Workplace Factors Associated With Neck Pain Experienced by Computer Users: A Systematic Review

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ABSTRACT

Introduction: The purpose of this systematic review was to examine literature on workplace factors associated with neck pain or symptoms in computer users performing clerical functions.

Methods: A systematic search of the Cochrane, Medline, CINAHL, and EMBASE databases was conducted for observational and experimental studies published since 2000. This review applied the case definition of The Bone and Joint Decade 2000-2010 Task Force on Neck Pain and Its Associated Disorders.

Results: Seven hundred twenty-nine studies were identified. Seven hundred and two studies were excluded. Twenty-seven studies fulfilled inclusion criteria and were assessed for risk of bias. Cross-sectional studies were commonly at risk from nonresponse bias and lack of adequate case definitions. Experimental studies were mostly at risk of bias due to confounding and participant recruitment methods.

Conclusions: Neck pain was not significantly associated with high job demands, low skill discretion, low decision authority, or low peer support. However, when these variables were combined with increased duration of computing tasks, or ergonomic demands, they reached significance. Supervisor support was found to be the only significant buffer capable of preventing these variables reaching significance in female office workers. (J Manipulative Physiol Ther 2018;41:508-529)

Key Indexing Terms: *Neck Pain; Computers; Workplace; Occupational Injuries*

INTRODUCTION

Recurrent and chronic pain is responsible for a substantial degree of absenteeism, of which low-back and neck pain are the 2 most common complaints.[1] Workplace computer users have the highest incidence of neck pain among all workers, higher than is observed in the general population.[2]

Neck pain is the fourth highest cause of global disability, in years living with a disability, and the 21st in overall burden, expressed in disability-adjusted life years. Disability-adjusted life years increased from 23.9 million years in 1990 to 33.6 million years in 2010. Neck pain in the Australian population ranks third for years living with a disability and 10th for disability-adjusted life years out of 291 conditions. The prevalence among males is 4.6% (95% confidence interval [CI], 3.4-6.1) and females is 6.7% (95% CI, 4.9-9.1).[3] Prevalence is also greater in higher-income countries, compared to low and middle-income countries (0.4%-86.8% [mean 26.3%] vs 0.8%-80.0% [mean 17.5%]).[4]

Annual prevalence of absenteeism from work, or the phenomenon of presenteeism (in which the worker attends the workplace but performs at a suboptimal level) due to neck pain, in office workers who use computers is unknown. Both have the potential to negatively affect productivity and increase health care and insurance burdens.

The prolonged interaction of workers with computer workstations, monitors, keyboards, and other devices may be associated with the incidence or prevalence of neck pain. The prevalence of neck pain in office workers has been accompanied by an increase in workplace interventions. However, little, if any, relief has been provided by interventions targeting workers with neck pain, and no intervention has been found to offer a sustained benefit.[1]

Studies of workplace factors associated with neck pain in computer users vary widely in methodology, data handling, and reported results. The purpose of this systematic review was to examine the literature on workplace factors associated with neck pain or symptoms in computer users performing clerical functions.

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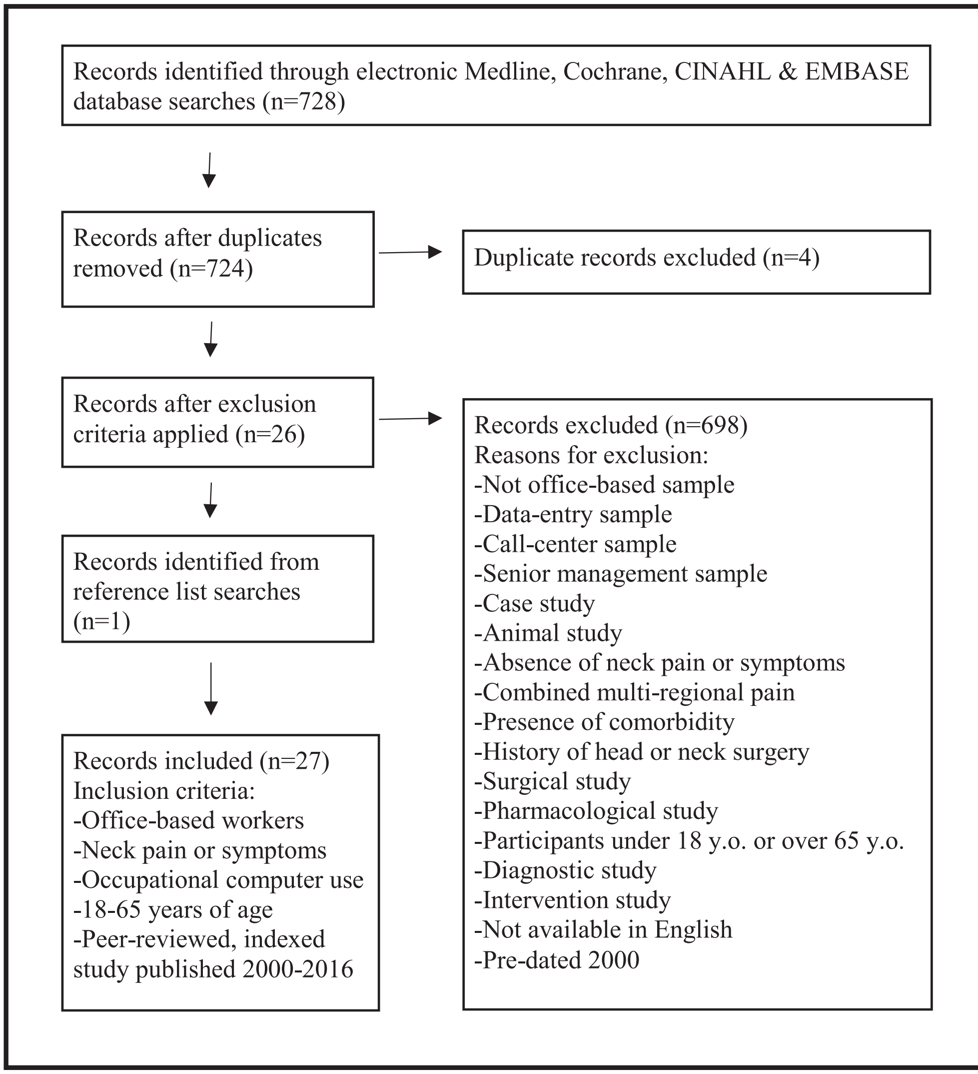

Fig 1. *Flow chart of included studies.*

Methods

Great variation exists in the anatomic definitions of the neck, with many studies reporting neck pain data based upon pain from combined anatomic regions, such as the neck and shoulder. This review focused on neck pain and excluded studies that combined shoulder, upper limb, and thoracic anatomic regions with the neck.

A protocol for this review does not exist. Study designs to be included, along with inclusion and exclusion criteria, were determined before the literature search commenced. These criteria are summarized in Figure 1.

Inclusion and Exclusion Criteria

An inclusion criterion was that studies had to be original research and not based upon synthesis of research, such as reviews. Observational study designs were included, such as case-control, cross-sectional, and cohort studies, but case studies and case-series designs were excluded. Experimental study designs were also included, such as randomized, nonrandomized, controlled, uncontrolled, blinded, and unblinded studies. Length of follow-up, if conducted, was not used as an inclusion or exclusion criterion. Studies were included regardless of whether data were statistically analyzed at conclusion of the period of intervention or after a period of follow-up. Reviews, including systematic, meta-analysis, literature, and narrative, were included in the literature search, but not in this review. Case definitions varied among reviews (if provided) and among the studies cited in reviews. This resulted in a risk of bias (ROB) and potentially inaccurate reports of synthesized data. Results reported in reviews were manually traced back through the cited references to the original study. These original studies were included if they met the inclusion criteria of this review. This increased the scope of the literature search. Reports, letters, books, conference proceedings, and posters were not included, due to lack of formal peer review.

Eligibility criteria for inclusion were that the study was original research that had been published and indexed in a peer-reviewed journal, between 2000 and 2017, and that the full text of the study was available for retrieval. Non–English-language studies were included if the full text was available in English. Studies were excluded if the full text was not available in English. Study participants had to be aged between 18 and 65 years, inclusive, but sex of participants was not used as an inclusion or exclusion criterion. Participants had to be civilian workers in an office workplace environment that involved computer usage in a clerical role.

