Physical Risk Factors Associated with the Work-Related Neck/Cervical Musculoskeletal Disorders: A Review

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Abstract: Work-related musculoskeletal disorders (MSD) of the neck or cervical spine result in longer sick leaves, substantial levels of human suffering, and high costs for society. Epidemiological studies clearly indicate strong associations between MSD of the neck and the work activities requiring forceful arm exertions and heavy lifting. However, most of the existing studies that evaluate the neck or cervical spine disorders focus mainly on exertions demanding sustained neck postures of repetitive arm exertions. The purpose of this study is to conduct a systematic review of existing epidemiological and experimental studies that evaluates neck or cervical spine disorders and identify the gaps in the literature for future research.

Keywords: Musculoskeletal Disorders, Neck, Cervical Spine

1. Introduction

1.1 Work-related Musculoskeletal Disorders of the Neck or Cervical Spine

Among work-related musculoskeletal disorders (MSD), incidents of neck pain as a cause of absenteeism are not as frequent as low-back pain, yet they contribute significantly to the morbidity in many working populations (Hales &Bernard, 1996). Work-related MSD of the neck encompass a wide range of inflammatory and degenerative diseases and disorders (Buckle & Devereux, 2002). Many types of tissue in the cervical region can be sites of pain, including the neck muscles, intervertebral discs, the posterior longitudinal ligament, and the facet joints (Cailliet, 1991). The neck disorders associated with musculoskeletal pain (i.e., inflammatory types) include tension neck syndrome and trapezius myalgia and are common among the occupations requiring prolonged and repetitive submaximal exertions by the neck muscles, e.g., VDT workers, sewing machine operators, and dentists. On the other hand, the disorders associated with degenerative disc diseases mainly include disorders of the cervical spine and are associated with occupations involved in physically demanding work activities (Hagberg & Wegman, 1987), e.g., health care, construction work, farm work, and manual material handling. Despite of having a high incidence rate among various occupational groups, cervical spine disorders currently remain largely unstudied, with only inferential hypotheses for their etiologies.

NIOSH (1997) performed a critical review of available epidemiologic studies that associate the MSD of the upper extremity and the lower back with exposure to physical factors at work. Over 40 epidemiologic studies were examined to understand the causal relationship between physical workplace factors and the neck/shoulder MSD. Substantial evidence for forceful exertions leading to the occurrence of neck/shoulder MSD was observed in the epidemiologic literature. The “forceful work” for the neck/shoulder was defined as work activities which involve forceful arm or hand movements that apply loads to the neck/shoulder area.

Ariens et al. (2000) reviewed 22 cross-sectional studies, two prospective cohort studies, and one case-referent study to identify physical risk factors for neck pain. The authors reported moderate evidence for a correlation between the work-related forceful arm exertions and neck-shoulder pain, as well as a correlation between heavy lifting and neck–shoulder pain. Malchaire et al. (2001) reviewed fifty-seven cross-sectional and seven longitudinal studies to determine factors associated with

musculoskeletal disorders of the neck and upper limbs. Sufficient evidence was found for a linkage between neck/shoulder disorders and occupational risk factors like repetitiveness, physical workload and static efforts.

Walker-Bone and Cooper (2005) presented a review of existing epidemiological studies that evaluate soft tissue musculoskeletal disorders of neck and upper extremity among a wide range of occupations. The study includes epidemiological studies performed during 1998-2001, as listed in the EMBASE and MEDLINE databases. The results of the reviewed studies indicate that neck pain is associated with exposure to sustained abnormal posture (e.g., prolonged sitting, neck/trunk held in prolonged flexion or rotation), forceful and/or repetitive arm exertions, poor workplace support from supervisors/colleagues, and high work demands on the workers. A review presented by Larsson et al. (2007) confirmed that there was a causal relationship between neck and shoulder disorders and highly repetitive work, forceful exertions, high level of static contractions, prolonged static loads, and extreme postures, as well as combination of these factors.

A state-of-the-art review was presented by NRC/IOM (2001) considering the epidemiological evidence as well as basic science including human biomechanics and experimental evidence research and the evidence from effective interventions. The state-of-the-art review scrutinized the available documentation on possible occupational risk factors for work-related low back and upper extremity disorders. From the perspective of observational epidemiology, the review summarized that there was a significant positive association between upper extremity MSD and exposure to repetitive tasks, forceful tasks, the combination of repetition and force, and the combination of repetition and cold. Vibration was also demonstrated as an important role for upper extremity MSD. From the upper limb biomechanical perspective, the review identified relationships between physical work attributes and external loads for force, posture, vibration, and temperature.

2. Methods

2.1 Search strategy

A comprehensive search was performed in MEDLINE, CINAHL, Google Scholar, and all EBSCOhost databases to find epidemiological and experimental studies on neck and cervical MSD. In order to follow up on the earlier reviews, the search was conducted for the epidemiological studies within the past 10 years (Jan 2000 – Apr 2010), while the search for the experimental studies was conducted within the past 15 years (Jan 1996 – Apr 2010).

The databases were searched for MSD of neck or cervical spine regions, including the terms like tension neck syndrome, trapezius myalgia. Then the search was restricted to the combination of keywords such as work-related, risk factors, association, relationship, predictor, physical exposure. Specifically, the epidemiological studies were searched with words such as cross-sectional, case-control, prospective, cohort; the experiment studies were searched with words such as muscle, activity, electromyography (EMG), neck movement, posture, and load. The references of all identified relevant studies, including reviews, were examined to identify additional relevant articles. The retrieved articles using these strategies were focused on the association between physical exposures and the neck or cervical spine MSDs in an occupational setting.

