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Environmental Health Insights

Supplementary Issue: Occupational Health and Industrial Hygiene

Workplace Exercise for Control of Occupational Neck/Shoulder Disorders: A Review of Prospective Studies

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ABSTRACT: A review was conducted of prospective studies (1997–2014) examining the efficacy of exercise as a workplace intervention to control neck/shoulder pain, symptoms, and disability. The review identified 38 relevant studies – 20 were classified with positive effects, 13 with null effects, and 5 as inconclusive. Of the positive studies, 12 were consistent with Level I evidence, 3 with Level II evidence, and 5 with Level IV evidence. Specific resistance training (SRT) exercise appeared to be associated with more positive studies (eight Level I studies) than other exercise modalities such as general resistance training, general physical exercise, stretching, and movement awareness exercises. Studies of longer trial duration tended toward more null findings and lower program compliance. Evidence for a primary *preventive* effect of workplace exercise is minimal. The findings of this review suggest that workplace exercise can be effective as tertiary prevention and therapeutic relief of neck/shoulder symptoms, at least over the shorter term.

KEYWORDS: shoulder, musculoskeletal disorders, exercise, pain, disability, workplace, occupational

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Background

The most recent US Bureau of Labor Statistics (BLS) survey of general US industry indicates 7.1 recordable occupational shoulder injuries and 1.3 neck injuries (under sprains, strains, tears or soreness, pain classifications) per 10,000 workers.[1] While this is a lower injury rate than that for back injuries, median lost time per case for shoulder injuries (25 days) is over 3 times that for back injuries and twice that of the average musculoskeletal disorder (MSD) case. This is reflected in the costs of these injuries. In a 2006 state workers compensation system report,[2] the average direct cost for a compensable shoulder injury claim was $14,651 (in 2004 dollars), which was 37% higher than for the average back injury claim. Lost time and direct costs represent only a portion of the direct and indirect societal burden, as it is well known that sufferers of neck- and/or shoulder-related pain and many clinical disorders continue to work.[3]

This review summarizes recent literature regarding the use of exercise as a workplace-based intervention for the control of work-related musculoskeletal disorders (MSDs) of the neck/shoulder. A number of exercise physiology theories support a plausible therapeutic and/or preventive role of exercise in the control of occupation-related musculoskeletal pain. General physiologic responses to exercise relevant to a therapeutic and/or analgesic effect include improved systemic circulatory and vasodilatory capacity[4] and increased stimulation of

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pituitary endorphins.[5] General fitness training has been shown to induce transient elevations in pain threshold,[4] and exercise that promotes increased muscle strength may moderate pain due to a reduction of the relative physical load at work.[6]

For painful and disabling conditions of the shoulder, such as shoulder impingement, specific protocols have been based on lengthening (stretching) and strengthening targeted tissues to improve outcomes through adaptations such as follows:

1. Improved contractile capability of the active stabilizers of the glenohumeral and scapulothoracic joint[7–9];
2. Reduced tightness of pectoralis[3,8,9];
3. Reduced tightness of the posterior capsule and increased strength of the shoulder rotator musculature[7,8];
4. Improved ability to resist activation of the upper trapezius in normal scapulothoracic kinematics.[3,10]

In spite of the physiologic basis for these exercise protocols, there has been uncertainty and lack of consensus regarding the appropriate role of exercise in the workplace for prevention and control of upper extremity MSDs.[11,12] Two factors that may have contributed to this uncertainty include the lack of reasonable opportunity for exercise in the workplace through lack of time and/or access to exercise facilities/equipment and conflicting evidence regarding the efficacy of workplace exercise programs with regard to improved MSD outcomes.