Inclusion criteria included the presence of neck pain or neck symptoms. Studies were excluded if they combined anatomic regions, such as neck–shoulder or neck–upper limb pain, unless it was possible to separate the data related solely to the neck. The Bone and Joint Decade 2000-2010 Task Force on Neck Pain and Its Associated Disorders examined epidemiologic literature and identified more than 300 case definitions for neck pain.[5] The anatomic definition of the neck used by the task force was adopted by the authors of this review (Fig 2). It extended from the superior nuchal line and external occipital protuberance inferiorly to the spine of the scapula, along the superior border of the clavicle to the suprasternal notch. It excluded the mandible, shoulder girdle, upper limb, and thoracic regions outside the anatomic boundaries defined.[5] Studies included in this review used various anatomic definitions of the neck, such as that of the Nordic or Maastricht Upper Extremity Questionnaires, or nonstandardized or unvalidated definitions, diagrams, or instruments. Sufficient flexibility had to be applied during study selection to allow for variation in anatomic boundaries of the neck, but studies had to satisfy the definition of the neck adopted for this review for purposes of inclusion.

Studies were excluded if they examined data entry, call center, or senior management samples because of workplace factors that differentiate these populations from the general clerical workforce. Studies were excluded if participants were under 18 years of age or over 65 years of age and if there was a history of surgery or existent comorbid pathology to the head or neck (eg, rheumatoid arthritis). Nonhuman studies were excluded, as were surgical, pharmacologic, diagnostic, and treatment intervention studies. The authors considered these criteria to represent civilian adults using computers to perform clerical functions in the workplace.

An electronic database search of the Cochrane, Medline, CINAHL, and EMBASE databases was conducted, searching from January 1, 2000, to December 31, 2016. The date of last search was March 13, 2017. The search and eligibility assessment was performed by 1 review author (G.A.K.) in a systematic, unblinded manner. This search and eligibility assessment was checked by the review supervisor (P.A.T.). MeSH terms “neck,” “pain,” and “computer” were used. Other terms were not included because of the small numbers of results returned. Design labels used for indexing and database filters are not used consistently across nonrandomized studies, resulting in unreliable indexing across databases. For this reason, the MeSH terms were not expanded, increasing the number of studies located during the search. Studies were then manually screened. Inclusion

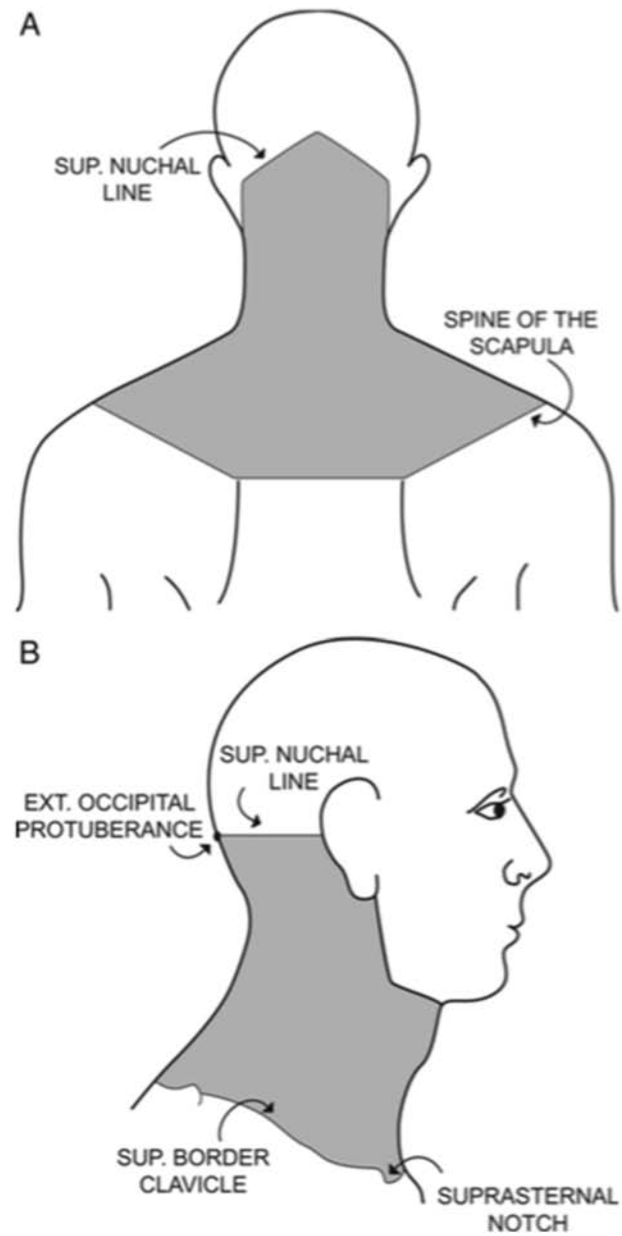

Fig 2. *Anatomical boundaries of the neck from the back (A) and the side (B) as defined by The Bone and Joint Decade 2000-2010 Task Force on Neck Pain and Its Associated Disorders. Reprinted with permission from Guzman et al.*[5]

and exclusion criteria were used to set limits on search parameters. Titles and abstracts of located studies were read and manually screened for inclusion or exclusion by the same author.

The Medline database search returned 504 studies. Twenty-six studies met the inclusion criteria, and 478 were excluded. The Cochrane database search located 3 reviews. The reference lists of these reviews were searched manually for studies that met the inclusion criteria. No further studies were identified. The CINAHL and EMBASE databases were searched using the same terms and strategy. The CINAHL search retrieved 79 studies, of which 3 studies met the inclusion criteria but were excluded because they were duplicates of studies retrieved during the Medline search. The EMBASE search retrieved 142 studies. One study met the inclusion criteria but was excluded as a duplicate of a study from the Medline database search. The reference lists of the 26 included studies were then manually searched for studies that met the inclusion criteria and had not been identified in electronic database searches. One additional study was identified, bringing the total number of studies meeting the inclusion criteria to 27.

Data were extracted by 1 review author (G.A.K.) and checked by the review supervisor (P.A.T.). Participant, intervention, comparison, outcome, and study design criteria for data extraction were based upon the inclusion and exclusion criteria: (1) participants were civilians aged between 18 and 65, inclusive, who performed computer-based clerical functions within a workplace environment, without a history of head or neck trauma or comorbidity; (2) a neck symptom dependent variable was measured with the independent variable; (3) a comparison or control group was not an inclusion criterion; (4) outcome measures included a neck symptom variable; and (5) an observational or experimental study design was used.

Some studies that met the inclusion criteria also reported results not relevant to this review. These irrelevant data were excluded from this review. Data relevant to this review were extracted and tabulated, regardless of whether they reached significance. The analysis of results was limited to a qualitative analysis due to heterogeneous factors between studies regarding case definitions; lack of standardization of outcome measures, including the use of unvalidated instruments in some studies; variations in study designs; grouping or subgrouping of participants based upon age ranges or sex; controlled and uncontrolled variables and confounders; variable risks of biases across studies; variations in statistical analyses and methods of reporting results; and variations in follow-up durations (if performed). It was not possible to perform a meta-analysis or to statistically combine data, or represent data in forest plots, for these reasons. Risks of biases across studies, therefore, were not a risk to cumulative evidence.

Statistically adjusted data were used to reduce the ROB. A systematic method or tool for data extraction and handling was not used due to heterogeneous factors. Odds ratios and hazard ratios were included, regardless of positive or negative associations between dependent and independent variables. A summary of data and statistical analyses were tabulated within the methodologic contexts. Duplicate studies were eliminated during the selection phase of this review. Some studies included shared authorship and reported data on the same cohorts. Due to the inability to perform a meta-analysis, or to combine data from studies, these data were included without the risk of double-counting data.

Risk of bias assessments were performed on all included studies by 1 review author (G.A.K.) and checked for agreement by the review supervisor (P.A.T.). Cross-sectional observational studies were assessed using a Risk of Bias Tool for Prevalence Studies (Table 1), modified by Hoy et al.[6] Experimental studies were assessed using the Risk of Bias in Nonrandomized Studies of Interventions tool (Table 2).[7] These tools are domain based and assess internal and external validity. They do not use numerical scores, the use of which has been discouraged by the Cochrane Collaboration due to variable weighting that does not accurately and validly reflect the quality of the study.[8] Data will be discussed in context of the ROB assessments that may affect the validity of the reported results.

