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Balancing the strain: The dual burden of musculoskeletal discomforts and mental workload in dentists

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A R T I C L E I N F O

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RULA
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A B S T R A C T

Background: Dentists often adopt static and awkward postures, resulting in a high prevalence of musculoskeletal discomforts and discomfort. Additionally, some experience significant mental workload. This study investigates the relationship between improper body postures, musculoskeletal discomforts (MSDs), and mental workload among general dentists.

Methods: This cross-sectional study involved 77 general dentists in Isfahan, Iran in 2024. The Rapid Upper Limb Assessment (RULA) tool and the Cornell Musculoskeletal Discomfort Questionnaire (CMDQ) evaluated ergonomic postures and MSDs, while the NASA Task Load Index (NASA-TLX) assessed mental workload. Data analysis was conducted using Pearson correlation in SPSS version 26.

Results: Among the participants, 57.1 % were classified as having a high ergonomic risk level. Inferential analyses using Pearson correlations identified key relationships. A significant positive correlation was found between RULA scores and neck MSDs ($r = 0.246$, $p = 0.031$). Overall mental workload correlated significantly with MSDs in the right forearm ($r = 0.293$, $p = 0.010$) and neck ($r = 0.221$, $p = 0.050$). Among workload dimensions, temporal demand exhibited the strongest correlation with neck MSDs ($r = 0.502$, $p < 0.001$) and also correlated with RULA scores ($r = 0.260$, $p = 0.024$). Other notable positive correlations included neck MSDs with mental demand ($r = 0.221$, $p = 0.053$, showing a descriptive trend) and effort ($r = 0.254$, $p = 0.026$), although overall workload was not associated with RULA scores. These findings support hypotheses linking ergonomic risk to MSD prevalence and mental workload to increased ergonomic strain and discomfort, consistent with broader literature on occupational health in dentistry.

Conclusion: This study explored the relationship between awkward postures, musculoskeletal discomfort, and mental workload among dentists. Despite the absence of severe musculoskeletal symptoms, the high ergonomic risk indicates potential future problems. Dentists reported considerable temporal demand, which was significantly correlated with ergonomic risk, underscoring the impact of time pressure on their practice.

1. Background

Proper body posture refers to a state in which the body is aligned in its natural and neutral position, exerting minimal stress on nerves, muscles, bones, tendons, joints, and other anatomical structures. Conversely, improper posture is characterized by deviations from this neutral alignment, which leads to increased pressure on these structures. These deviations result in alterations in body biomechanics, reduced muscle performance, and a subsequent decline in overall productivity (Barthelme et al., 2021; Palikhe et al., 2020). When muscles contract in suboptimal positions, such as inappropriate lengths due to poor postural alignment, their functional strength is significantly diminished.

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Additionally, performing tasks at improper angles exacerbates this reduction, with lumbar muscles experiencing a strength decrease of approximately 40 % to 56 %, depending on the specific activity and the plane of movement involved. This inability to fully utilize their natural potential results in increased fatigue and excessive mechanical strain on these structures. Over time, such conditions may predispose individuals to the development of musculoskeletal discomforts (Holzgreve et al., 2022).

Musculoskeletal discomforts are conditions that affect the muscles, tendons, peripheral nerves, or vascular system and are not the result of acute or instantaneous injuries. Globally, approximately 1.7 billion individuals are affected by musculoskeletal diseases and discomforts. These conditions account for the largest proportion—17 %—of total years lived with disability (YLD) (Cieza et al., 2021; Hartvigsen et al., 2018; Williams et al., 2018). The analysis of musculoskeletal discomforts can be conducted through medical diagnosis, imaging techniques, or self-reported measures, including prevalence, frequency, and pain severity. Findings from these analyses indicate that the primary causes of musculoskeletal discomforts arise from a combination of individual factors, such as age, gender, and family history; psychosocial factors, such as workload; and biomechanical factors, such as improper posture. These issues often result from the failure to apply ergonomic principles in the design of tools and work environments (Barthelme et al., 2021; Darvishi et al., 2022; et al., 2021). Workload generally encompasses two dimensions: physical and mental. The physical dimension pertains to physical activities, while the mental dimension involves the cognitive efforts required to complete a task (Krishnan et al., 2021). Mental workload is a multifaceted and complex concept, making it challenging to provide a precise definition. In the fields of ergonomics and human factors, mental workload is defined as the amount of mental effort required by an individual to perform a task. It can also be understood as the disparity between the demands of a task and the available cognitive resources necessary for its execution. In this context, when task demands surpass the available cognitive resources, the individual experiences an increased mental workload (Nino et al., 2023; Stramler, 1992). This concept is not limited to the perception of the physical demands of tasks; it also includes a variety of psychosocial factors (Adams & Nino, 2024). Therefore, it can be concluded that mental workload is affected by various factors, including work-related demands, the work environment, organizational psychosocial factors, and cognitive abilities (Rostami et al., 2021).

Healthcare professionals often have to bend and twist in awkward positions. As a result, many of them develop low back pain (LBP) due to the postures they adopt (Çınar-Medeni et al., 2017; Ji et al., 2023). A review study examining the working postures of healthcare professionals identified a high level of ergonomic risk among dental practitioners and a low level of ergonomic risk among individuals in the pharmaceutical sector, using the RULA tool. The findings highlight the potential need for changes in working postures (Kakaraparthi et al., 2022).

Musculoskeletal Discomforts (MSDs) are widespread among healthcare professionals, including physiotherapists, nurses, surgeons, and dentists. A review of the literature found that the lower back, neck, and shoulders are the most commonly affected areas in these professions. More than 60 % of surgeons and dentists report experiencing lower back discomforts, while nurses exhibit even higher rates of lower back issues (over 25 %) and upper limb discomforts (Gorce & Jacquier-Bret, 2023; Jacquier-Bret & Gorce, 2023).

