverse,³⁸ dplyr,³⁹ and car⁴⁰ packages in R (RStudio, Version 4.3.1) were used for data manipulation, descriptive analyses, and regression analyses.

RESULTS

Ten RULA evaluations were completed for each of 151 video observations, totaling 1510 individual RULA scores. Of these, we excluded 23 video clips with upright patient chair position (i.e., the angle between the floor and the patient chair greater than 55 degrees), resulting in 1487 RULA scores included in the final analysis. The 1487 video clips had an overall average RULA score of 4.8 and a median of 5, with scores ranging from 2 to 7. No video clips had an aggregate RULA score of 1, and only 5 videos scored 2; that is, less than 3% of videos demonstrated acceptable dental hygiene student postures. The most prominent RULA score was 4 (n=416), indicating moderate risk for poor posture. In looking at the subscales of the RULA, The arm and wrist scores (section A) were positively skewed with a median and mode of 3 (n=562), whereas neck, trunk, and leg scores (section B) were negatively skewed toward higher risks, with a median of 5 and a mode of 6 (n=312) (see Figure 1). Of the 1487 video clips, slightly more than half of RULA scores fell into "high-risk" (54.5%) category.

Table 1 provides the frequencies of videos within the high-risk and low-risk categories for each environmental factor. Chi-square tests showed statistically significant differences in RULA scores when compared with clock position, scaling method, and sit/stand position variables, indicating a significant association between these variables and the RULA outcome. The low-risk group tended to be at clock positions 9, 10, 11, and 12, while the high-risk group clock positions were predominantly 1, 2, 7, and 8. Across categorical variables that had a statistically significantly different distribution between risk groups, clock position 12 (mean = 4.1, SD = 1.1), sitting (mean = 4.7, SD = 1.2), and ultrasonic scaling (mean = 4.5, SD = 1.2) had the lowest average RULA scores. There were no significant associations between risk categories and chair position, head position, or mouth quadrant.

Univariate analyses comparing each environmental factor to the likelihood of high-risk RULA scores indicate that clock positions from 1 to 9 all were significantly associated with moderate to large odds ratios compared to the reference level of clock position 12. Positions 7 and 8 were the largest and were 9.1 times more likely to increase the odds of high-risk RULA scores. Clock positions 10 and 11 also increased odds by 1.9 times (Table 2). Hand scaling increased the risk of high-risk RULA scores by 2 times compared to ultrasonic scaling, and standing increased the odds by 1.9 compared to sitting.

All six environmental factors were considered in the predictive model based on the results of the univariate analyses. We ran a total of six multivariate predictive models. The final best-fit model with the smallest AIC value (AIC=1919.2; $R^2 = 0.125$) included clock position, sit/stand, and hand scaling method (Table 3). In the final model, standing during instrumentation versus sitting (OR 1.42, 95% CI 1.03-1.96, $p=0.034$) and hand scaling versus ultrasonic scaling (OR 1.67, 95% CI 1.28-2.18, $p<0.001$) were more likely to result in high-risk RULA scores. When compared to 12 o'clock, all other clock positions increased the odds of high-risk RULA outcome by at least two folds, with clock position 7-8 being the riskiest position, increasing odds of poor posture by more than 8 times (OR 8.4, 95% CI 5.02-14.50, $p<0.001$). Figure 2 depicts comparative examples from the three camera angles of these high-risk (i.e., sitting or standing at 7 or 8 using hand scaling) and low-risk postures (i.e., sitting at 12 using ultrasonic scaling).

DISCUSSION

The aim of this study was to explore the impact of environmental factors in dental educational settings on the risk of poor posture among emerging oral health professionals. Findings identified a combination of environmental factors involved in dental hygiene student clinical rotation sessions predictive of poor RULA scores, indicating a high risk of developing WMSDs. The final predictive model included three environmental factors—clock position, sit/stand position, and scaling method. The riskiest combination of environmental factors was manual dental scaling while students stood at clock positions 7 and 8. While clock positions 7 and 8 were the most hazardous, all clock positions between 7-10 and 1-4 have shown significant associations with high-risk RULA outcomes. In contrast, ultrasonic scaling tools and clock positions that offer more direct access to the patient's mouth (e.g., clock position 12) were associated with lower RULA outcomes.

Results from this study highlight the importance of orientation around the patient and the use of power-driven instruments to mitigate the risk of developing WMSDs due to poor postures among dental students.

