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Prevention and Rehabilitation of Musculoskeletal Disorders in Dental Professionals: A Systematic Review

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Abstract

Background: The objective of this systematic review was to describe the evidence for preventive and rehabilitative interventions for musculoskeletal disorders in dental professionals.

Types of Studies Reviewed: Systematic search, screening, and eligibility processes were conducted to identify experimental, quasi-experimental, observational, and survey research studies that either directly evaluated or predicted the effects of preventive or rehabilitative interventions on the reduction of musculoskeletal symptoms in dental professionals.

Results: A total of 3,571 unique abstracts were identified and screened, 256 full-text articles were assessed for eligibility, and 34 articles were included in the review. Seventeen experimental studies described the results of preventive or rehabilitation interventions and seventeen survey research studies predicted or correlated preventive/protective techniques to a reduction in musculoskeletal symptoms. The primary techniques evaluated in the studies included equipment modification, ergonomic training, and physical exercise.

Practical Implications: Current evidence suggests that magnification loupes and indirect-vision techniques have a positive effect on the reduction of musculoskeletal symptoms. Other techniques have mixed evidence or are limited by low level study design in evaluating intervention efficacy.

Keywords

Ergonomics; injury prevention; musculoskeletal disorders; dentists; dental hygienists

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Introduction

Work-related musculoskeletal disorders (MSDs) are a common occupational hazard for dentistry professionals. The nature of the work requires repetitive motion of the arms, wrists, and hands while adopting awkward static trunk, neck, and shoulder postures for extended periods of time.[1] It also has been well documented that tasks requiring repeated high hand forces applied at the finger tips and requiring prolonged awkward postures generate significant biomechanical stress and can promote injuries of the distal upper extremities such as carpal tunnel syndrome.[2, 3]

A previous review article determined the prevalence of MSD symptoms in the neck and shoulders (respectively) to be 17–73% and 20–65% in dentists, 54–83% and 27–76% in dental hygienists, and 38–62% and 62% in dental assistants.[4] In a more recent study, 81.4% of the dentists surveyed experienced musculoskeletal disorders, mostly in the neck, lower back, and/or shoulders.[5] Another study using the Nordic Musculoskeletal Questionnaire found that 76.2% of male dentists experienced symptoms of musculoskeletal disorders in the lower back, neck, and/or shoulders.[6]

A study conducted in 1993 found the loss of income for dentistry professionals due to musculoskeletal pain to be greater than $40 million per year.[7] In addition to financial costs, the presence of MSDs has been associated with poor quality of life and mental distress.[8] Also, the presence of MSDs also has been associated with factors that reduce the efficiency and quality of work, such as falling asleep during normal activity, stiffness, and loss of strength.[9]

Although extensive research and systematic reviews indicate a high prevalence of musculoskeletal disorders among dental professionals worldwide, there is a lack of research on antidotal measures. The objective of this systematic review was to identify the current consensus on preventive and rehabilitative interventions for MSDs for dental professionals.

Methods

Databases Searched

PubMed, BIOSIS, CINAHL and PsycInfo were searched using a combination of the medical subheadings (MeSH) and key terms, “dental hygienist, dentist, or dental assistant” and “human engineering, ergonomics, wound, injury, sprain, strain, stress, or musculoskeletal.” Searches were limited to studies published in English between January 1, 1990 and September 15, 2018. In addition to the systematic database search, a hand search was conducted by reviewing the references of all included articles and the tables of contents of the journals of dental professional societies published within this time frame. The following journals were included: *International Journal of Dental Hygiene*, *International Dental Journal*, *Journal of American Dental Association*, *Journal of Dental Education*, and *Journal of Dental Hygiene*. Tables of contents also were searched in *Applied Ergonomics* and *WORK: A Journal of Prevention, Assessment, and Rehabilitation* due to many articles appearing in the full text review and the existence of a special issue dedicated to dentistry, respectively.

Inclusion Criteria

Once duplicate records were removed, the remaining abstracts were screened by at least two raters to narrow the studies for inclusion. Abstracts were screened to identify records focused on interventions for the rehabilitation or prevention of musculoskeletal disorders in dental professionals using an experimental, quasi-experimental, observational, or survey design. Conference abstracts, educational articles, non-systematic reviews, editorials, and expert opinion manuscripts were not included. Additionally, articles on psychological stress versus musculoskeletal disorders or reported on patient injury instead of injuries in dental providers were not included.