Researchers have found that high workloads and stress can lead to MSDs among healthcare professionals. In fact, a cross-sectional study revealed that healthcare professionals in China often had MSDs due to their workload, psychological factors, and ergonomic concerns (Dong et al., 2019). Furthermore, a review of the literature found that healthcare workers, particularly nurses, are more likely to develop MSDs because of the demanding physical aspects of their jobs, as well as related stress and burnout (Jacquier-Bret & Gorce, 2023; Ribeiro et al., 2024).

One of the most significant components of healthcare services is dental practice. According to the World Health Organization, oral and dental diseases affect billions of individuals worldwide, with dental caries being the most prevalent health condition reported in the Global Burden of Disease study. The widespread impact of these diseases on populations underscores the critical importance of the dental profession (WHO, 2024). Dentists must handle small instruments with precision and skill, applying the appropriate static force to perform delicate procedures within the confined space of a patient's mouth. The continuous use of these instruments and the repetitive movements throughout the day place significant strain on the muscles and joints, particularly in the upper body. Furthermore, because the work is typically performed at eye level or below, the neck region is also subjected to stress, which can lead to reduced blood flow to the muscles, necrosis, and degenerative changes in the vertebral column (Saremi et al., 2022; Valachi & Valachi, 2003). Dentists must position themselves by rotating or bending their bodies to access the patient's teeth while maintaining muscle contraction. Additionally, the one-sided and asymmetric pressure experienced when sitting next to the patient can lead to strain on the joints (Simon et al., 2024). Statistics indicate that 75 % of non-fatal occupational injuries occur in the service industries, with the healthcare sector ranking second, following the trade and transportation industries. Additionally, 31 % of occupational injuries affect the musculoskeletal system (Alnaser et al., 2021). Compared to the general population, musculoskeletal discomforts, such as distal interphalangeal (DIP) joint osteoarthritis, are more frequently observed among dentists and typically occur in individuals under the age of 50 (Greggi et al., 2024). Furthermore, the prevalence of musculoskeletal discomforts in this group ranges from 64 % to 93 %, with the highest incidence observed in the upper body, and the most commonly reported pain occurring in the lower back and neck regions (Dulhani & Mukherjee, 2022; Rickert et al., 2021). Almeida et al. conducted a review study demonstrating that poor posture during dental procedures may lead to the development of MSDs as early as the initial years of dental education (Almeida et al., 2023). A study conducted by Rickert et al. in surveyed 600 dental professionals and found a high prevalence of musculoskeletal discomforts at 92.6 %. Participants reported experiencing pain and discomfort in at least one region of their bodies. Rickert also observed that improper working postures, particularly during tasks like manual scaling and ultrasonic scaling, increased the risk of musculoskeletal discomforts for dentists. Additionally, the study revealed a correlation between both physical and mental workloads and heightened musculoskeletal pain (Rickert et al., 2021). The association between musculoskeletal discomforts and static body postures was also reported by Pope-Ford et al., with all participants, except for one, experiencing both mental and physical fatigue, which is a significant factor influencing mental workload (Pope-Ford & Pope-Ozimba, 2020a). Dentistry is regarded as a high-stress profession due to its inherent demands for precision and constant patient interaction. Moreover, the substantial changes that have occurred in this field over the past few decades have increased the complexity of the profession. Consequently, dentists are among those most likely to experience a high mental workload due to the demands of their profession (Molina-Hernández et al., 2021). The findings of the study conducted by Marklund et al. on 371 dental students corroborated this, revealing that nearly 50 % of dentists encounter high workloads in their work environments and lack adequate control over their tasks (Marklund et al., 2021). Pop-Ford et al. found that performing dental procedures requires a high level of mental effort, which compounds the physical demands of the profession. Consequently, dentists often experience fatigue in both body and mind, which can exacerbate their dissatisfaction with their work (Pope-Ford & Pope-Ozimba, 2020b).

Given the nature of the dental profession, which requires specific body postures, general dentists are at an increased risk of experiencing musculoskeletal discomfort. Additionally, the demand for precision in performing professional tasks contributes to a significant mental workload due to the psychological stress involved. Despite the importance of these issues, few studies have explored the relationship between poor body postures, the incidence of musculoskeletal discomforts, and mental workload among general dentists. Therefore, conducting this study to examine and assess these relationships can help identify the factors influencing musculoskeletal discomfort and mental workload among general dentists. Accordingly, this study aimed to address the following research hypotheses:

H1. There is a significant correlation between ergonomic risk, as measured by RULA scores, and the prevalence of musculoskeletal discomfort among dentists.

H2. Higher mental workload scores are significantly associated with increased ergonomic risk and greater musculoskeletal discomfort.

2. Materials and methods

2.1. Study design

This cross-sectional descriptive-analytical study was conducted among general dentists in Isfahan, Iran in 2024. A total of 77 dentists were selected through random sampling. The eligibility criteria for participation included a minimum of one year of clinical experience, a willingness to participate in the study, the absence of evident musculoskeletal discomforts such as Guillain-Barré syndrome, and no history of diseases or medications that could affect cognitive performance, such as depression or the use of sedatives. Data were collected through direct observation of participants' work processes by researchers and through the completion of self-reported questionnaires by the dentists. The study was conducted in four main phases: 1. Compilation of demographic and occupational information regarding the participants; 2. Assessment of dentists' working postures using the Rapid Upper Limb Assessment (RULA) technique; 3. Evaluation of musculoskeletal discomfort using the Cornell Musculoskeletal Discomfort Questionnaire; and 4. Assessment of dentists' mental workload using the NASA Task Load Index (NASA-TLX) Questionnaire (Fig. 1).

2.2. Demographic information of the participants

This questionnaire aims to outline the demographic characteristics of the participants. It gathers general information regarding personal attributes such as age, gender, height, weight, body mass index (BMI), and marital status. Additionally, it collects occupational details, including work experience, daily working hours, and the number of working days per week.