RULA results indicate a moderate to high risk of developing WMSDs during dental hygiene clinical education sessions. Awkward postures associated with high-risk RULA outcomes in this study might be a contributing factor to the high prevalence of WMSD symptoms among dental hygiene students.^{9,10} Although all students wore magnification loupes, which is known to help improve neck trunk postures,^{41,42} the RULA subcomponent scores indicated that neck, trunk, and leg scores contribute more to the aggregate RULA outcomes than the upper arm and wrist scores. These subcomponent results align with the well-documented neck and back WMSD symptoms among dental professionals.^{10,43} Growing evidence supports the need for more continuous and targeted ergonomic education in dental hygiene curricula since few programs emphasize body mechanics or self-analysis.^{10,12,17} We suggest that ergonomics education during dental training should focus on reducing environmental hazards that could lead to awkward postures. The following paragraphs will dive into the influential environmental factors analyzed in this study.

Video observations of clinical patient visits in this study provided empirical evidence on the postural demands of different clock positions. Previous evidence on the relationship between working clock positions of dental professionals and WMSD development is either based on cross-sectional survey data or simulated laboratory studies. An early survey study suggested that working between clock positions 10 to 12 behind the patient was a significant predictor for carpal tunnel syndrome.⁴⁴ Several other studies found no significant differences in the prevalence of MSDs between sitting in front of (8 to 10 o'clock) and behind (10 to 12 o'clock) the patient.^{45,46} A recent laboratory study quantifying the biomechanical demands of clock positions aligned with our study as they discovered clock position 8 was associated with the highest muscle activities due to difficulties maintaining a neutral spine in that position.²²

Similarly, we observed that students were more likely to bend or twist their trunks and necks while working in clock positions 7 and 8 due to the physical restrictions of the patient chair, resulting in higher RULA scores. Yet, it is worth noting that all clock positions between 7 and 10 should be used with great care. In particular, clock position 9 increased the odds of poor RULA outcomes by almost four times compared to clock position 12, even though participants could maintain a neutral spine and pelvic posture by placing their feet directly under the patient's head position. Since clock position 9 is the most frequently adopted working position for right-handed dental professionals, dental schools should consider under what circumstances other positions might be adopted and train students to consider working in clock positions between 10 and 12 as much as possible during dental hygiene education programs.

Additionally, working clock positions must be considered together with students' sit and standing positions, as we found that standing was a significant predictor of poor RULA outcomes. Our results were consistent with a recent study comparing seated and standing postures among dental hygiene professionals, which found higher RULA scores for standing

than seated positions.¹⁸ The poor postural outcomes in standing position may be why alternating seated and standing protocol has not shown significant effects in improving ergonomic and pain scores in dental students.²⁰ While such intervention may help students break the routine of prolonged, static seating positions, our research suggested that the combined risk of standing and working in awkward clock positions 1 through 9 significantly increased the odds of poor ergonomic postural outcomes.

Besides clock positions, our study revealed the ergonomic benefits of introducing ultrasonic scaling instruments during dental clinical education. Despite evidence suggesting the benefits of ultrasonic scaling in reducing the physical workload of the upper extremities,⁴⁷ there is mixed evidence regarding whether ultrasonic scaling provides an ergonomic advantage over manual scaling. One study found no significant difference between manual and ultrasonic scaling,⁴⁸ whereas a more recent experimental study indicated postural and force-use advantages of power-driven scaling tools.⁴⁹ The results of this study indicated a statistically significant association between ultrasonic scaling and desirable postural outcomes based on video observations of dental hygiene students in naturalistic clinical environments. Our findings aligned with the experimental study where the authors found that power-driven instruments required less neck and head inclination as well as less wrist flexion, extension, and deviation.⁴⁹ Combined with the higher time efficiency when using ultrasonic scalers than manual instruments,^{15,50} our study indicates the benefit of introducing ultrasonic scaling during dental hygiene education to prevent students from adopting awkward postures. The introduction of ultrasonic devices must be considered with regard to each patient's oral health condition and diagnosis, and long-term clinical use in cases where manual technique may suffice could lead to increased risk in other ways. For example, it is worth noting that most existing studies on the use of ultrasonic scalers in dental hygiene practice point out that the vibration of ultrasonic instruments may contribute to damage in soft tissues and nerve receptors in the hands, which could damage tactile sensitivity⁵¹ and increase the risk of developing WMSD symptoms.¹

A practical insight of this study for clinical training is to consider multiple environmental factors when educating students on ergonomic techniques and how reducing one may help mitigate the effects of others. When students perform instrumentation activities using manual scalers instead of ultrasonic scalers, faculty may instruct the students to sit behind the patient in clock positions 10 to 12 and try to avoid prolonged standing between clock positions 7 to 10, especially 7 and 8. Similarly, when students have to work in front of the patient at clock positions 7 to 10, ultrasonic scalers and sitting positions may be preferable to mitigate the risk of developing WMSDs.