2.2 Inclusion criteria

Studies were included in the present review if the following conditions were met:

(a) The paper was published in English
(b) The study was conducted among or oriented towards a working population
(c) The exposures assessed were physical risk factors at work
(d) The outcome of epidemiological study included the prevalence/incidence of chronic neck and/or shoulder pain, complaints, or disorders
(e) In epidemiological studies on upper limb disorders or upper extremities or other symptoms, data on neck and/or shoulder symptoms were presented separately
(f) A consistent or significant relationship/association was found between neck and/or shoulder disorders and physical risk factors

2.3 Exclusion criteria

The exclusion criteria were as follows:

(a) Articles of review
(b) Studies focused on back pain and lower extremity symptoms

(c) Studies dealt with upper limb disorders as a whole, not presenting the data on neck and/or shoulders separately
(d) Studies focused on individual or psychosocial factors in the findings of exposures
(e) Studies on acute or traumatic injuries
(f) No consistent or significant relationship/association was found between neck and/or shoulder disorders and physical risk factors.

2.4 Data extraction

The results of the retrieved studies were presented in the form of tables. The findings of physical risk factors were grouped into five categories, according to the previous research and reviews: (1) repetitive motions, (2) awkward postures, (3) forceful exertions, (4) vibration, and (5) poor work or workstation design.

For each epidemiological study, characteristics extracted were the study(Author-year) and design(cross-sectional, cohort, or case-control design), study population (sample size, response rate, and occupational setting), exposure basis (questionnaire responses, or answers to interview questions, or workplace investigations, or other), outcome measurement (self-reported symptoms, or clinical examination, or other), results (prevalence ratio of neck and/or shoulder MSDs, or relative risk ratio of the exposure), and findings of risk factors for neck/shoulder MSD in the study.

For experimental study, characteristics extracted were the study, subjects (sample size), effects of interest (interested factors of the study), objective measurement in the laboratory-based study (muscles measured using electromyography, or body posture, or heart rate recordings, or others), and findings of risk factors for neck/shoulder MSD in the experiment.

3. Results

3.1: Epidemiological Studies

A total of 35 epidemiological studies were finally included in this review: 3 studies were carried out among general working population, not related to any specific occupational groups, 6 studies were carried out among health care workers, 2 studies were carried out among dentists, 11 studies were carried out among visual display terminal (VDT) workers, and 13 studies were carried out among industrial and service sector workers. Table 1 presents a summary of the study characteristics.

3.1.1 General working population

The general working population was examined in some studies to understand the overall trends of MSD, including neck or cervical spine disorders. Of the three studies, two were designed as prospective cohort study, one case-control study and one cross-sectional study. Awkward postures involving twisting or bending of the trunk, prolonged neck bending, as well as working with the arms at or above shoulder height were found in all the reviewed studies as a risk factor for neck/shoulders disorders.

3.1.2 Health care workers

Among the various working populations, the health care workers, especially nurses, ambulance attendants, and home care professionals have a high prevalence of work related neck MSD. The jobs of these professionals demand lifting heavy loads, work in awkward postures, and transfer of patients (Marras et al., 1999). A number of studies used survey questionnaires to identify the prevalence of neck/shoulder disorders among these health care professionals. Of the retrieved six studies, five were cross-sectional and one was longitudinal design. The factor of high force exertions in the patient transfer and manual materials handling tasks was identified by all the studies as a significant contributing factor for the development of neck/shoulder MSD. Half of the studies considered awkward posture as a risk factor for the disorders.

3.1.3 Dentists

Work-related musculoskeletal disorders, especially of the neck and upper limbs, are common among the dentists, dental hygienists. Dental work, a vision-demanding precision task, is characterized by work postures involving a prolonged static work load for the neck, shoulders, and arms (Akesson et al. 1997). Various investigators have pointed out that the dentists and dental hygienists adopt strenuous postures with excessive bending and twisting of the neck, forward bending of trunk, and elevation of the shoulders. The results of the two reviewed studies associated such postures with the risk of developing neck

MSD. Alexopoulos et al. (2004) also reported exposure to vibration tools as another risk factor for the occurrence of neck/shoulder MSD among the dental professionals.

3.1.4 Visual Display Terminal (VDT) workers

The use of computers at work as well as during leisure time has increased worldwide in recent years. The various risk factors, such as static and constrained head and neck posture, long duration of computer and/or mouse and/or keyboard use, repetitive elevated arm movements in seated posture, and poor placement of screen and/or mouse and/or keyboard, associated with the extensive use of computers, motivated researchers to study the development of musculoskeletal symptoms caused by working with computers. Our search retrieved 11 articles that studied the association of work-related physical risk factors and neck/shoulder MSD among VDT workers, with eight cross-sectional studies and three cohort studies.

3.1.5 Workers from various industrial occupations

Both NIOSH (1997) and NRC/ IOM (2001) reviewed a wide range of working populations in various industrial and service sector setting, including: shoe manufacturing assembly line workers, industrial plant workers, foundry workers and manual laborers, workers in aircraft engine division, workers in spinning industry, shipyard welders and plate workers, construction workers, female workers in fish processing, machine operators and carpenters, chocolate manufacturing workers, and letter carriers. Table 1 shows the 13 newest studies since 2000, covering various manufacturing assembly workers, manual workers, call center operators, farmers, machinists, mechanics, house painters, urban bus drivers, cosmetologists, forest industry workers, and sewing machine operators.