2.3. Ergonomic assessment

The Rapid Upper Limb Assessment (RULA) method was employed for this purpose. Specifically, the evaluation was conducted through direct observation using the standard RULA worksheet (pen-and-paper method) to assess the ergonomic risk load during dental tasks. This

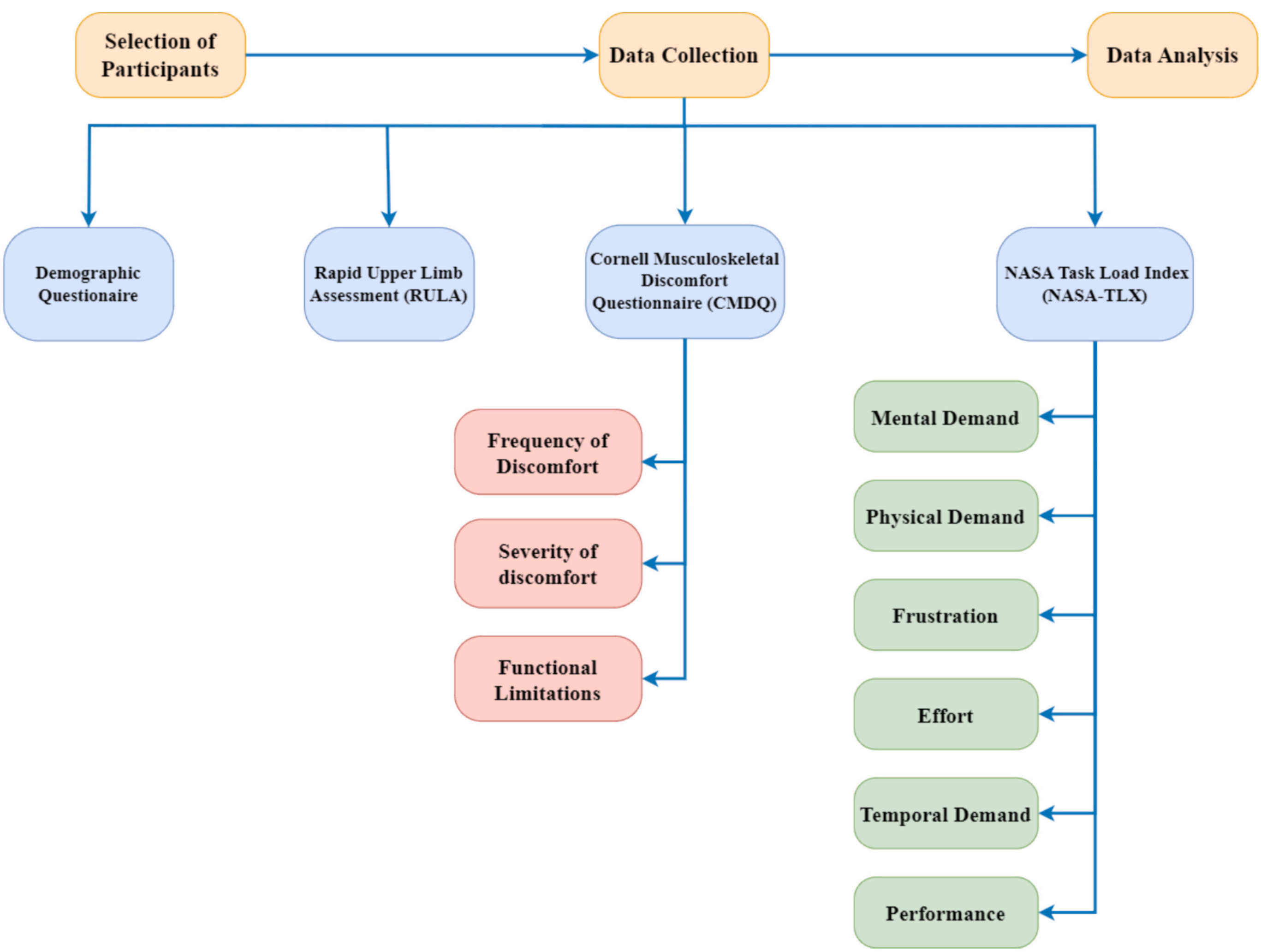

Fig. 1. Conceptual Model of Study Implementation Steps.

approach was developed to evaluate workers' exposure to risk factors associated with work-related upper limb discomforts. The RULA method utilizes posture diagrams and three scoring tables to assess the degree of exposure to these risk factors, which include body postures, exerted forces, repetitive movements, and the duration of time spent in specific postures. In this assessment, the body is divided into two regions: Region A and Region B. Region A comprises the arm, forearm, and wrist, while Region B encompasses the neck, trunk, and legs. Each body part is evaluated individually using corresponding diagrams. The scores for Region A and Region B are subsequently calculated using specific tables designed for each region. Next, the scores for force and repetitive motion are added to the scores for Regions A and B, resulting in scores C and D, respectively. Finally, these two scores are combined using a predefined table to determine the overall RULA score. The final stage of this assessment method provides a classification for evaluating and prioritizing the need for changes in work postures. Scores of 1 or 2 indicate an acceptable posture for short-term tasks, while scores of 3 or 4 suggest the need for further evaluation. Scores of 5 or 6 indicate the necessity for early intervention, and scores of 7 or higher necessitate immediate corrective actions. RULA scores were calculated manually using the standardized worksheet developed by McAtamney and Corlett (McAtamney & Nigel, 1993). Observational data were collected during dental procedures, and the most awkward posture adopted by each dentist during their work was selected for scoring (Fig. 2).