The full-text of any record identified as meeting the broad inclusion criteria by either rater were assessed for eligibility. Final inclusion required the following criteria: 1) the study population were dental professionals (i.e., dentists, dental hygienists, dental assistants, or students within these professions), 2) evaluated a preventive or rehabilitative intervention, and 3) measured an outcome related to musculoskeletal discomfort or dysfunction. Intervention studies that were purely laboratory-based or evaluated changes in tissue morphology/ physiology, postures, or participant preference without any measure of musculoskeletal disorder outcomes were excluded. Retrospective, observational, or cross-sectional survey studies were included if statistical analyses were used to correlate or predict the relationship of preventive or protective interventions or activities to musculoskeletal outcome measures. Surveys or cross-sectional studies that only reported descriptive data were not included.

Study Evaluation

All full-text articles were independently reviewed for eligibility by two raters and discrepancies were discussed with a third rater to achieve consensus on final eligibility. Included studies were coded as either cross-sectional or prospective intervention studies. Quality of reporting of cross-sectional studies was assessed using the STROBE checklist[10] and quality of methodological design of the intervention studies was evaluated using the Cochrane Risk of Bias assessment.[11] Data regarding intervention type, outcome measures, and study results were extracted. Qualitative synthesis and interpretation of the findings was conducted through an iterative process among the authors.

Results

A total of 3,939 abstracts from PubMed (n=2950), CINAHL (n=413), BIOSIS (n=359), and PsycInfo (n=217*)* were identified. Twenty-two additional studies were identified through the hand search. After the removal of duplicates, 3,571 abstracts were screened and 256 full-text articles were read to determine eligibility. After screening and completing an eligibility review, 34 studies were included in the final qualitative analysis (Figure 1). Across all included articles, three general categories emerged based on the type of interventions used to reduce the impact of MSDs. The most common type of intervention was physical activity, such as exercise or rehabilitative therapy techniques. Second, studies evaluated the impact of modifying the equipment being used by dental practitioners, such as the type of instrument handles and loupes. The final category was various methods of providing direct training to

dental professionals regarding ergonomic practices, proper posture, and other behavioral modifications to their practice patterns. For ease of reporting and interpretation, the included studies were organized as either cross-sectional or prospective intervention trials.

Cross-sectional Studies

Seventeen of the included articles were predictive, correlational or comparative statistical analyses of potential preventive or protective techniques within a cross-sectional survey or observational study design (Table 1). Three primary topics were evaluated across these 17 studies, some articles evaluating multiple topics, which included: physical activity (n=13), ergonomic training (n=6), and equipment modification (n=4). Quality assessment for presentation of these data was completed using the STROBE checklist.[10] Overall quality of presentation across the studies ranged from 17 to 22 based on the 22-item checklist. The primary criteria not met were not acknowledging funding sources, potential sources of bias, or limitations of the study.

Most of the studies that focused on physical activity interventions concluded that implementing regular physical activity reduced the frequency of musculoskeletal pain.[12–17] One study found a significant decrease in pain with 6–8 hours of physical activity per week.[17] Another survey study found that physical activity and massage were the most effective preventive measures for musculoskeletal pain.[15] Compared to walking, jogging, or other forms of aerobic exercise, yoga seemed to decrease musculoskeletal symptoms the most.[12] Similarly, stretching decreased musculoskeletal pain in dental students, while a lack of regular weekly exercise correlated with increased low back pain.[13, 18] In contrast, two studies found no significant relationships between stretching or physical activity with musculoskeletal pain.[19, 20] There was no significant relationship between the duration, frequency, or intensity of physical exercise and musculoskeletal pain.[21] One study on complementary and alternative medicine therapies found that it was correlated with higher physical functioning, but the CAM therapies used were inconsistent.[22]

Out of the six studies addressing ergonomic education and training, four studies found that it can decrease musculoskeletal symptoms and pain.[13, 20, 23, 24] According to one study, dentists who received ergonomic education during dental school were less likely to experience low back pain later on in their career.[23] Similarly, another study concluded that an increased awareness of ergonomic posture when working was linked to a lower risk of developing musculoskeletal pain.[13] In-session body posture adjusting and focusing on ergonomics was correlated with less pain, while chairs without lumbar support and arm rests were associated with more pain.[15] On the other hand, dentists who practiced four-handed dentistry reported more frequent pain; they also reported longer work hours before taking breaks.[25] Another study found that dentists who did not take rest breaks experienced significantly more hip pain.[20] Lastly, dentists who received postural feedback and recommendations had improvements in neck and upper back extensions during subsequent dental tasks.[24]