This study's findings should be interpreted cautiously relative to specific populations and factors examined. Firstly, the 1487 video observation clips only included right-handed female dental hygiene students. As such, the results are not intended to be generalized to all dental practitioners, and the results may not represent all dental hygiene students; it is unclear if clock position findings would be mirrored for left-handed individuals. Additional personal and patient factors that may have an important influence on posture were not explored in this analysis (e.g., age, skill level, patient disease level). Similarly, this study did not consider every potential environmental factor within dental hygiene education or oral

health clinical settings (e.g., sharpness of manual instruments). Of particular note, the study could not explore the effect of magnification loupes on posture because all students wore loupes, and the videos did not allow for a valid determination as to whether the students were using their loupes appropriately (i.e., looking through versus over).

In addition to the population and selected factors, the interpretation of findings must be considered within the limits of the RULA assessment. Firstly, the binary coding for this analysis categorized a score of 3 and 4 as low risk, whereas only scores of 1-2 are acceptable according to the RULA instrument—this would have only accounted for five videos. The conservative grouping of scores 3-4 into the low-risk category with these videos does not allow for a nuanced understanding of absolute best practices. Second, although mitigation efforts were employed, observer effects could have changed the students' postures; in such a case, our finding that more than half of students' postures were high risk would also be conservative, raising even more concern about poor student postures. Finally, the RULA can only be interpreted as a proxy for the risk of developing upper-extremity MSDs. Future studies should further evaluate the development of WMSDs and related pain and symptoms.

CONCLUSIONS

Clock position, sit/stand position, and scaling method are predictors of risk for WMSDs for dental hygiene students during instrumentation tasks. Within these environmental factors, specific clock positions, standing, and hand scaling methods contribute the most to higher aggregate RULA scores, indicating a need for investigation and/or change in how these tasks are done. Conversely, clock positions behind the patient, sitting, and use of ultrasonic scaling tools have been indicated as safer choices. These findings have implications for dental hygiene education in terms of the importance of setting up the dental training clinical environment to reduce the risk of awkward postures associated with WMSD development, both among current dental hygiene students and future entry-level dental hygiene professionals.

Acknowledgments:

The authors wish to thank Joan Beleno, Nikki Colclazier, Jane Forrest, Wendy Mack, Joyce Sumi, Cassie Tseng, Samantha Randolph, Rachel Eckerling, Yoko Fukumura, Mark Hardison, Kryztopher Tung, Jody Liu, and Yoojin Chung the input and support of many contributors to the collection, processing, and analysis of the data.

Funding:

This research is supported by the Centers for Disease Control, National Institute for Occupational Safety and Health (CDC/NIOSH), grant R01 OH010665, and the Undergraduate Research Associate Program at the University of Southern California.

References

1. Johnson CR, Kanji Z. The impact of occupation-related musculoskeletal disorders on dental hygienists. *Can J Dent Hyg.* 2016;50(2):72–79.
2. Hayes MJ, Smith DR, Taylor JA. Musculoskeletal disorders in a 3 year longitudinal cohort of dental hygiene students. *J Dent Hyg.* 2014;88(1):36–41. [PubMed: 24563051]
3. Marklin RW, Cherney K. Working postures of dentists and dental hygienists. *J Calif Dent Assoc.* 2005;33(2):133–136. [PubMed: 15816703]