2.4. Cornell musculoskeletal discomfort questionnaire (CMDQ)

To assess musculoskeletal discomfort, the CMDQ questionnaire, developed by Hedge et al. (1991), was utilized (Hedge et al., 1999). The reliability and validity of this questionnaire within the Iranian population were evaluated by Afifzadeh et al. (Afifehzadeh-Kashani et al., 2011), who reported a Cronbach's alpha of 0.986. This questionnaire allows individuals to self-report musculoskeletal discomfort across 20 body areas and consists of three sections. The first section asks participants to indicate the frequency of pain experienced in the past week for each body part, using the following scale: Never = 0, 1–2 times last week = 1.5, 3–4 times last week = 3.5, Once every day = 5, Several times every day = 10). If the individual has not experienced any pain in the past week, they are not required to answer the subsequent two sections. The second section rates the intensity of pain in each body part

Fig. 2. Representative diagrams of general dentists during clinical procedures: ***A.*** *anterior* View – Neck Flexion and Shoulder Elevation; **B.** Lateral View – Trunk Rotation and Arm Abduction; **C.** Oblique View – Elevated Arm and Wrist Extension; **D.** Lateral View – Forward Leaning and Trunk Flexion; **E.** Lateral View – Cross-Leg Sitting and Twisted Trunk; **F.** Oblique View – Neck Rotation and Forward Trunk Inclination.

as Mild = 1, Moderate = 2, and Severe = 3. The final section assesses the impact on the individual's work ability, rated as Not at all = 1, Slightly = 2, and Significantly = 3. The final score for each body part, derived from multiplying scores across three sections, ranges from 0 to 90 and is classified into six categories: "0-15 = Very Low," "16-30 = Low," "31-45 = Moderate," "46-60 = High," "61-75 = Very High," and "76-90 = Severe." Higher scores indicate greater frequency, intensity, and discomfort (Tuna et al., 2022).

2.5. NASA task load index (NASA-TLX)

The NASA-TLX technique assessed dentists' mental workload using a validated questionnaire with six dimensions: mental demand, physical demand, frustration, effort, time demand, and performance. Mohammadi et al. evaluated its validity and reliability in Iran, reporting a Cronbach's alpha of 0.847, indicating adequate reliability(Mohammadi et al., 2013). The NASA-TLX questionnaire consists of two main sections. In the first section, participants rate their perceived workload on six dimensions (Mental Demand, Physical Demand, Temporal Demand, Performance, Effort, and Frustration) using a Visual Analogue Scale ranging from 0 to 100. Participants mark their response along a horizontal line, and definitions for each scale point are provided to improve scoring consistency and understanding. In the second section, participants perform 15 pairwise comparisons between the six dimensions, selecting the dimension they perceive as more influential on their workload in each pair. For each dimension, the number of times it is selected is divided by 15 to calculate a weight ranging from 0 to 1. This weight is then multiplied by the corresponding score from the first section to obtain the weighted score for that dimension. Finally, the total NASA-TLX score for each participant is calculated by summing the weighted scores of all six dimensions. Fig. 3 illustrates this procedure step by step (Hart, 1986).

2.6. Data analysis

Statistical analyses were performed using SPSS software, version 26. The Kolmogorov–Smirnov test was applied to assess the normality of data distributions. Since the data were normally distributed, the Pearson correlation coefficient was used to examine relationships between continuous variables. To investigate the associations between musculoskeletal discomfort across various body regions and each dimension of mental workload, a total of 108 correlation tests were performed. Due to the large number of statistical comparisons and the heightened risk of Type I errors, the Benjamini–Hochberg false discovery rate (FDR) correction was applied to adjust the *p*-values within each category. This method effectively balances the control of false positives while preserving statistical power.

2.7. Ethical code

The study was approved by the Ethics Committee of […] University of Medical Sciences (IR.MUI.RESEARCH.REC.1402.200). Dentists received a comprehensive explanation of the research objectives and methods, ensuring voluntary and informed participation. All ethical principles for research publication were strictly followed, including avoiding data fabrication, misrepresentation, or suppression of results; proper citation; prevention of plagiarism; prohibition of duplicate publication; adherence to authorship criteria; and avoidance of invalid journals or unethical methods.

3. Results

3.1. Demographic information and job details

Among the dentists in this study, 49.4 % were female and 50.6 % were male, with a mean age of 29.72 years (SD = ±8.20, range = 23–57). The mean work experience was 5.50 years (SD = ±6.80, range = 2–29), daily working hours averaged 5.13 (SD = ±1.82, range = 3–10), and weekly working days averaged 4.81 (SD = ±4.98, range = 2–7). Participants worked a minimum of 3 h daily. Table 1 details the demographic and occupational characteristics.

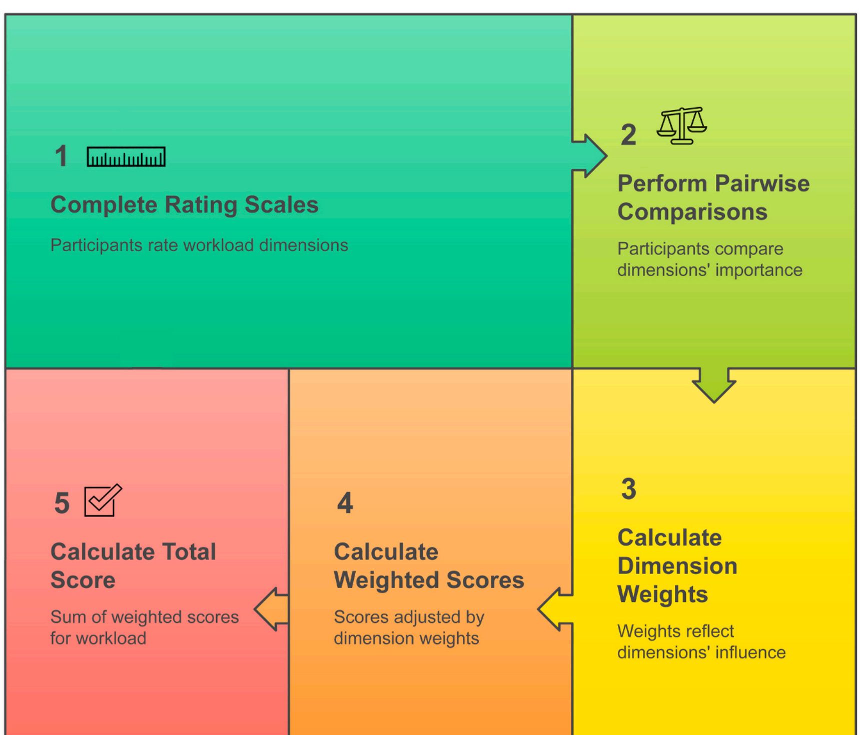

Fig. 3. Workflow of the NASA-TLX Questionnaire: From Rating Scales to Weighted Workload Score Calculation.

Table 1
demographic information of participants.