Three of the four studies focused on equipment modifications, specifically tool and visual modifications, found suggestive evidence that such modifications decreased musculoskeletal pain and symptoms.[23, 26, 27] In one study, dentists experienced decreased leg pain while

using of surgical magnification tools and lumbar supports.[23] Findings in another study comparing direct and indirect vision found that dentists who worked without visual modifications had significantly higher rates of musculoskeletal pain.[27] One study found that although there was a decrease in musculoskeletal pain with magnification loupes, there was an increase in pain using ultrasonic and hand scalers.[26] Additionally, one study noted an increase in musculoskeletal symptoms with incorrect tool size; however, there was an insignificant finding between extent of symptoms and tool diameter.[14]

Intervention Studies

The remaining 17 articles described results of prospective intervention studies for the prevention or rehabilitation of musculoskeletal disorders in dental professionals (Table 2). Interventions evaluated were categorized as physical activity (n=6), ergonomic training (n=6), and equipment modifications (n=7). Quality and bias assessment for these studies was completed using the Cochrane Risk of Bias assessment[11] (Table 3). Only 2 studies were randomized controlled trial with opportunity to meet all the criteria, with the remaining intervention trials failing to meet most of the criteria for rigor. Across the studies, common limitations included a small sample size and the use of convenience sampling.

Six articles focused on physical activity, including various types of physical therapy and stretching, concluded that physical activity had a positive impact on reducing musculoskeletal pain and symptoms.[28–32] One pre-test/post-test study comparing the outcomes of deep cervical flexor training and isometric training concluded that both had significant improvements in the neck disability index and visual analogue scale.[30] It also found that deep cervical flexor training had significant improvement in forward head posture.[30] Findings from another study found that combining medication and rehabilitation, such as electrotherapy, massage, kinesiotherapy and home programing decreased pain and dysfunction more effectively than medication alone.[31] Additionally, a quasi-experimental study found that 2.5 hours of mid-high intensity physical activity per week decreased upper extremity pain.[33] In one randomized control study, the dentists performed five finger stretches before starting scaling and root planning.[32] This intervention successfully decreased the drop in pinch strength after the dentists performed scaling and root planning.[32] Another randomized controlled trial implemented an ergonomic training intervention that included stretches, and found significant decrease in musculoskeletal pain as measured using the Nordic questionnaire.

Six studies measuring the effect of ergonomic training, including education, analysis, and posture, found a positive impact on the reduction of musculoskeletal pain and symptoms.[28, 29, 34–37] One case report implemented Global Postural Reeducation combined with Global Active Stretching and found a significant reduction in pain and dysfunction, indicating that a combination of postural education, regular stretching, and physical activity have a positive impact on musculoskeletal pain.[29] A randomized controlled trial with a multifaceted ergonomic intervention program found a significant decrease in musculoskeletal pain in the intervention group.[28] One cohort study found that the majority of the dentists attributed partial to full reduction of musculoskeletal symptoms to the implementation of ergonomic recommendations.[35] Moreover, specific to cervico-brachial

disorders, one quasi-experimental study found a significant reduction of symptoms after receiving ergonomic instruction with a psychosomatic approach.[37] Additionally, two case reports and one cross-sectional study found that ergonomic education and recommendations had the greatest impact when implemented until time of follow-up.[29, 34, 36]

Finally, most of the seven intervention studies focusing on equipment modifications reported a decrease in musculoskeletal symptoms.[38–42] A total of six studies assessed changes in pain, discomfort and function when using visual modifications such as magnification loupes and prism glasses, most of which found a decrease in neck discomfort and improvement in posture.[38–41, 43] One article did not find a significant difference in neck pain when wearing magnification loupes.[43] A single case study reported that musculoskeletal pain was mild or unnoticeable when the participant was using loupes.[40] Moreover, one randomized control trial assessing the impact of periodontal curette handles of varying weight and diameter found that using lighter curettes with a larger diameter handle had significant improvement on pain levels in the shoulder region.[42]

Discussion

Physical activity

There is currently insufficient literature available to conclusively suggest that physical activity benefits dentists and dental hygienists in alleviating musculoskeletal pain. Since most studies implemented physical exercise after musculoskeletal symptoms were present, there is little data on the preventive effects of physical activity. Most studies concerning physical activity, cross-sectional and prospective, focused on exercise that involved the entire body. Many cross-sectional studies did not differentiate specific types or intensity of exercise, making the findings hard to translate into practice. The studies that found significant improvement with physical activity often had limitations such as small sample size and/or inadequate explanation of the rehabilitation treatment.[30–32] Of the different types of physical activity studied, yoga was the most beneficial for decreasing pain once symptoms were already present. The cross-sectional study that considered the use of complementary alternative medicine found that it correlated with higher physical functioning, but the therapies used were too varied and inconsistent to draw any definitive conclusions.[22]

Compared to medication alone, a combination of rehabilitation and medication seemed to work better.[31] One case study implemented both postural reeducation and physical activity and found improvement measuring change using the Visual Analog Scale.[29] However, this study only included a single dental hygienist. According to these two studies, it seems that once musculoskeletal symptoms are present, a combination of different interventions could provide pain relief.