4. Gopinadh A, Devi KNN, Chiramana S, Manne P, Sampath A, Babu MS. Ergonomics and musculoskeletal disorder: As an occupational hazard in dentistry. *J Contemp Dent Pract*. 2013;14(2):299–303. [PubMed: 23811663]
5. Partido BB. Dental Hygiene Students' Self-Assessment of Ergonomics Utilizing Photography. *J Dent Educ*. 2017;81(10):1194–1202. [PubMed: 28966184]
6. Hayes MJ, Cockrell D, Smith DR. A systematic review of musculoskeletal disorders among dental professionals. *Int J Dent Hyg*. 2009;7(3):159–165. [PubMed: 19659711]
7. Danylak S, Walsh LJ, Zafar S. Measuring ergonomic interventions and prevention programs for reducing musculoskeletal injury risk in the dental workforce: A systematic review. *J Dent Educ*. 2024;88(2):128–141. [PubMed: 37990449]
8. Michalak-Turcotte C. Controlling dental hygiene work-related musculoskeletal disorders: the ergonomic process. *J Dent Hyg*. 2000;74(1):41–48. [PubMed: 11314116]
9. Khan SA, Yee Chew K. Effect of working characteristics and taught ergonomics on the prevalence of musculoskeletal disorders amongst dental students. *BMC Musculoskelet Disord*. 2013;14(1):118–118. [PubMed: 23547959]
10. Morse T, Bruneau H, Dussetschleger J. Musculoskeletal disorders of the neck and shoulder in the dental professions. *Work*. 2010;35(4):419–429. [PubMed: 20448321]
11. Ng A, Hayes MJ, Polster A. Musculoskeletal disorders and working posture among dental and oral health students. *Healthcare (Basel)*. 2016;4(1):13. [PubMed: 27417601]
12. Mills ME, Smilyanski I, Giblin-Scanlon L, Vineyard J. What are the effects of photographic self-assessment on students' risk for musculoskeletal disorders using Rapid Upper Limb Assessment. *J Dent Educ*. 2020;84(7):749–754. [PubMed: 32198757]
13. Hayes MJ, Smith DR, Cockrell D. Prevalence and correlates of musculoskeletal disorders among Australian dental hygiene students. *Int J Dent Hyg*. 2009;7(3):176–181. [PubMed: 19659713]
14. Roll SC, Tung KD, Chang H, et al. Prevention and rehabilitation of musculoskeletal disorders in oral health care professionals: A systematic review. *J Am Dent Assoc*. 2019;150(6):489–502. [PubMed: 31030935]
15. Fang Y, Tung KD, Beleno-Sanchez J, Forrest JL, Roll SC. Characterization of Tasks and Time Efficiency of Dental Hygiene Students During Clinical Training. *J Dent Hyg*. 2020;94(5):30–37. [PubMed: 33008947]
16. Netanel S, Luria S, Langer D. Musculoskeletal disorders among dental hygienist and students of dental hygiene. *Int J Dent Hyg*. 2020;18(2):210–216. [PubMed: 32012436]
17. Beach JC, DeBiase CB. Assessment of ergonomic education in dental hygiene curricula. *J Dent Educ*. 1998;62(6):421–425. [PubMed: 9698697]
18. Suedbeck JR, O'Connor T, Ludwig EA, Bradshaw B. The effects of static seated and standing positions on posture in dental hygiene students: a pilot study. *Can J Dent Hyg*. 2023;57(3):172–179. [PubMed: 37969425]
19. Morse TF, Michalak-Turcotte C, Atwood-Sanders M, et al. A pilot study of hand and arm musculoskeletal disorders in dental hygiene students. *J Dent Hyg*. 2003;77(3):173–179. [PubMed: 14596163]
20. Humann P, Rowe DJ. Relationship of Musculoskeletal Disorder Pain to Patterns of Clinical Care in California Dental Hygienists. *J Dent Hyg*. 2015;89(5):305–312. [PubMed: 26519494]
21. Partido BB, Henderson R, Lally M. Impact of a seated-standing protocol on postures and pain among undergraduate dental hygiene students: A pilot study. *J Dent Hyg*. 2021;95(4):70–78. [PubMed: 34376546]
22. Howarth SJ, Grondin DE, La Delfa NJ, Cox J, Potvin JR. Working position influences the biomechanical demands on the lower back during dental hygiene. *Ergonomics*. 2016;59(4):545–555. [PubMed: 26230089]
23. La Delfa NJ, Grondin DE, Cox J, Potvin JR, Howarth SJ. The biomechanical demands of manual scaling on the shoulders & neck of dental hygienists. *Ergonomics*. 2017;60(1):127–137. [PubMed: 27065201]
24. Roll SC, Hardison ME, Forrest JL, Colclazier NL, Sumi JY, Baker NA. A standardized protocol for the comprehensive assessment of dental hygiene work. *Work*. 2021;69(3):1041–1052. [PubMed: 34219697]