Variable	Mean ± SD	Range
Age(year)	29.72 ± 8.20	23–57
Height (m)	172.49 ± 9.71	150–197
Weight(kg)	69.72 ± 13.07	47–105
BMI	23.40 ± 3.79	17.99–40
Work experience	5.50 ± 6.80	2–29
Working hours per day	5.13 ± 1.82	3–10
Working days per week	4.81 ± 0.98	2–7
Gender (n (%))	Female 38(%49.4)	Male 39(%50.6)
Marital status (n (%))	Single 52(%70.3)	Married 22(%29.7)

3.2. Self-reported musculoskeletal symptoms

The analysis of self-reported MSD showed the highest mean scores in the neck (9.24 ± 17.98), lower back (6.67 ± 18.87), right wrist (6.55 ± 16.82), and right shoulder (5.27 ± 14.20), as shown in Fig. 4. MSD scores were primarily classified as "very low" or "low".

3.3. Postural assessment results with the RULA method

Based on the scoring procedure, intermediate values were obtained for RULA Regions A and B. These intermediate scores were then utilized to derive the final RULA score and the corresponding ergonomic risk level. The mean RULA score was 5.89 (SD = ±1.03), ranging from 3 to 7 (Table 2). The ergonomic risk analysis showed that 44 participants (57.1 %) were classified as high-risk (Fig. 5).

3.4. Mental workload assessment results using NASA-TLX

The mental workload assessment scores range from 0 to 100, with a mean of 61.68 ± 23.47. Among the dimensions, temporal demand had the highest mean score (14.14 ± 10.26), while performance had the lowest (8.38 ± 8.78), as illustrated in Fig. 6.

Table 2
Summary Statistics for Ergonomic Assessment Scores.

	Minimum	Maximum	Median	Mean ± SD	Variance
Region A Score	3	6	5	4.92 ± 0.97	0.94
Region B Score	3	6	5	5 ± 0.84	0.71
RULA Score	3	7	6	5.89 ± 1.03	1.07

3.5. Relationship between MSD, RULA scores, and mental workload

The results of the Pearson correlation test reveal a significant positive correlation only between RULA scores and neck discomfort (Table 3). Additionally, MSDs show significant positive correlations with workload in the neck and right forearm. Fig. 7 presents the Pearson correlation results between MSD and each dimension of workload. All significant correlations are positive. Notably, the strongest correlation is observed between neck discomfort and " Temporal Demand". However, after applying the Benjamini–Hochberg correction, none of the *p*-values remained statistically significant.

3.6. Relationship between mental workload and RULA scores

Although the overall mental workload was not significantly correlated with awkward postures, temporal demand was the only dimension that showed a significant positive association with non-neutral postures (Table 4).

4. Discussion

This study explores the relationship between improper posture, MSD, and mental workload among general dentists in Isfahan, Iran. The RULA method assesses postural conditions and ergonomic risks, while the

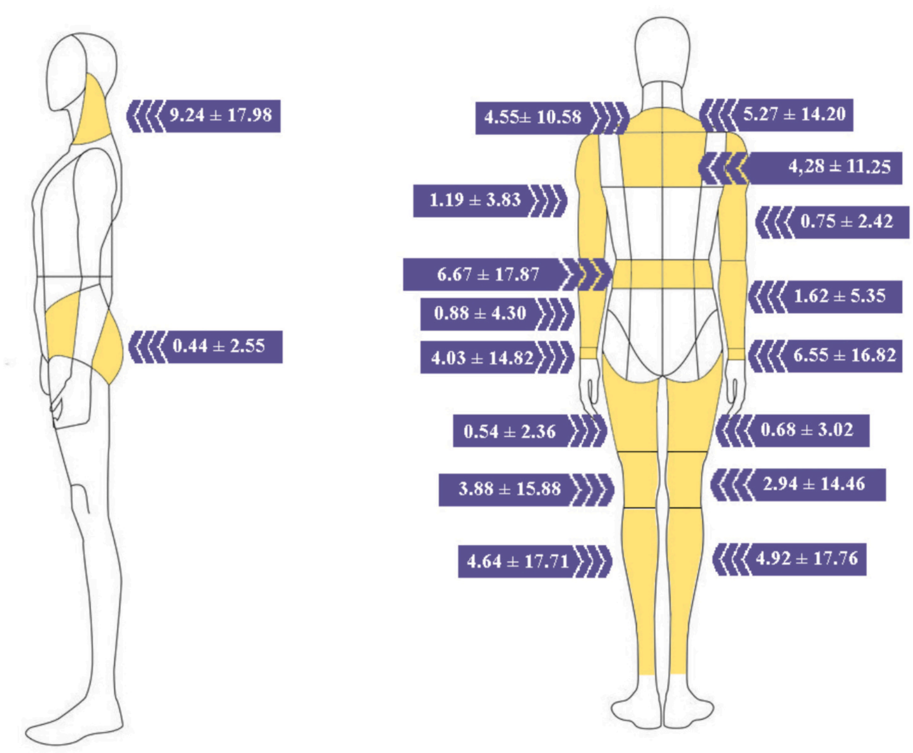

Fig. 4. Mean Scores of MSD for Body Regions.