One cross-sectional study compared the effect of different durations of physical activity, but there was not enough information on the intensity or type of activity to translate the findings into practice.[17] Another study implemented finger exercises and stretches before the hygienists performed scaling and root planning.[32] This study only looked at the drop in

pinch strength before and after performing scaling and root planning, and provides only suggestive evidence about musculoskeletal pain.

Ergonomic Training

According to the studies reviewed, when ergonomic training is implemented in practice, it seems to effectively decrease musculoskeletal pain. This shows the importance of education as well as the potential of symptom exacerbation with a lack of education. However, it is important to note that hobbies outside of work may also affect musculoskeletal symptoms. Additionally, one study found that four-handed dentistry significantly increased musculoskeletal pain, however this may have resulted from inadequate understanding of the technique.[25] Although most intervention studies showed decrease in musculoskeletal pain after receiving ergonomic training, most of these studies had small sample sizes.[29, 34–37] Despite limitations, when participants of ergonomic training studies followed ergonomic recommendations, researchers found the greatest decrease in pain, which suggests potential positive effects for ergonomic training. Further research to develop and evaluate methods to promote on-going and sustained implementation of ergonomic recommendations in clinical practice would be a beneficial next step to advance the effectiveness of ergonomic training for reduction of MSDs in dental professionals.

Equipment modification

Current literature also suggests tools that promote proper ergonomics have the potential to decrease the prevalence of musculoskeletal pain. The majority of studies concerning equipment modification implemented loupes to improve posture and decrease neck/back pain. Positive findings relative to the use of loupes to decrease neck discomfort and improve posture limit interpretation general recommendation for the overall use of loupes due to the fact that a variety of through the lens and flip-up loupes styles were evaluated across the studies.[38–43] Moreover, none of the studies discussed the evaluation of loupes capable of vertical adjustment to alter and maximize declination angles, which can further promote achievement of neutral neck positioning across users in all working situations. In addition to heterogeneity in the loupe type, intervention studies were limited by small sample sizes, non-equivalent control groups, and a lack of data on long-term effects,[38–43] and cross-sectional studies primarily failed to state potential sources of bias.[23, 26, 27] Future research that investigates differential or comparative effectiveness across various styles of equipment, especially between fixed and vertically adjustable loupes, would be beneficial in advancing knowledge of the most effective modifications for improving posture and reducing musculoskeletal discomfort.

Study Quality

Although there have been studies that establish tentative links between physical activity, ergonomic training, and equipment modification and the prevalence of MSDs in dental professionals, there is a lack of rigor and conclusive evidence reported in the current literature. As required by the STROBE checklist, cross sectional studies should report the source of funding, potential sources of bias, and limitations of the study.[10] However, these areas were not included in many of the studies. Also, most of the studies relied on surveys, which fail to prove causality due to their retrospective nature. In addition, many studies used

convenience sampling by surveying local schools, organizations, and institutions and did not explain sample selection or size.

Intervention studies had similar issues in participant selection, such as small sample size and convenience sampling, thus not representative of dental professionals.[11] Also, many studies were too brief to measure the long-term effect of the interventions. The nature of the interventions often did not lend themselves to allocation concealment, and many studies did not randomize allocation. Although there were several articles on rehabilitative care, none of them found a preventive intervention that reduces risk of MSDs in dental professionals.

Limitations

Only studies published in English were included in the systematic review, which may have led to biases due to available information. Despite the large number of studies reviewed, very few focused on preventive and rehabilitative care for musculoskeletal disorders in dental professionals. As such, some articles of low rigor, such as case reports, were included.

Conclusions

This systematic review has clearly demonstrated the lack of evidence in the field of preventive and rehabilitative care related to dental professionals, and to date, there are no other systematic reviews on this subject. Robust research is lacking that could otherwise comprise a body of evidence to support any of the three categories of interventions (physical activity, ergonomic training, and equipment modification). Given the high prevalence of MSDs in dental professionals and the fact that these problems may begin to develop during the education process, early intervention is crucial for the prevention and/or treatment of these disorders.[18] Further interventional research should be conducted on the topic to provide sufficient support for dental professionals.