25. Kee D. Systematic Comparison of OWAS, RULA, and REBA Based on a Literature Review. *Int J Environ Res Public Health*. 2022;19(1): 595. [PubMed: 35010850]
26. Dockrell S, O'Grady E, Bennett K, et al. An investigation of the reliability of Rapid Upper Limb Assessment (RULA) as a method of assessment of children's computing posture. *Appl Ergon*. 2012;43(3):632–636. [PubMed: 22018838]
27. Breen R, Pyper S, Rusk Y, Dockrell S. An investigation of children's posture and discomfort during computer use. *Ergonomics*. 2007;50(10):1582–1592. [PubMed: 17917899]
28. Laeser KL, Maxwell LE, Hedge A. The Effect of Computer Workstation Design on Student Posture. *J Res Comput Educ*. 1998;31(2):173–188.
29. Oates S, Evans GW, Hedge A. An Anthropometric and Postural Risk Assessment of Children's School Computer Work Environments. *Computers in the Schools*. 1999;14(3-4):55–63.
30. McAtamney L, Nigel Corlett E. RULA: a survey method for the investigation of work-related upper limb disorders. *Appl Ergon*. 1993;24(2):91–99. [PubMed: 15676903]
31. Kee D. An empirical comparison of OWAS, RULA and REBA based on self-reported discomfort. *Int J Occup Saf Ergon*. 2020;26(2):285–295. [PubMed: 31941428]
32. Fountain LJK. Examining RULA's Postural Scoring System With Selected Physiological and Psychophysiological Measures. *Int J Occup Saf Ergon*. 2003;9(4):383–392. [PubMed: 14675513]
33. Yazdanirad S, Khoshakhlagh AH, Habibi E, Zare A, Zeinodini M, Dehghani F. Comparing the Effectiveness of Three Ergonomic Risk Assessment Methods-RULA, LUBA, and NERPA- to Predict the Upper Extremity Musculoskeletal Disorders. *Indian J Occup Environ Med*. 2018;22(1):17–21. [PubMed: 29743780]
34. Kee D. Comparison of OWAS, RULA and REBA for assessing potential work-related musculoskeletal disorders. *Int J Ind Ergon*. 2021;83:103140.
35. Tung KD, Fukumura YE, Baker NA, Forrest JL, Roll SC. Identifying an Optimal Sampling Method to Estimate Postural Risk in a Dynamic Work Task. *Proc Hum Factors Ergon Soc Annu Meet*. 2019;63(1):1028–1033. [PubMed: 31911753]
36. Hosmer DW Jr., Lemeshow S, Sturdivant RX. Assessing the Fit of the Model. In: United States: John Wiley & Sons, Incorporated; 2013:153–225.
37. Heinze G, Dunkler D. Five myths about variable selection. *Transpl Int*. 2017;30(1):6–10. [PubMed: 27896874]
38. Wickham H, Averick M, Bryan J, et al. Welcome to the Tidyverse. *J Open Source Softw*. 2019;4(43):1686.
39. Wickham H, Francois R, Henry L, Muller K, Vaughan D. A Grammar of Data Manipulation.R package version 1.1.4. <https://github.com/tidyverse/dplyr> , <https://dplyr.tidyverse.org>. Published 2023. Accessed: November 18, 2024.
40. Fox J, Weisberg S. An R Companion to Applied Regression, 3rd Edition. In. Vol 2019. Beaverton: Ringgold, Inc; 2019.
41. Ludwig EA, Tolle SL, Jenkins E, Russell D. Magnification loupes influence on neck and trunk flexion of dental hygienists while scaling-A pilot study. *Int J Dent Hyg*. 2021;19(1):106–113. [PubMed: 33000517]
42. Mailliet JP, Millar AM, Burke JM, Mailliet MA, Mailliet WA, Neish NR. Effect of magnification loupes on dental hygiene student posture. *J Dent Educ*. 2008;72(1):33–44. [PubMed: 18172233]
43. Chaiklieng S, Suggaravetsiri P. Ergonomics Risk and Neck Shoulder Back Pain among Dental Professionals. *Procedia Manufact*. 2015;3:4900–4905.
44. Liss GM, Jesin E, Kusiak RA, White P. Musculoskeletal problems among ontario dental hygienists. *Am J Ind Med*. 1995;28(4):521–540. [PubMed: 8533793]
45. Barry RM, Spolarich AE, Weber M, Krause D, Woodall WD, Bailey JH. Impact of Operator Positioning on Musculoskeletal Disorders and Work Habits Among Mississippi Dental Hygienists. *J Dent Hyg*. 2017;91(6):6–14.
46. Anton D, Rosecrance J, Merlino L, Cook T. Prevalence of musculoskeletal symptoms and carpal tunnel syndrome among dental hygienists. *Am J Ind Med*. 2002;42(3):248–257. [PubMed: 12210693]