Results

A total of 729 studies were located during searches, of which 728 were located during electronic database searches and 1 study during manual searches of reference lists of included studies. Six hundred ninety-eight studies were excluded for failing to meet the inclusion criteria or for meeting the exclusion criteria, and 4 were excluded as duplicates. Twenty-seven studies met the inclusion criteria of this review (Fig 1). Inclusion and exclusion criteria were detailed in the “Methods” section. All studies meeting the inclusion criteria have been included in this review. All included studies underwent ROB assessments (Tables 1 and 2), as detailed previously in the “Methods” section.

A common ROB in the included cross-sectional studies, assessed using the Risk of Bias Tool for Prevalence Studies (Table 1), was nonresponse bias. This occurred when less than 75% of participants completed the required questionnaires, and the researchers did not complete an analysis comparing responders and nonresponders. The second common ROB in these studies related to a lack of an adequate case definition of neck pain or symptoms. Data collected in these studies were derived from subjective assessments by participants. Without adequate case definition, there was the potential that the instrument was not reliably measuring data from the same anatomic regions between participants within the same study or between different studies. This potentially affected the internal and external validity of these studies, and the

Table 1. *Risk of Bias Assessments of Cross-sectional Observational Studies Using the Risk of Bias Tool for Prevalence Studies*

First Author of Study	1. Was the Study's Target Population a Close Representation of the National Population in Relation to Relevant Variables?	2. Was the Sampling Frame a True or Close Representation of the Target Population?	3. Was Some Form of Random Selection Used to Select the Sample or Was a Census Undertaken?	4. Was the Likelihood of Nonresponse Bias Minimal?	5. Were Data Collected Directly From the Participants (as Opposed to a Proxy)?	6. Was an Acceptable Case Definition Used in the Study?	7. Was the Study Instrument That Measured the Parameter of Interest Shown to Have Reliability and Validity (if Necessary)?	8. Was the Same Mode of Data Collection Used for All Participants?	9. Was the Length of the Shortest Prevalence Period for the Parameter of Interest Appropriate?	10. Were the Numerator(s) and Denominator(s) for the Parameter of Interest Appropriate?	11. Summary Item on the Overall Risk of Study Bias
Johnston[9]	L	L	L	H	L	L	L	L	L	L	M
Johnston[10]	L	L	L	H	L	H	L	L	L	L	M
Cho[11]	L	L	L	H	L	H	L	L	L	L	H
Eltayeb[12]	L	L	L	H	L	L	L	L	L	L	L
Korhonen[14]	L	L	L	L	L	H	H	L	L	L	H
Johnston[16]	L	L	L	H	L	H	L	L	L	L	H
Cagnie[25]	L	L	L	H	L	L	H	L	L	L	H
Hush[26]	H	L	L	H	L	L	L	L	L	L	H
Janwantanakul[27]	L	L	L	H	L	H	H	L	L	L	H
Dahiya[28]	H	H	H	H	L	H	H	L	L	L	H

Criteria 1 to 10 assessed as low (L) or high (H) risk of bias. Criteria 11 assessed as L, H, or moderate (M) risk of bias. Criteria 1 to 4 assess external validity. Criteria 5 to 10 assess internal validity.

Table 2. *Risk of Bias Assessments of Experimental Studies Using ROBINS-I Tool*

First Author of Study	1. Bias Due to Confounding	2. Bias in Selection of Participants Into the Study	3. Bias in Classification of Intervention	4. Bias Due to Deviations From Intended Interventions	5. Bias Due to Missing Data	6. Bias in Measurement of Outcomes	7. Bias in Selection of the Reported Result	8. Overall Bias
Johnston[15]	M	M	L	L	L	S	M	S
Svensson[17]	S	L	L	L	L	L	L	S
Zetterberg[18]	M	L	L	L	L	L	L	M
Rempel[19]	S	L	L	S	L	L	L	S
Szeto[20]	S	L	L	L	L	S	L	S
Szeto[21]	S	L	L	L	L	L	L	S
Mainenti[22]	M	L	L	L	L	S	L	S
Hoyle[23]	S	L	L	L	S	S	M	S
Shahidi[29]	S	L	L	L	L	L	L	S
Bruno Garza[30]	M	L	L	L	L	L	L	M
Johnston[31]	S	L	L	L	L	L	L	S
Yoo[32]	S	L	L	L	L	L	L	S
Andersen[33]	S	L	L	L	L	L	L	S
Szeto[34]	S	L	L	L	L	L	L	S
Szeto[35]	S	L	L	L	L	L	L	S
Johnston[36]	S	L	L	L	L	L	L	S
Cagnie[37]	S	L	L	L	L	L	L	S

Risk of bias for each criterion is classified as low (L), moderate (M), serious (S), or critical (C). *ROBINS-I*, Risk of Bias in Nonrandomized Studies of Interventions.

ability to compare or combine results, due to a lack of standardization of a definition.

Most risks of bias in the experimental studies appeared in the first 3 criteria of the Risk of Bias in Non-randomized Studies of Interventions tool (Table 2), which assessed risks of biases due to confounding, selection, and classification of interventions. This was to be expected in nonrandomized designs. Confounding remained mostly due to selection biases, nonrandomized allocations, and small sample sizes. Some researchers attempted to statistically adjust for confounding, but this was mostly limited to age and anthropometric variables. Residual confounding or covariate imbalances remained in many studies and between studies. Residual or unmeasured confounding biases commonly cannot be excluded from nonrandomized studies.

The ROB due to selection of participants (criterion 2) was rated as low across studies because this criterion assessed selection of participants into a nonrandomized study, based upon participant characteristics observed after commencement of the intervention and not the method of recruitment of participants. Although this criterion assumes the existent risks associated with nonrandomized designs, it cannot be disregarded as a source of bias.

Many experimental studies did not allocate participants to different intervention arms, including control groups. Subsequently, there was no allocation concealment or blinding of participants to the intervention. Performance bias may have existed within some studies. Many of these studies did not blind the investigators; however, data were quantified and collected on laboratory equipment, reducing the potential for detection biases.

Studies included in this review examined a broad range of variables associated with neck symptoms and computer use in the workplace. These results were categorized and presented as extrinsic (workplace) or intrinsic (personal). The extrinsic category included factors that were external to individual participants and was subdivided into "biopsychosocial," "environmental," and "ergonomics" domains. The intrinsic category included factors that were internal to study participants and was subdivided into "posture, duration, and

Table 3. *Biopsychosocial Factors*

Author	Sample	Design	Associated Variable	Association With Neck Pain	Results	Significance	Comments
Johnston[9]	270 females	Cross-sectional	Low supervisor support	Mild neck pain and disability	Mean NDI 15.5/100 (SD 11.6). Adjusted P = .000, 95% CI -6.2, -2.1	Significant; $P < .01$	
Johnston[10]	270 females	Cross-sectional	Supervisor support	Decreased NDI	Adjusted P = .001, 95% CI -4.0, -1.0	$P < .01$	Job demands, decision authority, and skill discretion not significant individually.
			Time on computer tasks combined with:	All combinations; increased NDI			
			Low decision authority		P = .003	$P < .01$	All combinations buffered by high supervisor support and increased job control.
			Low skill discretion		P = .019	$P < .05$	
			Low supervisor support		P = .006	$P < .01$	
			Low supervisor support and typing method		P = .007	$P < .01$	
			Monitor distance >/< arm's length combined with:				
			Low decision authority		P = .003	$P < .01$	
			Low skill discretion		P = .019	$P < .05$	
			Low supervisor support		P = .006	$P < .01$	
			Mouse use and low supervisor support		P = .044	$P < .05$	
			Frequent sharing of workstation and high job demands		P = .024	$P < .05$	
Cho[11]	203 (87 females; 116 males); age 25-40 y	Cross-sectional	High psychological distress	Higher symptom and frequency scores	OR 0.86, 95% CI 0.46-1.56	None; P = .62	
Eltayeb[12]	186 (67 females; 119 males)	Prospective cohort (12-mo follow-up)	Time pressure	Increased pain	OR 1.31, 95% CI 1.00-1.90	Significant; P = .05	
			High task difficulty	Increased pain	OR 1.85, 95% CI 1.73-1.99	P = .03	
			Perceived high social support	Protective	OR 0.9, 95% CI 0.87-0.99	P = .01	

CI, confidence interval; *NDI*, neck disability index; *SD*, standard deviation.