Repetitive motion, awkward posture, high force exertions, and use of vibrating tools were concluded as risk factors for the development of neck/shoulder MSD. While poor task related factors like fewer rest breaks, inadequate thermal comfort, and driver-seat mismatch were also listed as the contributing factors for the development of neck/shoulder MSD.

3.1.6 Summary of Epidemiological Studies

Epidemiological studies show a prevalence of neck/shoulder MSD among a variety of occupational groups, showing a strong association between neck/shoulder MSD and forceful exertions, sustained and constrained working postures over an extended period of time, and repetitive arm or shoulder movements. Based on the epidemiological evidence, several laboratory-based studies experimentally examined the work activities of various occupational groups, to understand the mechanism that could cause the neck/shoulder MSD. In the following section, a number of experimental investigations, focusing on the neck/shoulder MSD for various occupational groups, are presented in detail.

Table 1. Epidemiological studies on occupational physical risk factors for neck and/or shoulder disorders (35 studies in total)

Study and design	Study population	Exposure basis	Outcome measurement	Results	Risk factors
Among general working population (3 studies)					
Cassou et al. (2002) Prospective cohort	21,378 French workers first, and 16,950 of them(80%) were followed up	Questionnaire responses	Self-reported symptoms Clinical examination	Neck/shoulder: 10.8%	(1)Repetitive movements (2)Awkward postures
Feveile et al (2002) Prospective cohort	5,940 of 8,664 (69%) Danish workers first, and 3,990 (68%) were followed up	Answers to interview	Self-reported symptoms	Neck/shoulder: 3.5%	(2)Twisting or bending of the trunk
Sim et al (2006) Cross-sectional	5,032 of 10,000 (51%) British workers	Questionnaire responses	Self-reported symptoms	Neck: 24% Shoulder: 31.7%	(2)Prolonged bending of the neck (2)Arms at/above shoulder height (3) Heavy lifting
Among health care workers (6 studies)					
Aasa et al. (2005) Cross-sectional	1,187 of 1,500 (80%) Swedish ambulance personnel	Questionnaire responses	Self-reported symptoms	Neck/shoulder:12%	(2)Awkward postures (3) Heavy manual materials handling
Alexopoulos et al. (2003) Cross-sectional	351 of 420 (84%) Greek nursing personnel	Questionnaire responses	Self-reported symptoms	Neck: 47% Shoulder: 37%	(1)Repetitive shoulder movements (3)Heavy manual materials handling
Lorusso et al. (2007) Cross-sectional	203 Italian X-ray technologists working in hospitals	Questionnaire responses	Self-reported symptoms	Neck: 19.7% Shoulder: 21.2%	(2)Awkward postures (3)Heavy lifting
Smedley et al. (2003) Longitudinal	1,239 of 2,200(57%) female nurses in two hospitals in England	Questionnaire responses	Self-reported symptoms	Neck/shoulder: 34%	(3)Patient handling tasks
Smith et al. (2006) Cross-sectional	844 of 1,162 (73%) hospital nurses in Japan	Questionnaire responses	Self-reported symptoms	Neck: 54.7% Shoulder: 71.9%	(3)Manually handling patients (3)Hard physical work
Trinkoff et al. (2003) Cross-sectional	1,163 of 2,000 (59%) licensed registered nurses from two US state registries	Questionnaire responses	Self-reported symptoms	Neck: 45.8% Shoulder: 35.1%	(2)Awkward postures (3)Heavy lifting loads or patients transfer
Among dentists (2 studies)					
Alexopoulos et al. (2004) Cross-sectional	430 of 490 (88%) Greek dentists	Questionnaire responses	Self-reported symptoms	Neck: 26% Shoulder: 20%	(5)Long working hours with few breaks (2)Strenuous awkward postures (4)Vibration from tools
Morse et al. (2007) Cohort	94 of 400 (23.5%) American experienced dental hygienists	Questionnaire responses	Self-reported symptoms Clinical examination	Neck:72% Shoulder:35%	(2)Working above shoulder height (2)Neck bending

(*continued*)