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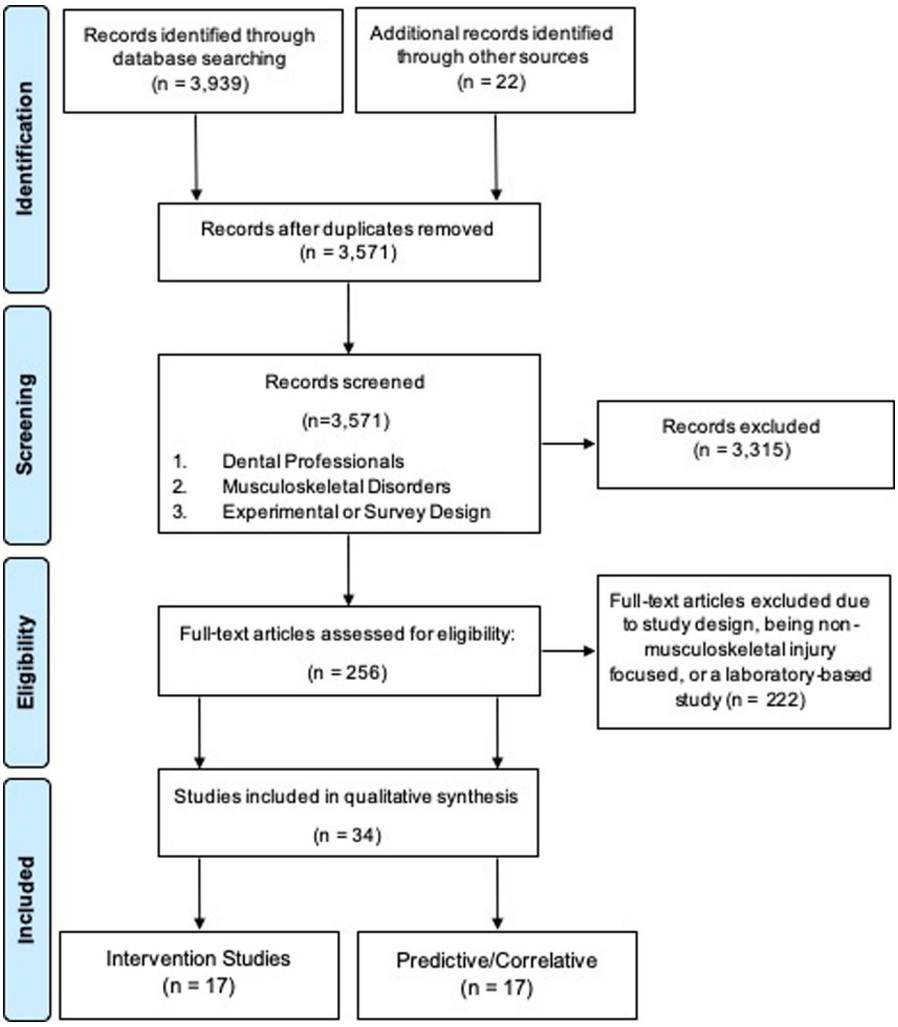

Figure 1.
Preferred Reporting Items for Systematic Reviews and Meta-Analyses flow diagram of study inclusion

Table 1.

Retrospective, observational, or cross-sectional survey studies that correlate or predict the relationship of preventive or protective interventions or activities to musculoskeletal outcome measures in dental professionals, listed chronologically (n=17).

Author (Year)	Location	Sample	Interventions			Outcomes Measure	Findings	STROBE [0–22]
			Phys Activity	Ergo Training	Equip Mod			
Marshall (1997)	New South Wales, Australia	353 dentists		x		Prevalence of musculoskeletal pain and four-handed dentistry	Increased pain with four-handed dentistry ($p<0.05$)	21 No discussion of limitations
Rucker (2002)	British Columbia	421 dentists		x	x	Prevalence of musculoskeletal pain and ergonomic training	Decreased low back pain with ergonomic education in dental school ($p=0.05$). Decreased low back pain with surgical magnification tool ($p=0.034$). Decreased leg pain with lumbar supports ($p=0.007$).	21 Potential sources bias not discussed
Rising (2005)	San Francisco, California	271 dental students	x			Prevalence of musculoskeletal pain and weekly physical activity	No statistically significant decrease in pain with different frequency, duration, or intensity of physical exercise.	19 Potential sources bias not discussed No discussions of limitations No interpretation of results
Hayes (2009)	Ourimbah, Australia	126 dental hygiene students	x			Prevalence of musculoskeletal pain and weekly physical activity	Increased low back pain with no regular weekly exercise (OR = 4.88; 95%, CI 1.75 to 14.0).	20 Potential sources bias not discussed Funding source (or lack of funding) not acknowledged
Harutunian (2011)	Barcelona, Spain	54 dental students, 20 faculty dentists	x			Prevalence of musculoskeletal pain and preventative measures	No statistically significant decrease in low back pain from stretching ($p>0.05$).	19 Potential sources bias not discussed No explanation of study size Funding source (or lack of funding) not acknowledged
Hayes (2012)	Ourimbah, Australia	560 dental hygienists			x	Prevalence of musculoskeletal pain, type of scaler, and magnification loupes	Decreased shoulder ($p<0.01$) or wrist ($p<0.01$) pain with loupes.	19 Potential sources bias not discussed No descriptive data of study participants Funding sources (or lack of funding) not acknowledged
Kierklo (2011)	Bialystok, Poland	219 dentists	x	x		Prevalence of musculoskeletal pain and frequency of physical activity	No statistically significant decrease of pain from physical activity or ergonomic training. More hip pain was experienced by dentists who did not take rest breaks ($p=.004$).	18 Participant selection not discussed Potential sources bias not discussed No explanation of study size Funding source (or lack of funding) not acknowledged