47. Åkesson I, Balogh I, Hansson G-Å. Physical workload in neck, shoulders and wrists/hands in dental hygienists during a work-day. *Appl Ergon.* 2012;43(4):803–811. [PubMed: 22208356]
48. Noh H, Roh H. Approach of industrial physical therapy to assessment of the musculoskeletal system and ergonomic risk factors of the dental hygienist. *J Phys Ther Sci.* 2013;25(7):821–826. [PubMed: 24259862]
49. Graetz C, Plaumann A, Rauschenbach S, Bielfeldt J, Dörfer CE, Schwendicke F. Removal of simulated biofilm: a preclinical ergonomic comparison of instruments and operators. *Clin Oral Investig.* 2016;20(6):1193–1201.
50. Muniz F, Langa G, Pimentel R, Martins J, Haubman D, Rösing C. Comparison Between Hand and Sonic/ Ultrasonic Instruments for Periodontal Treatment: Systematic Review with Meta-Analysis. *J Int Acad Periodontol.* 2020;22:187–204. [PubMed: 32980832]
51. Ryan DL, Darby M, Bauman D, Tolle SL, Naik D. Effects of Ultrasonic Scaling and Hand-Activated Scaling on Tactile Sensitivity in Dental Hygiene Students. *J Dent Hyg.* 2005;79(1):9.

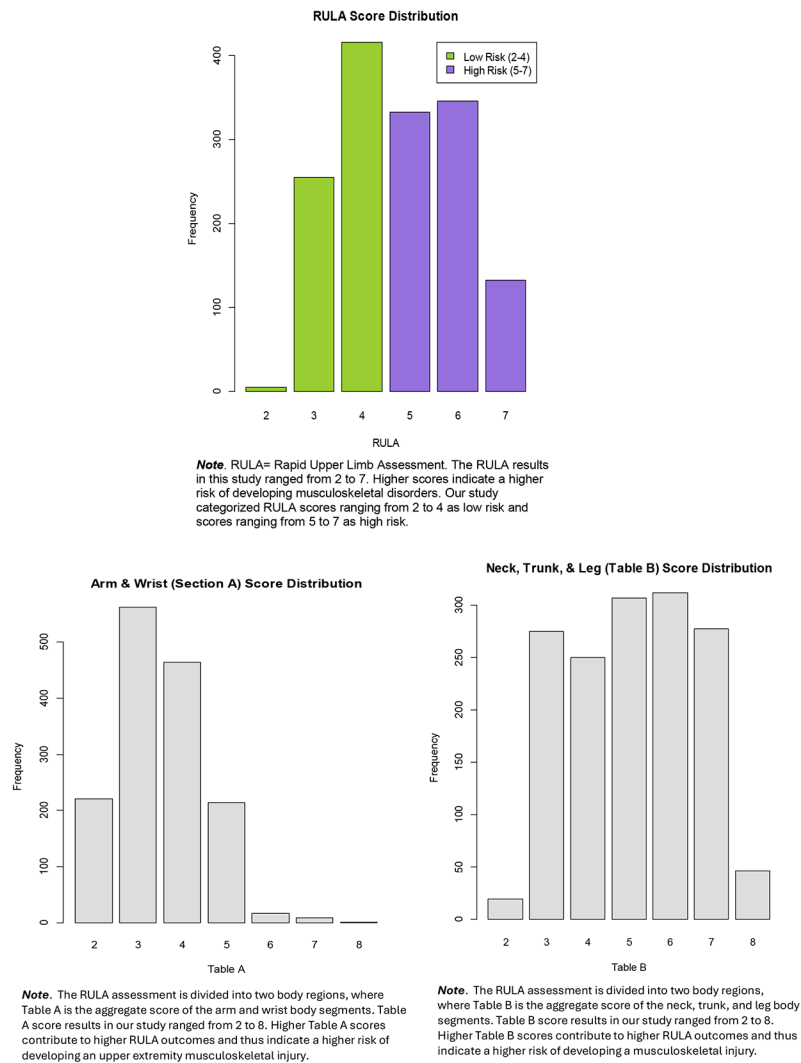


Figure 1.
Distribution of aggregate RULA, Table A, and Table B scores.