Table 1 – Continued

Study and design	Study population	Exposure basis	Outcome measurement	Results	Findings of risk factors
Among VDT workers (11 studies)					
Blatter and Bongers (2002) Cross-sectional	5,403 of 11,308 (48%) Dutch office workers	Questionnaire responses	Self-reported symptoms	Neck/shoulder:10.3%	(5)Long duration of computer use
Brandt et al.(2004) Cross-sectional	9,480 Danish computer workers (initial 73%, follow-up 82%)	Questionnaire responses	Self-reported symptoms Clinical examination	Neck: 4.1% Shoulder:3.4%	(5)Duration of mouse >25 hours/week (5)Duration of keyboard use >15hours/week
Chiu et al. (2002) Cross-sectional	150 of 780 (20%) full-time academic staff in one Hong Kong university	Questionnaire responses	Self-reported symptoms	Neck: 46.7%	(2)Poor head and body posture (2)Prolonged seated posture
Cook et al. (2000) Cross-sectional	302 of 431(71%) computer mouse users in Sydney, Australia	Questionnaire responses	Self-reported symptoms	Neck: 59.9 Shoulder: 45.7%	(2)Shoulder elevation (5)Improper screen height
Devereux et al. (2002) Cross-sectional	869 of 1,514 (58%) workers, most were office workers, in UK	Questionnaire responses	Self-reported symptoms	Neck: 34% Shoulder: 35%	(2)Seated static work posture (3)Heavy lifting (5)Working with computers for >75% time
Eltayeb et al.(2009) Prospective cohort	264 Dutch computer office workers	Questionnaire responses	Self-reported symptoms	Neck: 31% Shoulder: 33%	(2)Poor head and body posture (5)Long duration of computer use
Fogleman and Lewis (2002) Cross-sectional	292 of 373 (79%) VDT users in US	Questionnaire responses	Self-reported symptoms	Shoulder:39%	(5)Performing workstation stretches (5)Improper monitor and keyboard position
Jensen (2003) Cohort	3,475 of 5,033 (70%) Danish computer users	Questionnaire responses	Self-reported symptoms	Neck: 43.9%	(5)Highly placed computer screen
Korhonen et al. (2003) Cohort	416 Finish administrative staff surveyed first and 180 of 232 (78%) were followed up	Questionnaire responses	Self-reported symptoms	Neck: 34.4%	(5)Poor physical work environment (5)Poor placement of the keyboard
Palmer et al. (2001a) Cross-sectional	12,262 of 21,201 (58%)British workers, in which 1,871 (16%) were regular keyboard users	Questionnaire responses	Self-reported symptoms	Shoulders:20%	(5)Regular keyboard use for >4 h in an average working day
Sillanpaa et al. (2003) Cross-sectional	298 Office workers, 238 customer service workers, and 247 designers in Finland	Questionnaire responses	Self-reported symptoms	Neck: 63% Shoulder: 24%	(5)Poor placement of mouse and keyboard
Among various industrial workers (13 studies)					
Alipour et al. (2008) Prospective cohort	12,184 of 18,031(68%) workers in a car manufacturing company in Iran	Questionnaire responses	Self-reported symptoms Medical document	Neck/shoulder: 20.5%	(1)Repetitive motion (2)Awkward working and sitting positions
Andersen et al. (2003) Prospective cohort	1,546 of 3,123 (50%) Danish workers from industrial and service sector settings	Videotaped working postures	Self-reported symptoms Clinical examination	Neck/shoulder: 14.1%	(1)Repetitive shoulder movements (2)Neck flexion ≥ 20° for more than two thirds of their working time

(continued)

Table 1 – Continued

Study and design	Study population	Exposure basis	Outcome measurement	Results	Findings of risk factors
Ariens et al. (2001) Prospective cohort	977 of 1,334 (73%) Dutch workers from various industrial and service companies	Videotaped working postures	Self-reported symptoms	Neck: 14.4%	(2)Neck flexion $\geq 20°$ (2)Sitting at work for > 95% working time
Chee et al. (2004) cross-sectional	906 of 968 (94%) women semiconductor workers in 18 factories in Malaysia	Questionnaire responses	Self-reported symptoms	Neck/shoulder:51.3%	(2)Prolonged awkward postures (3)Frequent lifting
Hussain (2004) Cross-sectional	323 of 461 (70%)British truck assembly workers	Questionnaire responses	Self-reported symptoms	Neck: 60% Shoulder: 57%	(2)Neck extension for overhead work (2)Neck flexion (~45º) for a long time (2)Extreme shoulder postures
Palmer et al. (2001b) Cross-sectional	6,913 of 13,225 (53%) British male manual workers	Questionnaire responses	Self-reported symptoms	RR of vibration in Neck: 1.8 (95% CI:1.4-2.3)	(4)High dose of vibration
Rocha et al. (2005) Cross-sectional	95 of 108 (88%) Brazilian female call center operators	Questionnaire responses Workstation observations	Self-reported symptoms	Neck/shoulder: 43%	(5)Fewer rest breaks (5)Inadequate thermal comfort environment
Rosecrance et al. (2006) Cross-sectional	319 of 499 (64%) active farmers in Southeastern Kansas, USA	Questionnaire responses	Self-reported symptoms	Neck: 22.4% Shoulder: 25.9%	(3)Lifting and carrying heavy materials
Svendsen et al. (2004)	1886 male workers (machinists, car mechanics, and house painters)	Questionnaire responses Workplace observations	Clinical examination	Shoulder: 22.5%	(2)Upper arm elevated at above 90º
Szeto and Lam (2007) Cross-sectional	479 Hong Kong urban bus drivers	Questionnaire responses Physical assessment Workstation observations	Self-reported symptoms	Neck: 52%	(5)Driver-seat mismatch (5)Prolonged seated posture
Tsigonia et al. (2009) Cross-sectional	106 of 114 (90%) Greek certified beauty therapists	Questionnaire responses	Self-reported symptoms	Neck: 58% Shoulder: 35%	(2)Strenuous shoulder movements (4)Use of vibrating tools
Viikari-Juntura et al. (2001) Longitudinal	5,180 of 7,000 (75%) Finnish forest industry workers	Questionnaire responses	Self-reported symptoms	Neck: 33.5%	(2)Working with hands above shoulder level (2)Twisting movements of the trunk
Wang et al. (2007) Cross-sectional	520 of 555 (94%) sewing machine operators in USA	Standardized interviews	Self-reported symptoms	Neck/shoulder: 24%	(3)High physical exertions and loads (5)High work-rest ratio

3.2 Experimental Studies

This section provides a review of the experimental studies on neck or cervical spine MSD in different occupational settings. The objective of this section is to examine the biomechanical evidence of association between physical occupational demands and the risk of developing neck or cervical spine MSD. A total of 31 experimental studies were finally retrieved, which were carried out among dentists (2 studies), VDT workers (13 studies), and different industrial workers (16 studies). Table 2 shows the summary of the study characteristics.