Author (Year)	Location	Sample	Interventions			Outcomes Measure	Findings	STROBE [0–22]
			Phys Activity	Ergo Training	Equip Mod			
Kumar (2013)	Mangalore, India	536 dentists	x			Prevalence of musculoskeletal pain and level of physical activity	Physically active dentists experienced pain in the upper back (59.25%), wrist/hand (22.22%), and low back (14.81%) Physically inactive dentists experienced pain in the neck (82.96%), wrist/hand (78.83%), and low back (78.42%)	19 Potential sources bias not discussed No discussion of limitations Funding source (or lack of funding) not acknowledged
Rahmani (2013)	Tehran, Iran	300 dentists	x			Prevalence of neck pain and frequency of physical activity	Decreased pain with presence of assistant and good general health ($p<0.05$).	20 Potential sources bias not described, no discussion of limitations No discussion of limitations
Saxena (2014)	Madhya Predesh, India	213 dentists	x		x	Prevalence of musculoskeletal pain, visual positioning training, and physical activity	Increased low back ($p<0.001$) and neck ($p=0.002$) pain with direct vision. Increased low back pain without physical activity ($p<0.001$).	21 Potential sources bias not discussed
Yi (2013)	Sichuan, China	288 dental students	x			Prevalence of musculoskeletal pain and weekly physical activity	Decreased pain with 6–8 hours of exercise a week (OR = 0.53; 95% CI 0.30 to 0.94). Increased pain with <1 hour of exercise a week (OR = 1.83, 95% CI 1.13 to 2.95).	22
Feng (2014)	Guangzhou, China	272 dentists	x		x	Prevalence of musculoskeletal pain and frequency of physical activity	Decreased neck pain with regular physical activity (OR = 0.37; 95% CI 0.14 to 1.00). Incorrect tool selection associated with shoulder (OR = 1.43; 95% CI 1.03 to 1.98) and wrist/hand pain (OR = 2.47; 95% CI 1.15 to 5.32).	22
Thanathornwong (2015)	Bangkok, Thailand	16 dentists		x		Prevalence of musculoskeletal pain and ergonomic training	Statistically significant decrease of neck and upper back extensions with participants who received feedback in post-test ($p<0.05$).	21 Potential sources bias not discussed
Gupta (2015)	Eastern India	877 dentists	x			Prevalence of musculoskeletal pain and CAM therapies	Higher physical functioning with CAM (OR = 1.51; 95% CI 1.1 to 3.1).	19 No discussion of limitations No interpretation of results Funding sources (or lack of funding) not acknowledged
Koneru (2015)	Mumbai, India	220 dentists	x			Prevalence of musculoskeletal pain and type of physical activity	Prevalence of musculoskeletal pain: Yoga: 10.5% Other type of physical activity: 21.7% No regular physical activity: 45.6% Decreased pain with yoga or physical activity compared to no physical activity ($p<0.05$).	20 Potential sources bias not described Funding source (or lack of funding) not acknowledged
Shirzaei (2015)	Zahedan, Iran	120 dental students	x	x		Prevalence of musculoskeletal pain and level of physical activity	Decreased pain with exercise ($p<0.05$). According to their REBA scores, 84% of 5th-6th year students were in the medium to high risk level for musculoskeletal disorder.	22

Author (Year)	Location	Sample	Interventions			Outcomes Measure	Findings	STROBE [0–22]
			Phys Activity	Ergo Training	Equip Mod			
							Decreased musculoskeletal pain in students aware of posture compared to students unaware of posture (p=0.046).	
Pejcic (2017)	Serbia	356 dentists	x	x		Prevalence of musculoskeletal pain, postural education, chair design, use of magnification devices, presence of assistants, dentist health status, massage therapy, and exercise	Increased pain with physical activity (p<.01). Decreased pain with in-session body posture changing (p<.05) and focused on ergonomics (p<.01). Increased pain with chairs without lumbar support (p<.01) or without armrests (p<.05).	17 Lacks description of setting Potential sources bias not discussed No explanation of study size Lacks discussion of participants No discussion of limitations

Table 2.