Figure 2.
Examples of High-risk and Low-risk Postures

Table 1.
Distribution of environmental characteristics by risk group (n=1487)

	High risk ^a Frequency (%)	Low risk ^b Frequency (%)	p-value *
Clock position			< 0.001
1-2	61 (7.5%)	29 (4.3%)	
3-4	22 (2.7%)	16 (2.4%)	
7-8	102 (12.6%)	25 (3.7%)	
9	330 (40.7%)	189 (28.0%)	
10-11	227 (28.0%)	263 (38.9%)	
12	69 (8.5%)	154 (22.8%)	
Sit or Stand Position			< 0.001
Sit	615 (75.8%)	579 (85.7%)	
Stand	196 (24.2%)	97 (14.4%)	
Patient chair position			0.069
Semi-supine	155 (19.1%)	104 (15.4%)	
Supine	656 (80.9%)	572 (84.6%)	
Scaling method			< 0.001
Hand	669 (82.5%)	473 (70.0%)	
Ultrasonic	142 (17.5%)	203 (30.0%)	
Patient head position			0.160
Left	64 (7.9%)	45 (6.7%)	
Right	182 (22.4%)	179 (26.5%)	
Neutral	565 (69.7%)	452 (66.9%)	
Patient mouth quadrant			0.391
Lower left	242 (29.8%)	182 (26.9%)	
Lower right	291 (35.9%)	236 (34.9%)	
Upper left	117 (14.4%)	103 (15.2%)	
Upper right	161 (19.9%)	155 (22.9%)	

* p values were calculated using Chi-2 analysis.

^aHigh risk (RULA scores 1-4), n=811, 54.5%

^bLow risk (RULA scores 5-7), n=676, 45.5%

Table 2.
Unadjusted Odds Ratios of Univariate Logistic Regression Models for Predicting High-Risk RULA Outcomes (scores 5-7)

Variable	OR [95%CI]	p-value
Clock position (comparison group 12 o'clock)		
1-2	4.70 [2.80, 8.03]	< 0.001
3-4	3.07 [1.53, 6.29]	0.002
7-8	9.11 [5.48, 15.60]	< 0.001
9	3.90 [2.80, 5.48]	< 0.001
10-11	1.93 [1.38, 2.70]	< 0.001
Position (comparison group sit)		
Stand	1.90 [1.46, 2.50]	< 0.001
Patient chair position (comparison group supine)		
Semi-supine	1.30 [0.99, 1.71]	0.060
Scaling method (comparison group hand)		
Ultrasonic	0.70 [0.56, 0.87]	< 0.001
Patient head position (comparison group right)		
Left	1.40 [0.91, 2.17]	0.129
Neutral	1.23 [0.97, 1.56]	0.092
Patient mouth quadrant (comparison group upper right)		
Lower Left	1.28 [0.96, 1.72]	0.098
Lower right	1.19 [0.90, 1.57]	0.229
Upper left	1.09 [0.78, 1.55]	0.611

Note. CI= confidence Interval; OR = odds ratio

Table 3.

Final multivariate logistic model for predicting high-risk RULA outcomes (scores 5-7)

Variables	Coefficient	SE	OR [95%CI]	Wald χ^2	p-value
Intercept	-1.23	0.18	0.29 [0.21-0.42]	-6.85	< 0.001
Clock Positions					
1-2	1.25	0.28	3.50 [2.02, 6.15]	4.42	< 0.001
3-4	0.68	0.39	1.98 [0.93, 4.28]	1.76	0.079
7-8	2.13	0.27	8.40 [5.02, 14.50]	7.89	< 0.001
9	1.28	0.17	3.61 [2.58, 5.08]	7.42	< 0.001
10-11	0.73	0.17	2.07 [1.48, 2.92]	4.21	< 0.001
Scaling Method					
Hand scaling	0.51	0.14	1.67 [1.28, 2.18]	3.81	< 0.001
Sit/Stand Position					
Standing	0.35	0.16	1.42 [1.03, 1.96]	2.12	0.034

Notes. Nagelkerke $R^2 = 0.125$; Intercept = a mathematical constant (no clinical interpretation); SE = standard error; CI = confidence Interval; OR = odds ratio; Wald $\chi^2 = z$ values for the Wald tests.