3.2.1 Health care workers

Westgaard et al. (2001) studied shoulder muscle activity as a risk indicator for shoulder and neck pain in female healthcare workers. Authors recorded the EMG activity of the upper trapezius muscles throughout the workday from shopping center workers (n=22) and healthcare workers (n=44). Holte and Westgaard (2002) did a further study among 96 workers from four occupational groups: health care (n=20), retail (n=22), banking (n=26), and university secretaries (n=26). In these two studies the EMG activity level in the trapezius muscles was found to be very low, despite the high prevalence of neck/shoulder MSD among the population studied. Authors of the two studies concluded that it was difficult to argue that the observed trapezius EMG activity represented a risk of shoulder and neck complaints. Alternatively, psychosocial stressors appeared to be causative in the development of shoulder and neck pain for workers in service occupations.

3.2.2 Dentists

Even with the best ergonomic equipment, dentists can find themselves in sustained awkward postures. These postures often consist of forward bending and repeated rotation of the head, neck and trunk to one side. Valachi and Valachi (2003) found that dentists frequently assume forward-head-and-rounded-shoulder posture that increases forces on the upper neck muscles (upper trapezius and levator scapulae) and anterior muscles (scalene, sternocleidomastoid and pectoralis), and these muscles become much weaker over time.

Two studies were retrieved since 1996. They concluded that awkward postures, e.g. prolonged neck flexion and/or forward head bending, and/or working with upper arm abduction, as a risk factor for dentists to develop neck or cervical spine MSD.

3.2.3 VDT workers

In recent years, several studies have been performed to evaluate the effects of different aspects of the computer workstations, together with their effect on the role of the neck/shoulder musculature.

The Table 2 present 13 studies on relationship of VDT work to the increased risk of neck or cervical spine MSD. Half of them found awkward body posture, such as neck flexion, head or trunk inclination and arm movements in seated posture, as a risk factor for neck/shoulder symptoms. Other half studied the impact of poor work or workstation design, e.g., poor placement of screen and/or mouse and/or keyboard, use of bifocal lenses, strenuous work-rest schedules, all of which resulted in the increased risk of neck/shoulder MSD symptoms among VDT workers.

3.2.4 Workers from various industries

Table 2 shows16 studies among workers from various industries. In the selected studies, subjects were instructed to do special industrial work activities: masonry works with handling blocks, static overhead drilling or tapping, repetitive forearm supination, static heavy lifting, meat cutting, prolonged writing, working with hand grip in elevated arm position, light manual precision work, and house painting with different work techniques.

Most of the reviewed studies have reported awkward posture (e.g., overhead exertion, neck flexion and extension, forearm supination and additional shoulder abduction, working with arms at or above shoulder level) as the risk factors for neck/shoulder MSD.

3.2.5 Summary of Experimental Studies

A wide range of occupations and/or work activities have been studied experimentally to understand the causal risk factors associated with the neck/shoulder pathologies.

Mostly EMG of the neck/shoulder region muscles was used to understand the contribution of the neck/shoulder muscles, which then were interpreted to understand the underlying mechanism of neck/shoulder MSD. In the investigations

presented above, the EMG of the neck/shoulder muscles was found to show a characteristic association with the different work activities; however, work activities studied so far mainly consisted of repetitive arm movements with little or no forceful arm exertions and tasks requiring prolonged static neck postures.

Table 2. Experimental studies on occupational physical risk factors for neck and/or shoulder disorders (31 studies in total)

Study	Subjects	Effect of interest	Objective measurement	Risk factors
Among dentists (2 studies)				
Akesson et al. (1997)	n = 12	Work load of dentists	(1)EMG of upper trapezius muscle, and others (2)Body positions and movements	(2)Steep and prolonged forward head bending
Finsen et al. (1998)	n = 8	risk factors in dentistry	EMG of splenius ad upper trapezius muscles	(2)Prolonged neck flexion (2)Upper arm abduction
Among VDT workers (13 studies)				
Balci and Aghazadeh (1998)	n = 14	monitor locations	Work performance	(2)Lower monitor angle (5)Use of bifocal lenses
Balci and Aghazadeh (2003)	n = 10	work-rest schedules type of task	Task performance	(5)Fewer micro breaks
Bauer and Wittig (1998)	n = 8	positions of screen and copy holder head posture	(1)EMG of upper trapezius, splenius, cervical erector spinae muscles (2)Head posture	(2)Head inclination
Chen and Leung (2007)	n = 12	different slanted angles of mouse	EMG of upper trapezius muscle, and others	(5)Using mouse with low slanted angle
Delisle et al. (2006)	n = 18	computer office workstations offering forearm support	EMG of upper trapezius, anterior deltoid muscles, and others	(2)Neck flexion during keyboard work (5)Poor workstations design
Dennerlein and Johnson (2006)	n = 30	different computer tasks upper body postures	(1)EMG of anterior and medial deltoid, upper trapezius muscles (2)Body posture	(5)Using both mouse and keyboard (5)High mouse position
Haughie et al. (1995)	n = 54	forward head posture cervical backward bending	Cervical range of motion	(2)Forward head posture (2)Less cervical backward bending
McLean (2005)	n = 18	postural correction	EMG of levator scapulae, upper trapezius, supraspinatus, posterior deltoid, major rhomboideus, cervical erector spinae, and sternocleidomastoid muscles, and others	(2)Forward head posture
Mork and Westgaard (2007)	n = 26	arm posture and movement	(1)EMG of upper trapezius muscle (2)Arm posture and movement (3)Heart rate	(2)Arm elevation in seated posture
Psihogios et al. (2001)	n = 20	monitor placement	Posture angles	(5) Poor placement of monitor
Szeto et al. (2002)	n = 16	neck and shoulder postures	Postural angles and movements	(2)Forward head posture
Turville et al. (1998)	n = 12	monitor placements	(1)EMG of upper trapezius, cervical erector spinae, levator scapulae and sternocleidomastoid muscles, and others (2)Body posture (3)Heart rate	(5)Improper monitor placement
Villanueva et al. (1997)	n = 10	different screen height sitting posture	(1)EMG of neck extensor and upper trapezius muscles (2)Body posture	(2)More flexed neck (2)Trunk inclination