Table 4. *Environmental Factors*

Author	Sample	Design	Associated Variable	Association With Neck Pain	Results	Significance	Comment
Korhonen[14]	232 (106 females, 126 males), age 25-61y	Prospective cohort (12-mo follow-up)	Poor lighting	Increased risk of neck pain from combined variables	OR 1.4, 95% CI 0.7-2.8	Individual variables not significant	No combination data reported
			Temperature		OR 1.2, 95% CI 0.6-2.4		
			Air quality		OR 1.7, 95% CI 0.8-3.5		
			Room size		OR 1.5, 95% CI 0.7-3.0		
			Acoustic conditions		OR 1.4, 95% CI 0.7-2.8		

CI, confidence interval; *OR*, odds ratio.

repetition," "individual risk factors," and "cervical function and myalgia" domains. Data were extracted from studies and summarized in the respective tables associated with these domains (Tables 3-8). Some studies reported data relevant to more than 1 domain, so they appear cited under respective domains and summarized in more than 1 table.

Data extracted and tabulated included the sample size, design, adjusted data, and significance of results. Data were presented in context of the interventions and outcomes. Results of studies have been presented within these tables, including odds ratios, hazard ratios, CIs, and significance, regardless of whether the data reached significance. Adjusted data have been presented to reduce the risks of biases associated with unadjusted data, particularly in nonrandomized studies. Results have not been synthesized into summaries or forest plots due to heterogeneous factors. Selection bias was common in nonrandomized studies, resulting in samples that lacked comparability. It was inappropriate to use a generic inverse variance method to attempt to construct forest plots or to pool effect estimates. There was also the potential for larger, nonrandomized studies of poorer methodologic quality to statistically dominate smaller studies at lower ROB. Sensitivity analyses and funnel plots were not performed because the results were not synthesized into cumulative evidence. Consequently, selective reporting and publication biases were expected to have little effect.

Discussion

Workplace Factors

Biopsychosocial Domain. Neck pain was not significantly independently associated with job demands, skill discretion, decision authority, and peer support (Table 3). When these variables were combined with increased duration of computing tasks, or ergonomic demands, they reached significance. However, high supervisor support was found to significantly buffer these combinations, preventing these combinations from achieving significance. Conversely, low supervisor support was found to be a significant risk factor for the development of neck pain, independent of physical demands. As job demands increased, greater decision authority was associated with increased Neck Disability Index (NDI) scores when supervisor support was low, but not with an increase in neck symptoms. Decision authority may increase stress on clerical staff instead of acting as a psychological buffer, in the absence of supervisor support.[9,10] High psychologcal distress was associated with increased neck symptom and frequency scores, but not significantly.[11] Although supervisor support and greater job control may be protective against ergonomic and physical demands associated with higher NDI scores,[10] workplace peer support is also significantly protective.[12]

All studies reporting on these biopsychosocial variables used cross-sectional designs to collect data. These studies were at high risk of nonresponse bias due to low response rates. The studies reporting protective effects of supervisor support only included female participants. It is possible that this may have been overestimated due to nonresponse bias. Although supervisor support is plausibly significantly associated with neck pain, its association with other musculoskeletal complaints in the wider literature, such as low back pain, remains inconclusive.[13] This factor should be considered by health care providers and workplace supervisors.

Environmental Domain. The only study that satisfied the inclusion criteria was a prospective study that surveyed participants with nonvalidated questionnaires, asking for subjective ratings based upon participants' perceptions of environmental variables (Table 4). Neck pain was not significantly independently associated with poor lighting, temperature, air quality, room size, or acoustic environmental variables. However, participants who rated combinations of variables as poor had a significantly increased risk of neck pain.[14] There was a high ROB within this study due to the lack of an adequate case definition and the use of unvalidated instruments to measure the environmental variables. Combinatorial data were not reported by the authors, so it is not possible to comment on the statistical strength of various permutations associated with neck pain. Environmental variables in this study are capable of being objectively quantified alongside neck pain variables. This may be an area for future research. These findings may be relevant to occupational health professionals.

Ergonomics Domain. A validated ergonomic computer workstation setup that reduces the incidence or prevalence of neck pain by matching the multiple measurements variables to the anthropometric variables of a worker does not exist (Table 5). The existing, broader literature has examined keyboard and monitor placement, seat and desk heights, the use of armrests, forearm positions, and variables related to mouse use. Keyboards placed <15 cm from the edge of the desktop were not associated with neck pain,[14] and forearm position, keyboard position, and duration of continuous telephone and keyboard use were not associated with neck pain. The authors conceded that this may have been influenced by the small cohort,[15] and a potential ROB existed in the measurement of outcomes that were based upon subjective assessments and the lack of an adequate case definition. In a later, higher-powered study by the same authors, a monitor distance greater or less than arms-length was significantly associated with higher NDI scores, but this was moderated by decision authority, skill discretion, and supervisor support. Subjectively rating a workstation as very uncomfortable was significantly associated with neck pain and disability, regardless of supervisor support or job control.[10] Another study by the same authors found no significant relationship between workstation comfort and neck pain.[16] The difference in these results may be due to a lack of validation of workstation ergonomic setups and nonvalidated, subjective assessments used to evaluate workstations. Both studies may have been affected by nonresponse bias and a lack of adequate case definition.

Monitor position correlates with neck pain. A small study found that the center of a monitor positioned 20° below the horizontal plane of the eyes resulted in a significantly greater load moment force at the C7/T1 junction compared to a monitor positioned 3° above the plane of the eyes.[17] When visual accommodation was challenged, there was a significant increase in trapezius electromyographic (EMG) activity and neck discomfort. This effect was only significant with challenged binocular vision, not with monocular vision, suggesting incongruence between ocular accommodation and convergence and not accommodation alone.[18] Although there was no correlation between NDI scores and the use of eyewear,[15] the same authors found graduated lenses were significantly associated with increased NDI scores.[16]

When monitor distance was increased to stress visual acuity, participants adopted a slumped posture to view a monitor at a mean distance of 85.3 cm, with the center of the monitor positioned 15° below the horizontal axis of vision. Flexion of the thoracic and lumbar spines lowered the body height in the seat. Forward head positioning occurred at the C7 vertebra, but symptoms of neck ache increased nonsignificantly.[19] Participants were permitted to readjust their posture from the initial reference posture after commencement of the test condition. Consequently, monitor distances and postures differed from the initial reference values. This potentially affected the neck ache results.

In another study, participants were observed working at computer workstations in their workplace. Greater head tilt, neck flexion, and acromion protraction angles occurred nonsignificantly in participants reporting neck discomfort. Neck flexion angles were disproportionately larger than head tilt angles, suggesting symptomatic participants had greater lower cervical neck flexion angulation.[20] No data were reported on ergonomic variables in this study, so it was not possible to correlate workstation variables with reported angulations. A larger study by the same authors, using a standardized ergonomic workstation setup that was adjusted by individual participants, found a significant difference in mean global head flexion angles, as well as a greater range of flexion angles in symptomatic participants, but not in lateral flexion or rotational positions.[21] Another study found symptomatic participants had significantly greater head protrusion angles, and a prevalence of 62.5% of neck pain correlated with participants not taking rest breaks.[22] However, this study was at ROB due to lack of an adequate case definition.

Myofascial trigger points (MTrPs) developed and reached significance after 1 hour of computer work in a poor ergonomic setup. Setup included a monitor positioned at 45° to the right of the participant, at 66 cm distance, with the bottom of the screen positioned at eye level. Table height was above elbow height, and elbow angle was <90°. Forearms were not supported, and the shoulders were loaded. Knees were higher than the hips in the seated position, with <90° knee flexion. The keyboard was positioned at the edge of the desk, without any forearm or wrist support.[23] This study used a small cohort without a control group. Myofascial trigger points were assessed by each participant's description, combined with a clinician's subjective assessment. The clinician was blinded to the 3 test conditions, but potential biases may have affected the internal validity of this study. In combination with the small cohort, this may have led to an overestimated result.