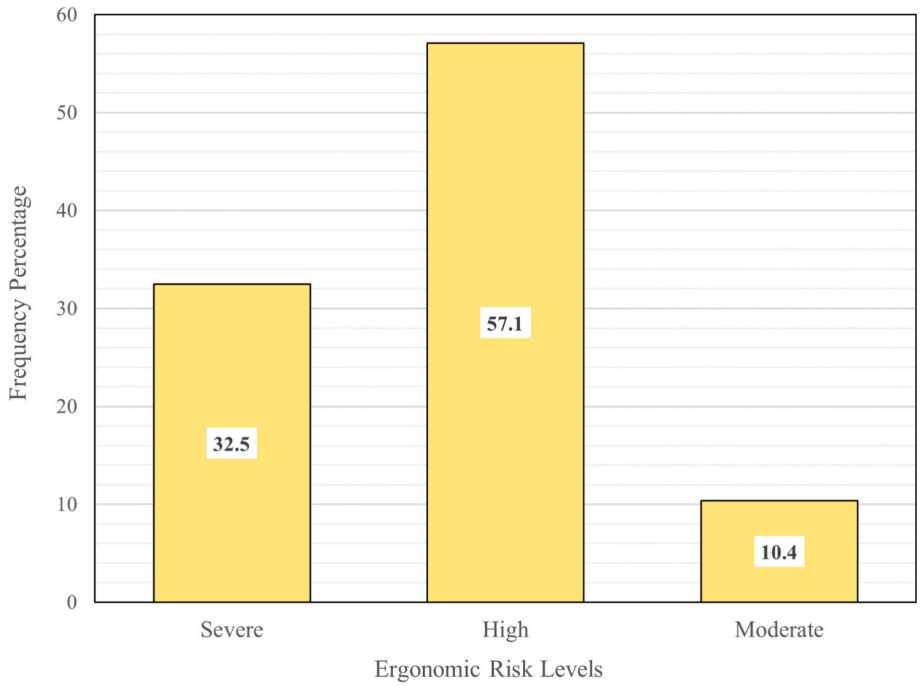

Fig. 5. Frequency Distribution of Ergonomic Risk Levels.

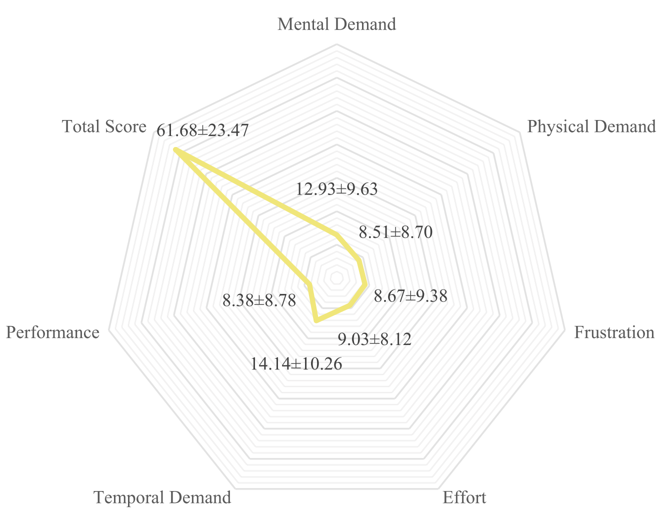

Fig. 6. A Radar Chart Visualization of NASA-TLX Workload Dimensions.

CMDQ and NASA-TLX questionnaires evaluate MSD and mental workload, respectively. Results show that over 89 % of participants were classified as high or very high ergonomic risk, with an average RULA score of 5.89 ± 1.03. These results indicate a concerning issue with dentists' improper postural conditions, highlighting the need for immediate interventions. The results indicated that MSD levels were low or very low across most body regions. Although the highest mean discomfort scores were observed in the neck, followed by the lower back, their severity remained within the low range. Regarding workload, temporal demand exhibited the highest mean score among the assessed dimensions. MSDs in certain body regions showed a significant positive association with mental workload. To account for the large number of statistical comparisons, the Benjamini–Hochberg correction was applied across all correlations between workload dimensions and MSDs in different body regions. After this adjustment, some associations that were initially significant did not remain statistically significant. For example, the correlation between upper back discomfort and frustration

Table 3
Pearson Correlation Coefficients Between MSDs, RULA Scores, and Mental Workload Dimensions.

Body Region			RULA Scores	p_adj RULA	NASA-TLX Scores	p_adj NASA-TLX
Neck		*r*	0.246		0.221	
		P	0.031*	0.558	0.050*	0.220
Shoulder	Right	*r*	0.063		0.149	
		P	0.587	0.767	0.196	0.350
	Left	*r*	0.081		0.168	
		P	0.483	0.767	0.143	0.286
Upper Back		*r*	0.113		0.089	
		P	0.328	0.767	0.442	0.582
Upper Arm	Right	*r*	0.047		0.189	
		P	0.682	0.767	0.099	0.255
	Left	*r*	0.053		0.080	
		P	0.645	0.767	0.489	0.582
Lower Back		*r*	0.109		0.049	
		P	0.347	0.767	0.489	0.582
Forearm	Right	*r*	0.126		0.293	
		P	0.274	0.767	0.010*	0.180
	Left	*r*	0.061		0.168	
		P	0.599	0.767	0.143	0.286
Wrist	Right	*r*	0.063		−0.129	
		P	0.588	0.767	0.263	0.394
	Left	*r*	0.073		−0.143	
		P	0.527	0.767	0.214	0.350
Hip/Buttocks		*r*	0.032		0.022	
		P	0.782	0.828	0.846	0.846
Thigh	Right	*r*	0.162		0.050	
		P	0.159	0.767	0.668	0.707
	Left	*r*	0.185		0.075	
		P	0.107	0.767	0.517	0.582
Knee	Right	*r*	−0.061		0.220	
		P	0.600	0.767	0.055	0.220
	Left	*r*	0.010		0.240	
		P	0.929	0.929	0.054	0.220
Lower Leg	Right	*r*	0.064		0.263	
		P	0.582	0.767	0.061	0.220
	Left	*r*	0.063		0.269	
		P	0.586	0.767	0.085	0.255

P-value (adj) refers to the p-values adjusted using the Benjamini–Hochberg method. Statistical significance was set at 0.05.