In 1995, McGorry and Courtney[11] reviewed eight studies of upper extremity exercise intervention programs in the workplace and their efficacy in the control of CTDs (cumulative trauma disorders). Only three studies reported statistical testing, and only one showed a statistically significant positive outcome attributable to the exercise intervention, and this was a physiologic outcome. The authors concluded that there was insufficient evidence to conclude that worksite exercise programs significantly reduced CTD incidence or symptoms. In 2006, McGorry and Courtney[12] updated their review by summarizing six new studies, but the conclusion was similar to that of the review a decade earlier. In a 2009 systematic review, it was concluded that supervised workplace exercise, using heavy resistance, had positive effects in controlling neck pain, and to a lesser extent, back pain, but no effect in reducing specific shoulder pain.[13] This is in contrast to the findings in studies of rehabilitative exercise treatment in which three reviews[14–16] have reported at least *limited evidence* of exercise effectiveness in the treatment of subacromial impingement syndrome. Another recent review of workplace management of upper-limb MSDs[17] concluded that there is limited but high-quality evidence that multidisciplinary rehabilitation programs, including both physical (pain management, exercises, relaxation, ergonomic education) and psychosocial (cognitive behavioral, coping strategies, stress management) components, are beneficial workplace interventions for nonspecific arm pain.

In their 1995 paper, McGorry and Courtney[11] differentiated MSD prevention exercise programs, defined as those "…executed on the shop floor or in the office and involve several breaks from the work routine" (p. 22), from employer-sponsored corporate fitness or wellness programs occurring outside work hours and emphasizing general physical exercise and cardiovascular fitness. Current trends may be eroding this distinction as integrated health protection and health promotion programs are believed to be more effective in safeguarding and improving total worker health than traditionally disjointed programs.[18] Increasing emphasis on workplace health promotion and employee "wellness" may also be increasing the opportunities for workplace exercise. According to a 2013 employer health benefits survey, 69% of employers with over 200 employees and 84% of the largest employers currently provide on-site, or offer membership discounts to, exercise facilities.[19] This is a 15% increase from that reported in 2008, and the survey did not even report employer-sponsored exercise in 2005. Increasing employer support for exercise *opportunity* is apparent; however, evidence of a translation of this opportunity into improved health outcomes is tenuous.

Workplace health promotion programs have traditionally focused on general physical exercise to address cardiorespiratory fitness, cardiovascular disease (CVD), and metabolic/obesity risk factors, rather than prevention of MSDs.[11] However, public health policy initiatives to address these risk factors may be influencing the prescription of exercise in a broader workplace health promotion context. An example is the current US emphasis on the aging workforce and recommendations that employers promote exercise and weight management programs in the workplace management of arthritis.[20] Concurrently, a recent, widely published, one-year randomized control trial (RCT) has evaluated workplace resistance training program with a focus on relief of neck/shoulder pain.[21–24] Additional recent studies have addressed the challenges with workplace exercise compliance by establishing training locations in proximity to employee workstations,[25] by designing self-directed programs with minimal equipment so that exercises can be performed at work or at home,[26] and by evaluating the efficacy of brief resistance training sessions.[27,28]

Given the recent emphasis on the workplace as an environment for health and exercise promotion, as well as growth in the literature related to workplace exercise to address musculoskeletal pain, an updated review on exercise for neck/shoulder MSD control is warranted. The present review sought to identify recent workplace exercise studies relevant to the control of shoulder and neck/shoulder pain with specific consideration given to the design of exercise programs: namely exercise modality, exercise time/dose, program duration, and program compliance, all of which have unique considerations in the workplace.