The ability to focus upon the visual information on a monitor screen appears to be an influential factor in relation to posture and the subsequent effect upon the neck. This is further influenced by regular work breaks that serve to interrupt the prolonged postures that predispose the neck to becoming symptomatic. Workplace ergonomics is a complex topic that involves multiple interactions of variables that may predispose a worker to neck pain. Among these are workstation designs and setups, interacting with the individual anthropomorphic variables of workers, which may be influenced by biopsychosocial variables, such as supervisor support and prolonged static postures. Further research is necessary to identify the

Table 5. *Ergonomics*

Author	Sample	Design	Associated Variable	Association With Neck Pain	Results	Significance	Comment
Johnston[10]	270 females	Cross-sectional	Perception of poor ergonomics	Increased prevalence of pain	OR 1.47, 95% CI 1.12-1.94	None; $P > .001$	Combinations buffered by high supervisor support and increased job control.
			Monitor distance >/< arms-length		$P = .024$	Significant; $P < .05$	
Korhonen[14]	232 (106 females, 126 males), age 25-61y	Prospective cohort (12-month follow-up)	Keyboard <15 cm from table edge	Increased risk of pain	OR 2.1, 95% CI 1.0-4.5	None; $P = .19$	None
Johnston[15]	107 females (52 with neck pain, 33 no pain, 22 controls)	Experimental case control and cross-sectional	Monitor height, distance and position	None	No data reported	None	None
			Forearm position				
			Keyboard position				
			Duration of continuous telephone and keyboard use				
			Eyewear use				
Johnston[16]	273 females	Cross-sectional	Wearing graduated lenses	Increased NDI scores	OR 4.6, 95% CI 1.7-12.5	Significant; $P \leq .01$	None
			Workstation setup	None	No data reported	None	
Svensson[17]	8 females	Experimental	Load moments at C7-T1 segment measured when viewing the center of a monitor 20° below the horizontal plane of the eyes	None	Median 2.07 Nm, IQR = 1.82-2.10 Nm, compared to 3° above horizontal (median 1.36 Nm, IQR = 0.58-1.92 Nm)	Significant; $P < .05$	None

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Table 5. (*continued*)

Author	Sample	Design	Associated Variable	Association With Neck Pain	Results	Significance	Comment
Zetterberg[18]	66 (33 participants [27 females, 6 males], 33 age and sex matched controls), age 20-47y	Experimental case control	Visual accommodation challenge with binocular -3.5 diopter lens during a task	Increased trapezius EMG activity	EMG RMS 0.76, SD 0.55	Significant; $P \leq .05$	Not significant with monocular vision
Rempel[19]	24 (8 females, 16 males), age 18-35y	Experimental repeated measures	Monitor distances of 52.4, 73, and 85.3 cm	None	$P = .62$	None	Significant for blurred vision ($P = .01$), dry or irritated eyes ($P = .03$), and headache ($P = .01$)
Szeto[20]	16 females (8 symptomatic, 8 nonsymptomatic), age 22-40y	Experimental controlled	Forward head tilt	Greater in case participants than controls	60.6° (±6.1°) vs 57.1° (±6.2°)	None; $P = .282$	Upper cervical extension was 4° greater in case participants than controls (175°), no data reported
			Neck flexion at C7		59.3° (±10.0°) vs 52.5° (±7.1°)	$P = .134$	
Szeto[21]	38 females (21 case; 17 controls)	Experimental controlled	Head flexion	Greater in case vs controls	Mean difference 3.9°, $F_{1,36} = 4.74$	Significant only in group MANOVA; $P = .036$	Lateral flexion and rotation positions did not reach significance
Mainenti[22]	15 (5 females, 10 males), age 18-60y, all right-handed	Cross-sectional	Symptomatic workers had greater head protrusion angles compared to asymptomatic workers	Increased pain	38.2° (35.4°-38.7°) vs 46.1° (39.5°-47.7°)	Significant; $P < .05$	62.5% of symptomatic participants had no short rest breaks
Hoyle[23]	12 (6 males, 6 females)	Experimental	1-hour computer work in poor ergonomic (high postural stress) setup	Myofascial trigger points developed in the UT	Mean rating 2.50/5.00 (SD 0.67)	Significant; $P < .05$	None
Janwantanakul[27]	1185 (807 females, 378 males)	Cross-sectional	Perception of ergonomics of desk	Increased pain	OR 1.47, 95% CI 1.12-1.94	None; $P = .005$	Not significant after Bonferroni correction

CI, confidence interval; *EMG*, electromyographic; *IQR*, interquartile range; *MANOVA*, multivariate analysis of variance; *Nm*, newton-meters; *OR*, odds ratio; *RMS*, root mean square; *SD*, standard deviation; *UT*, upper trapezius.

Table 6. *Posture, Duration, and Repetition*

Author	Sample	Design	Associated Variable	Association With Neck Pain	Results	Significance	Comment
Johnston[10]	333 females	Cross-sectional	Time on computer tasks combined with:	Increased NDI score		Significant; *P* = .003	Buffered by high supervisor support and increased job control
			Low decision authority		R^2 change .022, F change (df 1, n 317) = 8.98		
			Low skill discretion		R^2 = .014, $F_{1,317}$ = 5.58	*P* = .019	
			Low supervisor support		R^2 = .018, $F_{1,317}$ = 7.52	*P* = .006	
			Mouse use >6 hours/day		$F_{1,322}$ = 5.37	*P* = .021	
			Continuous computer-based tasks >2 hours		$F_{1,322}$ = 9.59	*P* = .002	
Johnston[16]	333 females	Cross-sectional	>2 hours on computer tasks	Increased NDI score	$F_{1,219}$ = 16.6	Significant; *P* = .000	None
			>2 hours sitting before taking a break		$F_{1,220}$ = 4.6	*P* = .033	
			>6 hours use of mouse		$F_{1,219}$ = 4.9	*P* = .029	
			>6 hours use of keyboard		$F_{1,220}$ = 4.3	*P* = .039	
Cagnie[25]	512 (225 females, 287 males)	Cross-sectional	Prolonged neck flexion	Increased prevalence of pain	OR 2.01, 95% CI 1.20-3.38	Significant	None
			Regular prolonged sitting		OR 2.06, 95% CI 1.17-3.62		
			Repetitive movements per minute		OR 1.63, 95% CI 1.02-2.60		
Hush[26]	53 (34 females, 19 males)	Cross-sectional longitudinal cohort (12-mo follow-up)	Prolonged sitting ≥1 hour before taking a break	Lower risk of neck pain	HR 0.49, 95% CI 0.2-1.2 (dichotomized data)	None; *P* = .317 (based on continuous data)	Unexpected and unexplained result
Janwantanakul[27]	1185 (807 females, 378 males)	Cross-sectional	Frequency of repetitive activity	Increased pain	OR 1.66, 95% CI 1.24-2.21	None; *P* = .001	None
			Frequency of long period in uncomfortable posture		OR 1.81, 95% CI 1.35-2.44	Significant; *P* < .001	
Dahiya[28]	100 (case: 50 [12 females, 38 males], control: 50 [10 females, 40 males])	Case control	Scapula protraction	Increased pain	Mean difference case: 1.36 cm vs controls: 0.49 cm	Significant; *P* = .0007	None
					Hands on hips case: 1.3 cm vs controls: 0.43 cm	*P* = .0009	
					90° GHJ abduction case: 1.37 cm vs control: 0.43 cm	*P* = .0006	

CI, confidence interval; *GHJ*, glenohumeral joint; *NDI*, neck disability index; *OR*, odds ratio.

Table 7. *Individual Risk Factors*

Author	Sample	Design	Associated Value	Association With Neck Pain	Results	Significance	Comment
Johnston[10]	333 females	Cross-sectional	History of neck trauma	Increased NDI score	95% CI 4.4-10.7, β = .25	Significant; *P* = .000	No OR reported
Eltayeb[12]	186 (67 females, 119 males)	Prospective cohort with 12-mo follow-up	History of neck symptoms	Increased pain	OR 4.02, 95% CI 2.08-7.79	None	None
Korhonen[14]	232 (106 females, 126 males), age 25-61y	Prospective cohort	Female sex	Increased risk of pain	OR 2.9, 95% CI 1.3-6.7	Significant	None
Johnston[16]	333 females	Cross-sectional	History of neck trauma	Increased pain	OR 4.8, 95% CI 1.9-11.9	Significant; *P* = .00	None
			Negative affect		OR 2.7, 95% CI 1.8-3.8	*P* = .00	
Cagnie[25]	512 (225 females, 287 males)	Cross-sectional	Female	Increased risk of pain	OR 1.95, 95% CI 1.22-3.13	All significant	Trend declines >50 y
			Persons >30 y		OR 2.61, 95% CI 1.32-3.47		
			Mental tiredness at end of workday		OR 2.05, 95% CI 1.29-3.26		
			Physical activity	Decreased risk of pain	OR 1.85, 95% CI 1.14-2.99		
Hush[26]	53 (34 females, 19 males)	Cross-sectional longitudinal cohort (12-mo follow-up)	Female	Increased risk of pain	HR 3.07, 95% CI 1.18-7.99	Significant; *P* = .037	None
			Anxiety		HR 2.39, 95% CI 1.09-5.22	None	
			Psychological stress		HR 1.64, 95% CI 0.66-4.07	None	
Janwantanakul[27]	1185 (807 females; 378 males)	Cross-sectional	Tiredness at end of working day	Increased pain	OR 1.43, 95% CI 1.11-1.85	None; *P* = .006	Not significant after Bonferroni correction
			High concentration		OR 1.53, 95% CI 1.13-2.07	None; *P* = .006	Female Reference OR 0.00
			Sex		OR 0.67, 95% CI 0.51-0.88	None; *P* = .004	
			Living alone		OR 0.56, 95% CI 0.35-0.91	None; *P* = .018	

CI, confidence interval; *HR*, hazard ratio; *OR*, odds ratio.