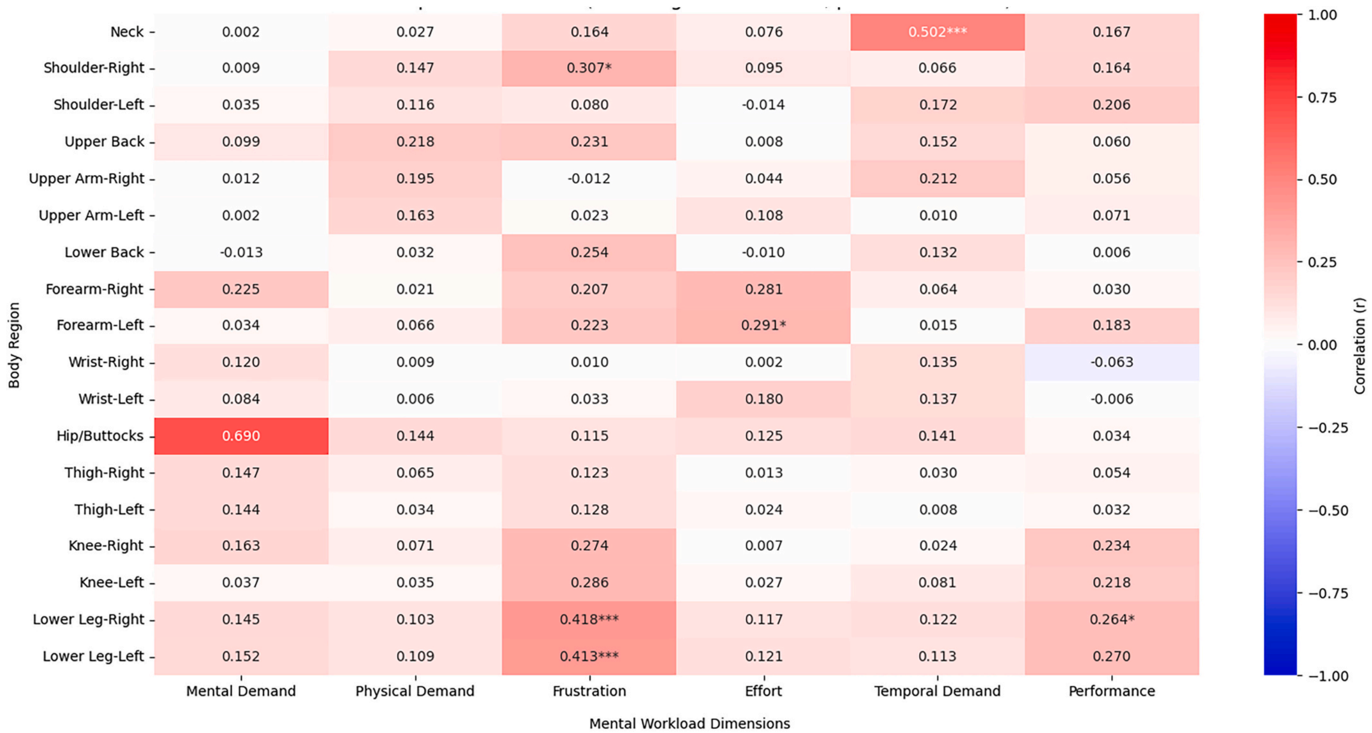

Fig. 7. Heatmap illustrating Pearson's correlation coefficients (r) between musculoskeletal disorder (MSD) levels across body regions and dimensions of mental workload. Darker shades represent stronger correlations, with red indicating positive associations and blue indicating negative ones. Numerical values within the cells correspond to the correlation coefficients (r) and include significance markers (p-values adjusted using the Benjamini–Hochberg correction; * $p < 0.0108$, ** $p < 0.005$, *** $p < 0.001$). (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

Table 4
Pearson Correlation Coefficient Between RULA Scores and Total Mental Workload Dimensions.

Total NASA Scores	RULA Scores	
	r	P
Mental Demand	0.068	0.554
Physical Demand	0.081	0.482
Frustration	0.030	0.794
Effort	0.033	0.777
Temporal Demand	0.26	0.024*
Performance	0.0121	0.918
Total	0.121	0.293

was attenuated and lost significance after correction. Notably, among the mental workload dimensions, the strongest and most consistent correlation was observed between temporal demand and MSD in the neck. The only body posture associated with MSD was in the neck region, where poor posture demonstrated a significant correlation with discomfort.

Similar to the present study, several other investigations have utilized RULA to evaluate dentists' working postures. Their findings suggest that RULA is an effective tool not only for assessing ergonomic risks but also for increasing dentists' awareness of improper postures. These studies report a high level of ergonomic risk among dentists and suggest that those who use microscopes during procedures tend to adopt less hazardous postures compared to those who rely on loupes or unaided vision (Kakaraparthi et al., 2022; Mills et al., 2020).

A considerable number of studies over the past decades have examined MSDs among dentists. Several investigations, including the present study, have identified the neck as one of the most affected regions. For example, Rickert et al. (Rickert et al., 2021) reported the highest prevalence of discomfort in the neck among dentists. Similarly, Gandolfi et al. (Gandolfi et al., 2021) and Bhatia et al. (Bhatia et al., 2024) also identified the neck as the most common site of discomfort. The findings of the present study likewise revealed the highest mean level of musculoskeletal discomfort in the neck, followed by the lower back. Consistent with this, Hashim et al. (Hashim et al., 2021) reported that dentists most frequently experienced pain in the neck, followed by the lower back.

Aljanakh (Aljanakh, 2024) found that awareness of the work environment and proper posture significantly predicted shoulder musculoskeletal discomforts among dental assistants (OR: 0.14; 95 % CI: 0.037–0.53). This indicates that individuals who are aware of proper posture are 86 % less likely to experience such discomforts. In this study, participants with improper posture reported greater neck discomfort; however, posture did not significantly correlate with shoulder discomfort. Aljanakh employed the Nordic questionnaire for assessment, which differs from the method utilized in this study. Lin et al. (Lin et al., 2020) found that 45.9 % of dental specialists reported experiencing high to very high levels of ergonomic exposure in the neck region, indicating poor posture. The present study demonstrates increased MSD in the neck, with a significant correlation between discomfort and poor posture, suggesting that dentists frequently adopt improper neck postures during their tasks.