Experimental and quasi-experimental studies evaluating a preventive or rehabilitative intervention for a musculoskeletal outcome measure in dental professionals, listed chronologically (n=17).

Author (Year)	Location	Design	Sample	Interventions			Outcomes Measure	Findings	Limitations
				Phys Activity	Ergo Training	Equip Mod			
Rundcrantz (1991)	Lund, Sweden	Quasi-experimental	45 dentists		x		Visual Analogue Scale (VAS)	VAS: Psychometric approach had a decrease of pain and discomfort in neck ($p < 0.05$). Significant decrease of neck symptoms five weeks post intervention ($p < 0.01$)	Small sample size Five weeks may not have been adequate time for understanding and implementation of ergonomic techniques.
Sanders (2002)	Hamden, Connecticut, USA	Case Reports	2 dental hygienist		x		Body Map to determine pain levels	Case 1: *Follow-up*: Decrease in left scapular area pain from 3/5 to a 1/5 – 2/5 *2.5 year follow-up*: No pain most of the time, pain level of 2 when stressed Case 2: *Follow-up*: More relaxed hand due to stretching, no pain in shoulders, minimal pain in wrist *2.5 year follow-up*: Symptoms occurred 2–3 times/year due to engagement in hobbies	Small sample size
Smith (2002)	North Carolina, USA	Laboratory semi-experimental	5 dental hygienists			x	Neck discomfort	Significant decrease in discomfort with visual modification for both novice and dentist groups.	Small sample size Different tasks performed in the two parts of the study
Droeze (2005)	The Netherlands	Cohort Study	56 dentists		x		Implementation of recommendations MSD symptoms	53% of participants implemented ergonomic interventions 72% reported pain reduction of their main complaint.	Small sample size and low compliance Questionnaire lacks salience and validation to some extent
von Thiele Schwarz (2008)	Stockholm, Sweden	Quasi-experimental study	162 dentists	x			Physical activity and MSD symptoms	Significant decrease in upper extremity disorders with physical activity ($p=0.012$).	Workplace differences impact intervention effects All participants were women
Ferrari (2009)	Padova, Italy	Case Report	1 dental hygienist	x			Visual Analogue Scale (VAS) Neck Pain and Disability Scale (NPDS)	VAS: Significant decrease in pain after treatment. NSPDS: Significant decrease in pain and dysfunction after two months of treatment.	Small sample size
Branson (2010)	Kansas City, Missouri, USA	Case Study	1 dental hygiene student			x	Branson's Posture Assessment Instrument (BPAI) and musculoskeletal pain	BPAI: Positive change in neck and low back posture and mild to unnoticeable pain with magnification loupes	Small sample size Multiple choice journal entries may have limited personal comments in journal
Rempel (2012)	San Francisco, California, USA	Randomized control Trial	110 dentists and dental hygienists			x	Pain levels in the right wrist/hand, elbow/forearm and shoulder	Significant decrease in shoulder pain with wider-diameter, light curettes ($p=0.02$)	Findings included data of 5 participants who dropped out of study
Gupta (2013)	Delhi, India	Pre-test post-test design	30 dentists	x			Forward Head Posture (FHP) Neck Disability Index (NDI) Visual Analogue Scale (VAS)	FHP: Significant improvement for deep cervical flexion training ($p=0.000$) but not for isometrics training. NDI: Significant improvement for both deep cervical flexion and isometrics training ($p=0.000$).	Small sample size Postures observed and photographically analyzed may not reflect participant's working postures