Table 8. *Cervical Function and Myalgia*

Author	Sample	Design	Associated Variable	Associated With Neck Pain	Results	Significance	Comment
Johnston[15]	107 females (52 with neck pain, 33 no pain, 22 controls)	Experimental case control and cross-sectional	Typing task with superimposed stress (fast typing with backspace disabled, researcher calling out mistakes)	Increased sEMG in SCM muscles during Cranio-Cervical Flexion tasks associated with higher NDI score.	OR 1.44, 95% CI 1.17-1.78	Significant; $P = .001$	None
				Sensory deficit using CPT over cervical spine associated with higher NDI score.	OR 1.27, 95% CI 1.08-1.49	$P = .004$	
				Duration of symptoms associated with higher NDI score.	OR 1.19, 95% CI 1.03-1.38	$P = .018$	
				Increased risk of sEMG-detected activity in SCM and cervical extensor muscles	OR 1.08, 95% CI 1.005-1.16 OR 1.03, 95% CI 1.002-1.05	$P = .037$ $P = .036$	
Hoyle[23]	12 (6 males, 6 females)	Experimental	1-hour computer work in poor ergonomic setup	MTrPs developed in UT after high postural stress	Mean rating 2.50/5.0 (SD 0.67)	Significant; $P < .05$	Low postural stress not significant
				Reduced UT EMG median frequency cycling	High visual stress mean 5.35 High postural stress mean 3.76	$P < .05$	
				Increased pain VAS score	High postural stress mean VAS change 46.75 mm High visual stress mean VAS change 33.25 mm	$P < .05$	
Hush[26]	53 (34 females, 19 males)	Cross-sectional longitudinal cohort (12-mo follow-up)	Cervical ROM	Increased cervical flexion-extension mobility was protective against pain	HR 0.44, 95% CI 0.19-1.05 (dichotomized data)	None	2.3-fold reduction in neck pain with flexion-extension

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Table 8. (*continued*)

Author	Sample	Design	Associated Variable	Associated With Neck Pain	Results	Significance	Comment
					HR 0.97, 95% CI 0.94-0.99 (continuous data)	Significant; $P = .028$	≥120°
Shahidi[29]	79 (60 cohorts [45 females, 15 males], 19 controls [12 females, 7 males])	Experimental control	Changes from baseline to low psychosocial stress mousing task (performance unmonitored, supervised by supportive tester)	Increased nondominant and dominant CES EMG activity	$r = .37$ $r = .22$	Significant; $P = .007$ None; $P = .139$	None
				Forward head posture	F = 30.29	Significant; $P < .001$	
			Changes from low to high psychosocial stress mousing task (speed and accuracy demands, financial reward, supervised by nonsupportive tester)	No change to CES or SCM EMG		None; $P \geq .051$ $P \geq .586$	
				No change in head posture		None; $P = 1.00$	
				Increased dominant and non-dominant UT EMG		Significant; $P = .007$ $P = .020$	
Bruno Garza[30]	120 (86 females; 34 males); age 23-63y	Experimental	2-hour computing task	EMG higher in right UT, and increased neck flexion in high over-commitment and low reward group	Median adjusted right UT 5.8% MVC vs left 4.3% MVC	Significant; $P = .02$ interaction $P = .03$	None
					Med adjusted neck flexion 5^0	$P = .04$	
Johnston[31]	107 females (cohort: 85; controls: 22)	Experimental control	Mild pain compared to no pain group	Reduced flexion	Not quantified	Significant; $P = .038$	None
				Reduced extension		None; $P > .06$	
			Increasing pain	Reduced rotation	Left > Right	None	
				Lateral flexion unchanged	Statistically indiscernible		
Yoo[32]	16 males; (8 with UT pain, 8 with LS pain), age 21-30y	Experimental	1 hour of computer work	Reduced upper cervical flexion (LS pain vs UT pain)	10.5° ± 3.0° vs 15.2° ± 2.1°	Significant; $P < .05$	None
				Reduced total cervical flexion (UT pain vs	52.0° ± 3.2° vs 56.9° ± 4.0°	Significant; $P < .05$	

				LS pain)			
Andersen[33]	62 females (symptomatic case: 42, asymptomatic control: 20)	Experimental control	Shoulder abductions with dynamometry	Reduced trapezius activation in neck pain participants compared to asymptomatic controls	Group x velocity EMG lower during slow eccentric, slow concentric and static contraction	Significant; $P < .01$ $P < .01$ $P < .05$, respectively	None
					Group x velocity torque lower during slow concentric (27 ± 1.3 vs 33 ± 1.6 Nm) and slow eccentric (38 ± 1.5 vs 48 ± 1.9 Nm) contractions	Significant: $P < .001$	
					Fast concentric contraction EMG and torque	None	
Szeto[34]	43 females (symptomatic case: 23, asymptomatic control: 20)	Experimental control	1 hour typing task	Increased EMG in right UT with right and left neck discomfort.	$\rho = .623, .458$, respectively	Significant; $P = .0001\text{-}.007$, respectively	None
				Left UT EMG not correlated with right and left neck discomfort.	$\rho = .229, .063$, respectively	None; $P = .157\text{-}.707$, respectively	
				High discomfort group had higher UT and lower CES EMG on right, compared to low discomfort and control groups, which had low UT and high CES EMG.	$t_{40} = 2.37$ $t_{40} = -2.15$, respectively	Significant; $P = .032$ $P = .48$, respectively	
Szeto[35]	39 females, age 20-50 (case 21, control 18)	Experimental case control		Higher sEMG amplitudes	Mean differences of case minus control:	Significant; $P < .001$	1 case participant was not right-hand dominant; all other participants were right-handed
			Typing		Right CES muscles 4.3% MVC, 95% CI 0.1-8.4 and left CES 4.2% MVC, 95% CI 0.2-8.2		
			Mouse use		Right CES 3.1% MVC, 95% CI 0.2-5.9, and left UT 3.6% MVC, 95% CI 0.1-7.2		
			Typing and mouse use		Right CES 3.5% MVC, 95% CI 0.1-6.9		
Johnston[36]	107 females	Experimental controlled	5-minute typing tasks:	Higher EMG 10-seconds	Left CES	Significant;	Effect greatest in right

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Table 8. (*continued*)

Author	Sample	Design	Associated Variable	Associated With Neck Pain	Results	Significance	Comment
	(cohort: 85; controls: 22)		standard copy typing, with mental stressors, with Stroop color word test	post-task in cohort vs controls	$F_{3,103} = 4.0$ Left UT $F_{3,103} = 13.7$ Right UT $F_{3,103} = 9.3$	$P = .01$ $P = .000$ $P = .000$	UT following typing tasks with superimposed stress
				Higher UT EMG during typing with mental stressor	Task x group effect $F_{3,103} = 3.1$	$P = .034$	
				Mild and moderate pain cohort maintained higher EMG readings vs controls, and vs asymptomatic cohort (UT only)	UT CES UT	$P = .000$ $P < .02$ $P < .012$	
Cagnie[37]	20, sex not specified (case: 10, control: 10), all right-handed	Experimental controlled	1-hour typing and mousing task	Oxygen saturation and blood flow diminished in upper, middle, and lower trapezius in both groups	MANOVA time x muscle part F = 3890	Significant; $P = .010$	None
				Blood flow lower in right vs left UT	F = 6075	Significant; $P = .026$	
				Oxygen saturation lower in middle trapezius in case vs control	F = 6000	Significant; $P = .027$	
				Case reported higher pain intensity scores after 30 minutes	F = 18 263	Significant; $P \leq .001$	

CES, cervical erector spinae; *CI*, confidence interval; *CPT*, cold pain threshold; *EMG*, electromyographic; *HR*, hazard ratio; *LS*, levator scapulae; *MANOVA*, multivariate analysis of variance; *MTrP*, myofascial trigger point; *MVC*, maximum voluntary contraction; *NDI*, neck disability index; *Nm*, newton-meters; *OR*, odds ratio; *ROM*, range of motion; *SD*, standard deviation; *SCM*, sternocleidomastoid; *sEMG*, surface electromyography; *UT*, upper trapezius; *VAS*, visual analog scale.

permutations of these variables that may significantly affect neck pain. Research supporting a validated computer workplace ergonomic setup is lacking, and this is evidenced in the broader literature regarding other musculoskeletal complaints, such as low back pain.[24] This information is relevant to occupational health professionals.