(continued)

Table 2 – Continued

Study	Subjects	Effect of interest	Measurement	Findings of risk factors
Among various industrial workers (16 studies)				
Anton et al. (2001)	n =20	Overhead drilling position	(1)EMG of anterior deltoid, and others (2)Shoulder joint moment	(2)Overhead posture at far reach position
Anton et al. (2005)	n = 21	concrete block weight wall height	(1)EMG of upper trapezius muscle, and others (2)Heart rate	(2)Working with arms at or above shoulder level
Bertmaring et al. (2008)	n = 10	Static overhead work	(1)Thermal images of both arms (2)Shoulder angle (3)Exertion level	(2)Overhead exertions with high shoulder angle
Brookham et al. (2010)	n = 10	Shoulder flexion and humeral rotaion during hand exertion tasks	EMG of anerior, middle and posterior deltoid, upper trapezius, infraspinatus muscles, and others	(2)Awkward postures with shoulder flexion and humeral rotation
Chopp et al. (2010)	n = 14	Work configuration, target angle and hand force direction during overhead work	EMG of upper trapezius, anterior, middle and posterior deltoid, infraspinatus muscles, and others	(2)Overhead work when pulling backwards
Ebaugh et al. (2006)	n = 20	Scapulothoracic and glenohumeral kinematics during overhead activities	(1) EMG of upper trapezius, anterior and posterior deltoid, and infraspinatus muscles, and others (2) Scapulothoracic and glenohumeral kinematics	(2)Increased amounts of scapulothoracic motion and decreased amounts of humeral external rotation
Garg et al. (2006)	n = 10	Short-cycle overhead work tasks	EMG of upper trapezius and middle deltoid muscles	(2) Strenuous overhead work with combinations of weights, arm exertion time and shoulder posture
Grant and Habes (1997)	n = 15	meat cutting tasks	(1)EMG of posterior deltoid muscle, and others (2)Maximum force exertion capacity	(2)Working with hand at or below shoulder level
Jiang et al. (2006)	n = 20	repetitive forearm supination task	(1)EMG of upper trapezius and medial deltoid muscles, and others (2)Upper body motion	(2)Forearm supination and shoulder abduction
Leonard et al. (2010)	n = 50	prolonged writing task	EMG of upper trapezius muscle	(1)Prolonged and continuous writing tasks
Nussbaum et al. (2001)	n = 16	Fatigue and endurance limits Overhead work	EMG of anterior and medial deltoid, infraspinatus, and trapezius muscles	(5)Improper work/rest schedule
Nimbarte et al. (2010)	n = 15	Manual materials handling tasks	(1)EMG of sternocleidomastoid and upper trapezius muscles (2)Maximum shoulder height static strength	(2)Neck flexion and extension (3)Heavy lifting
Sood et al. (2007)	n = 10	Prolonged intermittent overhead work at different working heights	EMG of anterior and medial deltoid, and upper trapezius muscles	(2)Overhead work at high working heights
Sprrong et al. (1996)	n = 9	Hand grip force in different arm positions	EMG of upper trapezius, middle deltoid, supra- and infra-spinatus muscles	(2)High handgrip force in elevated arm positions
Sporrong et al. (1998)	n = 10	Light manual precision work	EMG of upper trapezius, anterior and medial deltoid, levator scapulae, major rhomboideus, supra- and infra-spinatus muscles	(2)Working with the arm in its highest location
Stenlund et al. (2002)	n = 40	House painter's work techniques during overhead work	Kinematic measurements by motion analysis system	(2)Overhead work not using pushing technique

4. Discussion

In most epidemiological studies reviewed, the exposure assessment was based on the questionnaire responses from subjects, making the studies difficult to interpret. Very few studies (Andersen et al., 2003; Ariens et al., 2001; Rocha et al., 2005; Svendsen et al., 2004; Szeto and Lam, 2007) described the job characteristics, such as working postures, arm and head movements, physical assessment, and workstation observations. Overall, the results of experimental studies indicate that neck and shoulder muscles play a significant role in various tasks in occupational settings, such as VDT workers, dentists, light assembly, and construction workers. Repeated muscle contraction predominantly has been shown to be a cause of neck and shoulder MSD. Based on the review of physical risk factors associated with neck shoulder pain, by Westgaard (1999), muscle activation at or above 8-10% of maximal voluntary contractions (MVC) is associated with MSD . Particularly isometric muscle contraction has been suggested to create intramuscular pressure, which might lead to tears of muscle fibers, inadequate arterial circulation, reduced blood flow, and delayed dissipation of metabolites, which can result in structural tissue deformation and localized muscle fatigue (Cailliet, 1991; Armstrong et al., 1993; Hagberg and Wegman, 1987).