Author (Year)	Location	Design	Sample	Interventions			Outcomes Measure	Findings	Limitations
				Phys Activity	Ergo Training	Equip Mod			
								VAS: Significant improvement for both deep cervical flexion and isometrics training (p=0.000).	
Hayes (2012)	Ourimbah, NSW, Australia	Pre-test post-test design	12 Dental hygienists			x	Disabilities of the Shoulder, Arm, and Hand (DASH) and musculoskeletal symptoms	DASH: Significant decrease in pain in treatment group (p<0.04).	Participants were volunteers Control not matched to treatment group due to convenience Measurement error and sensitivity
Nemes (2013)	Timisoara, Romania	Randomized prospective study	390 dentists	x			Visual Analogue Scale (VAS) Health Assessment Questionnaire for Dentists (HAQD)	VAS: Significant decrease in scores at 1 and 2 years HADQ: Significant decrease in scores in group receiving rehabilitation treatment at 1 and 2 years	Limited information on rehabilitation treatment
Hayes (2014)	Ourinbah, New South Wales, Australia	Pre-test post-test design	12 dental hygienists and 17 final year dental hygiene students			x	The Disabilities of the Shoulder, Arm, and Hand (DASH) Shoulder ROM, scapular position, grip and pinch strength	Significant improvement in DASH scores in intervention group (p<0.04) and worsening of symptoms in control group. No statistically significant difference in musculoskeletal measure.	Small sample size, convenience sample, predominantly female Non-equivalent control group
Bedi (2015)	Northern India	Cross-Sectional	60 dentists		x		Standardized Nordic Questionnaire (SNQ)	SNQ: Significant reduction in pain for dentists who implemented the ergonomic recommendations for 3 months (p<0.048)	Small sample size due to decreased number of participants at follow-up
Aghilinesjad (2016)	Milad hospital in Tehran province	Semi-experimental, census method	75 dentists			x	Musculoskeletal pain	Significant decrease in pain in neck, shoulders and arms, back, elbow, forearm, and the whole body (p<.05).	Only the short-term effects were studied during a 7–8 hour shift
Dehghan (2016)	Milad hospital in Tehran province	Randomized controlled trial	102 male dentists	x	x		Nordic Questionnaire (NQ)	NQ: Significant decrease in MSD symptoms with intervention (p<0.05).	Lack of representation; average age of dentists was fairly young and there were no female subjects.
Hayes (2016)	University of Newcastle, Callaghan, Ourinbah, NSW, Australia	Pre-test post-test design	12 dental hygienists and 17 final year dental hygiene students			x	Neck Pain and Disability Scape (NPDS) Cervical ROM, low load craniocervical flexion, cervical proprioception, and craniovertebral angle	No significant difference in outcomes according to ANOVA No significant difference in musculoskeletal measures pre/post intervention. No change in NPDS between baseline and follow up for intervention group.	Small sample size, convenience sample, predominantly female Non-equivalent control group
Padhye (2017)	Mahatma Gandhi Mission's Dental College and Hospital, Navi Mumbai, India	Randomized Control Study	40 dental professionals	x			3-point pinch with Jamar Hydraulic pinch gauge.	Significant decrease in drop of pinch strength post-SRP with 5 stretch intervention (p=0.05).	Small sample size, not stratified for age.

Table 3.

Risk of bias assessment for all prospective intervention studies included in the review.

Author (Year)	Random Sequence Generation	Allocation Concealment	Performance Bias: Blinding of Participants and Personnel	Detection Bias: Blinding of Patient-Reported Outcome Assessment	Attrition: Short Term (2–6 Weeks)	Attrition: Long Term (>6 Weeks)	Reporting Bias
Rundcrantz (1991)	[+]	[−]	[−]	[−]	N/A	N/A	[+]
Sanders (2002)	[−]	[−]	[−]	[−]	N/A	N/A	[−]
Smith (2002)	[−]	[−]	[−]	[−]	N/A	N/A	[−]
Droeze (2005)	[−]	[−]	[−]	[−]	N/A	N/A	[−]
von Thiele Schwarz (2008)	[+]	[−]	[−]	[−]	[+]	[+]	[+]
Ferrari (2009)	[−]	[−]	[−]	[−]	N/A	N/A	[−]
Branson (2010)	[−]	[−]	[−]	[−]	N/A	N/A	[−]
Rempel (2012)	[+]	[+]	[+]	[+]	[+]	[+]	[+]
Gupta (2013)	[+]	[−]	[−]	[−]	[+]	[+]	[+]
Hayes (2012)	[−]	[−]	[−]	[−]	N/A	N/A	[−]
Nemes (2013)	[+]	[−]	[−]	[−]	N/A	[−]	[+]
Hayes (2014)	[−]	[−]	[−]	[−]	N/A	N/A	[−]
Bedi (2015)	[−]	[−]	[−]	[−]	[−]	[−]	[−]
Aghilinejad (2016)	[−]	[−]	[−]	[−]	N/A	N/A	[+]
Dehghan (2016)	[+]	[−]	[−]	[−]	N/A	N/A	[+]
Hayes (2016)	[−]	[−]	[−]	[−]	N/A	N/A	[−]
Padhye (2017)	[+]	[−]	[−]	[?]	N/A	N/A	[+]

N/A, Not Applicable due to study design; ?, unable to determine