Personal Factors

Posture, Duration, and Repetition Domain. Computer work often involves repetitive motor functions of the upper limbs in the use of a keyboard and mouse. A stable posture is necessary to facilitate fine motor skills and to hold the head steady to maintain visual fixation (Table 6). A significant association was found between the 12-month prevalence of neck pain and prolonged neck flexion; however, this study was at risk of recall bias and nonresponse bias and used a nonvalidated scale to collect subjective data.[25] Another study found that neck pain and disability was significantly associated with durations of >2 hours of continuous computer-based tasks, >2 hours spent sitting at a workstation before taking a break, and >6 hours' use of mouse and keyboard, per day.[16] In another study, the same authors found that these factors were buffered by high supervisor support and increased job control, involving greater skill discretion and decision authority.[10] However, these studies were at risk of nonresponse bias and lacked an adequate case definition. A longitudinal study found workers sitting ≥1 hour before taking a break were less likely to experience neck pain.[26] The authors were unable to explain this anomalous result, which conflicts with the broader literature on musculoskeletal pain.

Repeatedly working for prolonged periods in seated positions increased the probability of developing neck pain[25]; however, the authors did not quantify durations or repetitions. Similarly, frequently working for long periods in a posture perceived as uncomfortable was significantly associated with neck symptoms.[27] This study was at high risk of nonresponse bias, lacked an adequate case definition, and used an ordinal scale instead of quantifying frequency intervals. One study found that repetitive movements performed every minute were associated with neck pain,[25] whereas another study reported that the frequency of performing a repetitive activity fell narrowly short of a significant association with neck symptoms.[27] This study did not quantify frequency. The authors of both studies did not describe the repetitive variables, and both were at high risk of nonresponse bias.

Neck pain was significantly associated with bilaterally protracted scapulae in workers, compared to controls.[28] This study included male and female participants, but data were not reported regarding sex. This study was at high ROB across all external validity domains. It is plausible that rest breaks interrupt prolonged postures involving sustained muscle and joint loading, as well as interrupting repetitive motor functions. Increased job control and supervisor support were protective against neck pain associated with duration variables. This is relevant to occupational health professionals.

Individual Risk Factors Domain. Three nonmodifiable risk factors were significantly associated with neck pain: female sex,[10,14,25-27] a history of neck trauma[10,16] or neck symptoms,[12] and age >30 years (this trend declined after 50 years of age)[25] (Table 7).

Significant modifiable risk factors included psychological variables. Negative affectivity was significantly associated with neck pain, and NDI scores increased as severity increased.[16] Anxiety correlated with neck pain, but it did not reach significance, and psychological stress did not show any association.[26] Perceptions of tiredness, or jobs requiring high levels of concentration, were not significantly associated with neck pain,[27] but mental tiredness at the end of the day reached significance.[25,27] The number of sleeping hours were not associated with neck pain,[25] but this study did not examine whether this offered a protective effect. These latter 2 studies were at high risk of nonresponse bias and used unvalidated questionnaires to collect psychological data.

The only modifiable, nonpsychological variable significantly associated with neck pain was physical activity, which showed a protective effect.[25] The authors did not report the type of activity, frequency, intensity, or duration associated with this effect. Cigarette smoking or being an ex-smoker was not significantly associated with neck pain.[14,25]

Age, sex, history of trauma, and negative affectivity are significantly associated with neck pain, as they are with other musculoskeletal conditions reported in the broader literature. Physical activity appears protective against neck pain, but the evidence supporting physical activity in the broader literature for other musculoskeletal complaints, such as low back pain, is low to moderate quality.[24] This is relevant to occupational and clinical health care professionals.

Cervical Function and Myalgia Domain. Most studies that examined cervical function used experimental designs, enabling objective quantification of variables. Many used independent variables that simulated office-based tasks, such as typing and mouse use, to act as stressors upon the cohorts (Table 8).

An experimental study with both male and female participants found that cervical extensor (CE) muscle EMG activity increased significantly from baseline to a low-stress mousing task, but only on the nondominant side (there was a nonsignificant increase on the dominant side). Forward head posture also increased due to significant cervicothoracic flexion. However, there was no change in forward head posture or CE or sternocleidomastoid (SCM) muscle activity between low- and high-stress conditions. The dominant and nondominant upper trapezius (UT) were the only muscles to show significantly elevated EMG values in the presence of high psychosocial stressors. This was not due to a change in peak EMG and, therefore, muscle fatigue.[29] In a study of both male and female participants, those reporting the psychosocial stressor combination of high overcommitment and low reward showed EMG readings significantly higher in their right UT muscles (2% of the maximum voluntary contraction), compared to low overcommitment and low reward. This was accompanied by a significant 5° increase in neck flexion. There was no significant difference among those reporting high reward.[30]

Cervical flexion was significantly reduced in the presence of mild pain. Cervical extension and bilateral cervical rotational range of motion (ROM) was diminished as pain increased, more notably to the left, but these deficits did not reach significance. Bilateral cervical lateral flexion differences were statistically indiscernible between the case and control groups. This study included female participants only.[31] A study of symptomatic males found that global cervical flexion was significantly reduced with UT pain, compared to those with levator scapulae muscle pain, whereas upper cervical flexion was significantly reduced with levator scapulae pain, compared to those with UT pain.[32] A study that included both male and female participants found that an increase in cervical flexion-extension ROM had a protective effect against neck pain and that ≥120° ROM showed a 2.3-fold reduction in neck pain.[26]

Significantly less EMG activity was recorded in the trapezius muscles during slow eccentric, slow concentric, and static contractions in workers with chronic neck pain, compared to asymptomatic controls. There was also a significant difference in the torque generated at the shoulder joint during slow eccentric and slow concentric contractions of the trapezius in the symptomatic workers compared to the asymptomatic controls. Fast concentric contraction EMG values and torque did not reach significance. There was no significant difference in trapezius muscle thickness between groups, leading the authors to discount morphologic factors as an explanation for the differences in EMG activity and torque. The authors postulated that the likely cause of the selective inhibition of the muscles in the chronic neck pain group was pain-induced hypersensitivity activation of nociceptors in groups III and IV. This study only included female participants.[33]

A positive correlation was found between increased EMG activity in the right UT muscle, with right and left neck discomfort; however, left UT activity was not correlated with right and left neck discomfort. This was significantly higher in the high-discomfort group, compared to the low-discomfort and control groups. Participants in the high-discomfort group had significantly higher UT and lower cervical erector spinae (CES) EMG activity on the right, compared to the low discomfort and control groups, both of which displayed the opposite activity (ie, low UT and high CES EMG activity). All participants in this study were female.[34]

Superimposed stress during a typing task significantly increased surface electromyography (sEMG) activity in the SCM and CE muscles of workers with no pain and disability, compared to controls. However, there was no significant difference compared to workers with pain and disability. The authors hypothesized that increased muscle activity precedes symptoms and sensory changes and may also contribute to persistence of symptoms and perceived disability, once chronic pain is established. Higher NDI scores were significantly associated with increased sEMG in SCM and CE muscles during a craniocervical flexion task.[15] Another study found a significant increase in bilateral CES sEMG activity during a simulated typing task, the right CES and left UT muscles during a mousing task, and the right CES during a combination of these tasks (all participants were right-handed, with the exception of 1 case participant).[35] All participants in these 2 studies were female.