Electromyography (EMG) has been extensively used in most of the experimental studies to quantify muscular load or fatigue. While translating EMG activation of the muscles into physical risk factors associated with neck and shoulder disorders, upper trapezius muscle (along C7-Acromion bone level) has been widely studied to quantify the shoulder muscle load (Akesson et al., 1997; Anton et al., 2005; Bauer and Wittig, 1998; Brookham et al., 2010; Chen and Leung, 2007; Chopp et al., 2010; Delisle et al., 2006; Dennerlein and Johnson, 2006; Ebaugh et al., 2006; Finsen et al., 1998; Garg et al., 2006; Jiang et al., 2006; Leonard et al., 2010;McLean, 2005; Mork and Westgaard, 2007; Nimbarte et al., 2010; Nussbaum et al., 2001; Sood et al., 2007; Sporrong et al., 1996; Sporrong et al., 1998; Turville et al., 1998; Villanueva et al., 1997).

Some other muscle groups that were studied to quantify the muscle load in the cervical spine region were sternocleidomastoid (McLean, 2005; Nimbarte et al., 2010; Turville et al., 1998), anterior, medial, and posterior deltoid (Anton et al., 2001; Brookham et al., 2010; Chopp et al., 2010; Delisle et al., 2006; Dennerlein and Johnson, 2006; Ebaugh et al., 2006; Garg et al., 2006; Grant and Habes, 1997; Jiang et al., 2006; Nussbaum et al., 2001; Sood et al., 2007; Sporrong et al., 1996; Sporrong et al., 1998), supraspinatus and infraspinatus (Brookham et al., 2010; Chopp et al., 2010; Ebaugh et al., 2006; McLean, 2005; Nussbaum et al., 2001; Sporrong et al., 1996; Sporrong et al., 1998), cervical erector spinae (Bauer and Wittig, 1998; McLean, 2005; Turville et al., 1998), splenius (Bauer and Wittig, 1998; Finsen et al., 1998), levator scapulae (McLean, 2005; Sporrong et al., 1998; Turville et al., 1998), major rhomboids (McLean, 2005; Sporrong et al., 1998), and neck extensor (Villanueva et al., 1997).

The work-related physical risk factors for neck and shoulder MSD have been documented by the reviewed experimental studies commonly include: (1) repetitive motions, (2) awkward postures, (3) forceful exertions, (4) vibration, and (5) poor work or workstation design.

4.1 Repetitive motions

There is evidence for a causal relationship between highly repetitive motion and neck/shoulder MSD from the reviewed epidemiological studies, e.g. Cassou et al. (2002), Alexopoulos et al. (2003), Alipour et al. (2008), and Andersen et al. (2003). Most of the studies defined “repetitive task” as work activities that involve continuous repetitive hand or arm movements. Examples of repetitive tasks are sewing machine work, packing, continuous data entering, shop cashier, deboning ham or poultry, and manual machine feeding (Andersen et al., 2003). Leonard et al. (2010) studied subjects performing prolonged and continuous writing tasks, and found that the mean EMG activity of upper trapezius muscle was significantly higher in subjects with neck pain as compared to the asymptomatic group.

4.2 Awkward postures

There is strong evidence that working with sustained awkward postures involving neck/shoulder muscles put individuals at high risk of neck/shoulder disorders. In particular, working with arm at or above shoulder level, shoulder abduction, neck flexion and extension, and forward head posture have been frequently concluded as the important parameters of awkward postures.

4.2.1 Neck flexion and extension

Neck flexion was suggested as the main cause of neck/shoulder disorders. The assumed causative factor is static contraction of the neck and shoulder muscles to counteract the weight of the head (Hagberg, 1984). Thus, the greater the angle of the neck flexion, the greater the load on the muscles and joints (Magnusson and Pope, 1998). Szeto et al. (2002) found that office workers with neck and shoulder pain had generally more head tilt and neck flexion posture than asymptomatic workers.

More flexed neck were found to impose more static load on the upper trapezius muscle as measured by EMG, among computer workers (Delisle et al., 2006), dentists (Finsen et al., 1998), and construction workers doing manual materials handling tasks (Nimbarte et al., 2010). The study performed by Villanueva et al. (1997) also found that there is a significant correlation between neck flexion and neck extensor muscle activity among VDT workers. Among construction workers performing manual material handling tasks, independent of the weight lifted, the sternocleidomastoid muscle was most active at the extended neck posture (Nimbarte et al., 2010).

4.2.2 Forward head posture

The discomfort posture of forward bending of the head has been suggested as a risk factor for developing neck and shoulder MSD among VDT workers (Bauer and Wittig, 1998; Haughie et al., 1995; McLean, 2005; Szeto et al., 2002) and dentists (Akesson et al., 1997).

Dentists and VDT workers often assume prolonged forward head posture, which may shorten the soft tissues, and cause muscle tension, weakness and fatigue. When head position is too far forward, it will make the small spinal muscles to work twice as hard as they normally would (Ming et al., 2004). Because neck muscles partially loose the support of the spine in this position and must do much of the work to keep head in this awkward posture, they become overloaded and may result in various pain conditions in the neck and shoulder area.

4.2.3 Discomfort shoulder/arm postures

Electromyographic studies have shown significantly increased muscle activity shoulder muscles in work situations with the arms at or above shoulder level or at the highest location (Anton et al., 2005; Sporrong et al., 1998), overhead exertions (Anton et al., 2001; Bertmaring et al., 2008; Chopp et al., 2010; Garg et al., 2006; Sood et al., 2007; Stenlund et al., 2002), arm elevated in seated posture (Mork and Westgaard, 2007), shoulder abduction and/or flexion and/or humeral rotation (Brookham et al., 2010; Ebaugh et al., 2006; Finsen et al., 1998; Jiang et al., 2006), and high handgrip force in elevated arm positions (Sporrong et al., 1996).