Li et al. (Li et al., 2025) utilized structural equation modeling to demonstrate that mental workload has a significant direct effect on work-related MSDs among dentists ($\beta = 0.458$, $p < 0.05$). This finding indicates that as mental workload increases, the likelihood of experiencing these discomforts also rises. Marklund et al. (Marklund et al., 2021) found that 50 % of dentists experienced high mental and physical workloads with limited control over their work, resulting in dissatisfaction with ergonomic conditions. In the present study, inappropriate postures were found to be significantly associated with high temporal demand, which is one of the dimensions of mental workload. Maleki et al. (Maleki Roveshti et al., 2024) assessed the mental workload of dentists across pediatric, restorative, and diagnostic departments. The pediatric section had an average Physical Demand score of 74.1 ±

21.77, while the restorative and diagnostic sections reported the highest Effort averages of 70.0 ± 26.44 and 67.6 ± 26.3, respectively. In contrast, the present study identified temporal demand as the dimension with the highest average score. Cezar-Vaz et al. (Cezar-Vaz et al., 2023) found that perceived ergonomic risk and mental workload were associated with neck and lower back pain among primary healthcare workers, with frustration and mental demand correlating with these issues. In the present study, significant associations were observed not only between neck discomfort and higher mental workload but also between mental workload and discomfort in the right forearm. Among the dimensions of mental workload, only temporal demand demonstrated a significant positive correlation with RULA scores and exhibited the strongest positive correlation with neck pain. Since the participants in this study were exclusively general dentists, these differences may be attributed to variations in occupational tasks compared to those of participants in the two aforementioned studies.

Current and previous studies indicate a high prevalence of awkward working postures and elevated ergonomic risks among dentists (Mane & Rajhans, 2024; Soo et al., 2023). Although the overall level of MSD reported in the present study was low, the lower back and neck were identified as the primary sites of discomfort, consistent with previous investigations (Bhatia et al., 2024; Gandolfi et al., 2021; Hashim et al., 2021). Similar to prior research, neck pain showed a significant correlation with mental workload (Cezar-Vaz et al., 2023).

Moreover, the dentists participating in this study reported temporal demand as the dimension of mental workload with the highest mean score. This finding, along with other research underscores the considerable cognitive demands of the profession (Maleki Roveshti et al., 2024; Marklund et al., 2021). Variations in mental workload across different dental specialties were also observed, suggesting that each specialty imposes unique cognitive challenges (Maleki Roveshti et al., 2024). Importantly, MSD in certain body regions showed a significant correlation with higher mental workload, indicating that prolonged exposure to mental workload may adversely affect both the physical and psychological health of dentists (Cezar-Vaz et al., 2023).

These findings can inform the development of recommendations aimed at enhancing awareness and education among dental professionals. Awareness campaigns, webinars, and health journals can be utilized to highlight the high prevalence of MSDs in the neck and lower back among dentists, as well as to explain their association with poor working postures. Based on this information, educational programs can be designed to promote the maintenance of neutral body postures, particularly for the neck, and lower back. Stress management workshops and time management strategies can be implemented to help reduce the mental workload of dentists. Additionally, due to variations in workload among different subgroups, targeted awareness initiatives can be tailored accordingly. By applying these recommendations, a culture of prevention can be fostered within the dental community.

This study has several limitations. Its cross-sectional design restricts the ability to draw causal inferences (Iftikhar, 2025). Additionally, reliance on self-reported questionnaires may introduce recall and reporting biases (Loo et al., 2012). Data collection was confined to a single session, without repeated assessments or interviews, which diminishes the capacity to capture variability over time (Wan et al., 2011). Furthermore, potentially influential factors—such as environmental conditions (e.g., lighting, temperature) and individual lifestyle habits (e.g., physical activity, rest)—were not measured(Hilmi et al., 2024; MJJ et al., 2021). These limitations could not be fully controlled beforehand due to practical and organizational constraints. For instance, participating clinics and their settings could not be modified, and logistical restrictions prevented the implementation of repeated measurements. Future studies should employ longitudinal designs, utilize objective assessment tools, and consider a broader range of contextual variables to provide a more comprehensive understanding.

5. Conclusion

This study examined the relationship between awkward postures, MSD, and mental workload among general dentists. The findings reveal a high prevalence of awkward postures, placing dentists at significant ergonomic risk. Although severe MSD was not reported, the elevated ergonomic risk suggests that such issues may develop in the near future. Dentists reported higher temporal demand compared to other dimensions of mental workload, indicating that they experience considerable time pressure while performing their tasks. A significant correlation was also observed between temporal demand and ergonomic risk. Therefore, to reduce ergonomic hazards, dental workstations should be designed according to ergonomic principles to support neutral neck postures. Additionally, effective task planning, advanced technologies such as CAD/CAM, and accessible instrument arrangement may improve efficiency and alleviate time pressure for dentists. Beyond workstation design, future research should also explore ergonomic teaching interventions and the promotion of physical activity, as these approaches may help mitigate musculoskeletal imbalance and stress, thereby supporting the long-term well-being of dental professionals.

CRediT authorship contribution statement

Shahin Darabzadeh: Writing – review & editing, Writing – original draft, Visualization, Investigation, Data curation. **Anahita larestani:** Writing – review & editing, Writing – original draft, Visualization, Investigation, Data curation. **Reza Esmaeili:** Writing – review & editing, Writing – original draft, Validation, Supervision, Software, Project administration, Conceptualization. **Mahdi Jalali:** Writing – review & editing, Writing – original draft, Methodology, Formal analysis. **Sajad Farhadi:** Writing – review & editing, Writing – original draft, Visualization, Software. **Hamideh Ghasemian:** Writing – review & editing, Writing – original draft, Validation, Investigation.

Consent for publication

Written informed consent was obtained from all study participants for publication.

Clinical trial number

Not applicable.

Ethics approval and consent to participate

This study was approved as a research project in the ethics committee of Isfahan University of Medical Sciences with code number IR.MUI.RESEARCH.REC.1402.200 and was performed in accordance with Declaration of Helsinki. In the present study all participants were above 18 years old and signed an informed consent form prior to taking part in the study.

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Declaration of competing interest

The authors declare that they have no competing interests.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.actpsy.2025.105923.

Data availability

Due to the request of the participants in the study and the protection of their privacy, we are exempt from disclosing their personal information publicly. The datasets used and analyzed during the current study are available from the corresponding author on reasonable request.

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