In a controlled study of female participants, EMG remained significantly higher in workers 10 seconds after completion of an experimental task, compared to controls, in the left CE and bilateral UT muscles. This significant effect was greatest in the dominant UT after typing tasks with superimposed mental stressors, compared to a typing task without mental stressors, and typing tasks combined with a Stroop test. Workers with mild and moderate pain maintained elevated EMG readings to the UT, compared to controls and asymptomatic workers.[36]

Oxygen saturation and blood flow significantly diminished in all parts of the trapezii muscles in right-handed control and case groups during a 1-hour experimental computing task. Blood flow was significantly lower in the right UT, compared to the left, in both groups after 30 to 40 minutes of the task. Oxygen saturation was significantly lower in the middle trapezius in the case group, who reported significantly higher NDI scores after 30 minutes, compared to controls. The observed reduction in blood flow suggested low oxygen saturation was due to reduced perfusion, and not increased oxygen consumption. It was unclear whether UT vasoconstriction and hypoxia led to nociceptor activation and myalgia, or vice versa. The authors hypothesized that this may have resulted from sympathetically mediated vasoconstriction and higher intramuscular pressure. They conceded that it was not possible to determine whether chronic disturbances in microcirculation may have resulted in sensitization of regional muscle nociceptors, or conversely, that nociception and the release of substance P and calcitonin gene-related peptide may have resulted in localized edema and intramuscular hypoperfusion, manifesting in hypoxia. The authors did not specify the sex of participants in this small study[37]; however, the authors of a study with female participants only hypothesized that increased muscle activity preceded the appearance of symptoms.[15]

A small experimental study of both male and female participants found that UT MTrPs developed after 1 hour of typing at a computer workstation designed to increase postural stress on participants. Electromyographic median cycling frequency of the UT significantly diminished when visual stress was introduced and then significantly diminished further with increased postural stress. This diminished cycling was also significantly spatially related to the location of the MTrPs.

Visual analog scale scores for neck pain were significantly higher with high postural stress but did not reach significance with high visual stress. There was a ROB in this study due to the use of an unvalidated 5-level scale to classify the severity of MTrPs, which relied upon subjective assessment by an assessor and by the participant. Combined with the small number of participants, this may have detrimentally affected reliability.[23]

The CES and UT muscles are important for maintaining posture and control of the upper limb when performing computer-related tasks. Studies that satisfied the inclusion criteria for this review showed increased EMG activity in the dominant UT, which correlated with increased neck pain scores and diminished perfusion and oxygen saturation. Increased EMG activity in the UT was also found significantly correlated with psychosocial and mental stressors. The greatest risk of biases in many studies included within this domain related to methods of participant recruitment (eg, convenience sampling), lack of control groups, and the high risk of confounding biases. Many of these studies only included female participants, so it is not possible to confidently extrapolate results to male workers. These results are relevant to occupational health professionals.

Limitations of the Included Studies

Many studies relied upon voluntary participation from convenience samples, both of which potentially introduced biases and limit the ability to extrapolate data. Most cross-sectional studies were at high risk of nonresponse bias and were particularly susceptible to self-selection and recall biases. These nonrandomized, uncontrolled designs have potentially resulted in statistically overestimated effects.

Great variation exists in the definition of the anatomic boundaries of the neck.[3] Some studies required participants to complete questionnaires about their neck pain. Some used validated questionnaires, such as the Nordic Musculoskeletal Questionnaire, which contained a diagram identifying the anatomic boundaries of the neck. Others included a diagram identifying the anatomic boundaries of the neck or a physical examination by a researcher. These were not validated prior to the study but attempted to standardize the definition of the neck.[9,12,20,22,25,26] One study relied upon a modified Nordic Musculoskeletal Questionnaire, but the authors did not include details of the modifications or effect upon reliability or validity. It could not be determined whether the anatomic boundaries of the neck were defined in this study.[34] Other studies used nonvalidated questionnaires, validated questionnaires such as the NDI or Maastricht Upper Extremity Questionnaire, or nonvalidated modified versions of these, none of which identified the anatomic boundaries of the neck.[10,11,14-16,19,27,31,37] Another study did not identify the method used to determine neck symptoms.[21] The lack of adequate case definitions potentially introduced bias that may have detrimentally affected the external validity of these studies.

Many authors attempted to limit confounding biases, but these were mostly age, sex, weight, height, and other anthropometrical variables. The common nonoccupational use of computers, tablets, smartphones, and video games in prolonged or nonoptimal postures has the potential to confound both dependent and independent variables. Likewise, nonoccupational psychosocial variables have the potential to confound occupational psychosocial variables. Studies that did not examine or control for psychosocial variables may have been affected by the confounding effect of psychosocial variables on neck pain or posture. It is impossible to determine whether these confounders affected the results of the included studies if they were not statistically considered or controlled.

Limitations of This Study

Studies that included anatomic regions other than the neck were excluded. However, many studies that met the inclusion criteria did not adequately define the neck. It is not possible to determine the variations of interpretation of anatomic boundaries of the neck among participants in any of these given studies or among separate study populations. The lack of case definitions has the potential to weaken internal and external validity of these studies and, by extension, to weaken the findings in this review that are based upon these studies.

This review included various study designs and methodologies, resulting in heterogeneous data sets. Some variables associated with neck pain were only investigated by 1 study that met this review's inclusion criteria. Other variables were investigated in more than 1 study, but due to heterogeneous methods, interventions, and outcomes, it was not possible to statistically combine data or present forest plots. Likewise, it was not possible to perform sensitivity analyses. Many studies included in this review were nonrandomized and uncontrolled. Consequently, conclusions of this systematic review, based largely upon nonrandomized studies, are likely weaker than conclusions based upon randomized controlled trials.

Recommendations and Future Studies

More research needs to be conducted into workplace factors associated with occupational neck pain. Future studies should aim to improve homogeneity through standardization of case definitions and methodologic designs that facilitate statistical comparison of interventions and outcomes. Future studies would also benefit from inclusion of control or comparator groups and randomization to reduce biases.

Conclusion

Neck pain was not significantly associated with high job demands, low skill discretion, low decision authority, or low peer support. However, when these variables were combined with increased duration of computing tasks, or ergonomic demands, they reached significance. Supervisor support was found to be the only significant buffer capable of preventing these variables from reaching significance in female office workers. Low levels of support were associated with increased development of neck pain, whereas high levels of support were significantly protective. A history of negative affectivity or neck symptoms or trauma were significantly associated with neck pain, whereas physical activity was significantly protective.

There is a lack of validation of computer workstation ergonomic setups that are protective of neck pain. Among the multiple variables of a computer workstation setup, monitor position was significantly associated with neck pain. When accommodation and convergence were challenged, there was a significant increase in UT EMG activity and subjectively reported neck discomfort. When visual acuity was stressed, slumped lumbar and thoracic spinal postures were observed, accompanied by forward head positioning and increased loading of the cervicothoracic junction, but no craniocervical extension. Neck pain was significantly associated with >2 hours of continuous mouse use, >6 hours of continuous computer use, or computer work performed in stressful postures exceeding 1 hour without regular rest breaks. These rest breaks may disrupt prolonged neuromusculoskeletal postural loading, protecting workers from neck pain.

Female sex was a significant risk factor for experiencing neck pain, especially between the ages of 30 to 50 years. Supervisor support was found to significantly protect against neck pain in female office workers, whereas low support was a significant risk factor. The dominant UT muscle showed increased EMG activity and diminished blood flow in females in the presence of low supervisor support and an association with neck pain.

Neck pain represents a significant health burden. The purpose of this systematic review was to investigate peer-reviewed, published literature examining the workplace factors associated with neck pain experienced by computer users. This review looked at biopsychosocial, environmental, ergonomic, and postural factors; duration and repetition; individual risk factors; and cervical function and myalgia domains. Variables within each of these domains were identified as significant contributors to neck pain. These variables are relevant to health care providers, workplace supervisors, and occupational health professionals.

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Contributorship Information

Concept development (provided idea for the research): P.A.T.

Design (planned the methods to generate the results): G.A.K., P.A.T.

Supervision (provided oversight, responsible for organization and implementation, writing of the manuscript): G.A.K., P.A.T.

Data collection/processing (responsible for experiments, patient management, organization, or reporting data): G.A.K., P.A.T.

Analysis/interpretation (responsible for statistical analysis, evaluation, and presentation of the results): G.A.K., P.A.T.

Literature search (performed the literature search): G.A.K.

Writing (responsible for writing a substantive part of the manuscript): G.A.K.

Critical review (revised manuscript for intellectual content, this does not relate to spelling and grammar checking): G.A.K., P.A.T.

Practical Applications

- High psychosocial stress manifested as upper trapezius myalgia in female office workers but not in males.
- Diminished blood flow appeared to contribute to onset of myalgia and not prolonged loading or fatigue.
- Other neck, back, and shoulder muscles also showed increased sEMG activity and diminished blood flow but remained asymptomatic.
- Supervisor support had a significant buffering effect on the incidence of neck pain.

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