When the arms are elevated during work activities, large number of muscles of the shoulder joint are involved. Poppen and Walker (1978) found the glenohumeral joint forces at 90^{o} of shoulder abduction to be close to body weight. Thus, great muscle forces are necessary to keep the arms elevated, especially in working postures where the arms are at or above shoulder level and the arms are unsupported (Magnusson and Pope, 1998). Hagberg et al. (1984) proposed that working with elevated arms may accelerate degeneration of the rotator cuff tendons through impairment of circulation due to static tension and compression of tendons against underlying bone.

4.3 Forceful exertions

There is also evidence for correlation between forceful exertions or strain and the occurrence of neck/shoulder MSD. Most of the epidemiological studies reviewed found high prevalence rate of neck/shoulder MSD among health care workers, who are frequently involved in heavy lifting and patient handling tasks (Aasa et al., 2005; Alexopoulos et al., 2003; Lorusso et al., 2007; Smedley etal., 2003; Smith et al., 2006; Trinkoff et al., 2003). Chee et al. (2004) found that there is a causal relationship between frequent heavy lifting and neck/shoulder MSD among female semiconductor workers. Farmers who are involved in lifting and carrying heavy materials were found to have high prevalence rate of neck and shoulder disorders compared to other farmers (Rosecrance et al., 2006). Nimbarte et al. (2010) found that there was high levels of muscle activation and static load of the sternocleidomastoid and upper trapezius muscles during manual materials handling tasks that involve forceful arm exertions among construction workers.

4.4 Vibration

Three reviewed epidemiological studies found some evidence that exposure to vibrating hand tools or machines may increase the risk of neck/shoulder MSD. Alexopoulos et al. (2004) found statistically significant association between exposure to vibrating tools and the complaints of shoulder pain with high odds ratio (OR) of 2.57 (95% CI: 1.01-6.51) among 430 dentists. Palmer el al. (2001b) demonstrated that the relative risk (RR) of developing neck pain among workers who were exposed to more than 2.8 m/s^2 daily were 1.8 times (95% CI: 1.4-2.3) higher than those never exposed to hand-transmitted vibration tools. However, since vibration is maximally transmitted to the fingers and hands, the transmission to the upper limb and neck depends on vibration frequency. Thus the highest relative risk was observed at the elbow with the value of 3.7 (95% CI: 1.8-7.5). Tsigonia et al. (2009) found that handling vibrating tools appeared to have a significant relationship for cosmetologists to care seeking because of neck pain. “Use of vibrating tools” may indicate that cosmetologists need to work

with their trunk severely flexed, which may lead to awkward and constrained neck posture burdening the neck muscles and vertebrae.

4.5 Poor work or workstation design

Poor work or workstation design factors such as long duration of computer and/or mouse and/or keyboard use among VDT workers (Blatter and Bongers, 2002; Brandt et al., 2004; Devereux et al., 2002; Eltayeb et al., 2009; Palmer et al., 2001a), improper placement of monitor/screen and/or mouse and/or keyboard (Cook et al., 2000; Fogleman and Lewis, 2002; Jensen, 2003; Korhonen et al., 2003; Sillanpaa et al., 2003), fewer rest breaks during working time (Alexopoulos et al., 2004; Rocha et al., 2005), poor physical environment (Korhonen et al., 2003; Rocha et al., 2005), and other improper anthropometric workstation design (Fogleman and Lewis, 2002; Szeto and Lam, 2007) were found as risk factors for the developments of neck/shoulder MSD in the epidemiological studies.

Laboratory studies have shown that computer users working with poor VDT workstation, such as workstations without forearm support, improper placement of monitor/screen and/or mouse and/or keyboard may increase muscular activity in the upper trapezius muscle as well as other muscles in the neck-shoulder area, e.g. anterior and medial deltoid, cervical erector spinae, and sternocleidomastoid muscles (Chen and Leung, 2007; Dennerlein and Johnson, 2006; Delisle et al., 2006; Turville et al., 1998). The study of Psihogios et al. (2001) showed that the participant's location preference generally corresponded to the location in which he or she experienced neck discomfort. Balci and Aghazadeh(1998) found that the 40^{o} angle monitor caused less neck discomfort than the 15^{o} angle monitor. Authors also demonstrated that VDT users with bifocal lenses had significantly higher neck discomfort and lower performance than nonbifocal users.

Balci and Aghazadeh (2003) found that 15-minute work/micro breaks work-rest schedule resulted in significantly lower discomfort in the neck, as well as lower back and chest region than other schedules for data entry work. Nussbaum et al. (2001) simulate overhead assembly tasks with two different duty cycles: 20-minute work/40-minute rest (20/40) and 40-minute work/20-minute rest (40/20). The study demonstrated that work-rest schedule is a critical parameter in the work tasks design. The results also suggested that emphasis should be placed on the anterior and middle deltoid muscles, given that signs of fatigue were more frequently apparent in either upper trapezius or infraspinatus muscles.

5. Conclusion

The present review took a comprehensive and interesting approach from both epidemiological and experimental perspectives, developing a systematic list of physical factors that are associated with MSD of the neck region. The present review confirms findings from previous studies about the causal relationship between neck MSD and repetitive movements, awkward working postures, forceful exertions, as well as poor work or workstation design and high dose of vibration. There is need for future research that explores effect of exposures that combine physical, workstation and psychosocial factors on the response of neck musculature to improve our understanding of causation and prevention of work-related neck/cervical MSD.

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