Methods

Search strategy. We searched the literature from 1997 to 2013 related to workplace exercise and the control of occupational pain and disability of the shoulder and neck/shoulder. The literature search was conducted through PubMED

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in addition to databases for CINAHL, CISILO, Embase, Ergonomics Abstracts, Health and Safety Science Abstracts, HSELine, OSHLine, PubMed, SportDiscus, Web of Science, and WorldCat using the search terms shown in Table 1. Except where noted, the PubMED search used these terms as a controlled MeSH vocabulary. The other databases were searched on text words. The emphasis of the review was on studies with occupational study populations in which the exercise program was administered as an intervention to address shoulder pain, symptoms, or disability. The review included studies for which exercise was primarily a workplace intervention; however, several studies included occupational groups and addressed occupational shoulder or neck/shoulder pain, but the program consisted of home exercises (or home in combination with the workplace) or a program at a therapy clinic. These studies were included. The strategy was to exclude studies in the areas of athletic and sports performance, general fitness training, and the strength and conditioning literature, which were general nonoccupational study populations and not considered workplace-administered exercise. The review was defined more broadly to include articles in which the shoulder or neck/shoulder was revealed in the search strategy because a number of exercise intervention studies include neck/shoulder pain outcomes together. Studies were excluded if a publication was not available in English or if the study was not prospective in design.

The initial search returned 393 references, which were manually filtered for possible relevance. This resulted in 116 primary references identified for which abstracts were reviewed by a single author. Studies were frequently rejected because the workplace intervention did not include exercise. After review of these abstracts, full articles were retrieved for 46 studies. An additional nine studies and abstracts were identified from reference lists. After further screening of full articles and combining duplicate publications, 38 relevant studies[3,4,6,8,10,21,25–56] were included in the final review.

Data extraction. Data extraction from the articles was performed by a single author and entered into a form indicating the publication year, country, occupational group from which participants were recruited, inclusion criteria (diagnosis), exercise modality, exercise environment, study design, measure of program compliance, progressive nature of exercise training, program duration, sample size, percentage continuation with program, exercise training sessions frequency, exercise session duration, total exercise time, outcomes, and statistical summary. We did not document the funding sources because we did not think commercial interests were a potential source of bias in these studies.

Each study was assessed according to the levels of evidence, considering its design/randomization, consistent with evidence-based medicine guidelines.[57] Level I evidence (strongest) was assigned to RCTs, and Level II to lower quality control group trials with group-level randomization or matched controls. Level IV (weakest) was assigned to case series designs and study designs lacking a nontreatment control group (eg, comparing two types of exercise programs). The review adhered to guidelines of Preferred Reporting Items for Systematic Reviews and Meta-analyses (PRISMA)[58] with some key exceptions. A protocol was not registered for this review. Second, risks of bias in individual studies and across studies were not formally assessed beyond the randomization of treatment, as described previously. The most notable source of potential bias, prevented by blinding of participants to the intervention treatment, is infeasible with an exercise program. We did not document concealment of allocation of studies because this was rarely reported in the articles. Third, no *quantitative* synthesis of results, or meta-analysis, is reported.

Studies were classified according to a positive or null effect, indicated by a statistically significant (0.05 alpha error criterion) reduction in musculoskeletal outcomes attributable to exercise, without the confounding presence of co-intervention. If no statistically significant improvement in outcome was associated with exercise, the study was classified as a null effect (no difference between exercise group and the nonexercise control group).

Results

Table 2 summarizes the data extracted from the 38 relevant studies included in the review. The *statistical summary* column summarizes key statistical findings. The resulting classification of studies was as follows: 12 positive at Level I evidence, 3 positive at Level II, 5 positive at Level IV, 4 null at Level I, 5 null at Level II, and 4 null at Level IV. Five studies (at the end of Table 2) were classified as inconclusive.

Outcomes were most frequently pain- or symptom-based (S),[15] but in some cases included lost time (LT) or disability (D). If pain and symptom-based outcomes were reported for multiple specific musculoskeletal regions, it was the outcome for the shoulder or neck/shoulder that determined the attribution of positive, null, or inconclusive effect. However, the review included a number of studies in which the outcome was a musculoskeletal pain/symptom rating without specification of the body region. When exercise resulted in statistically significant improvements in the rating of pain relative to nonexercising controls, the study was classified as positive, even if the outcome (pain, symptoms) was not specific to the shoulder or neck/shoulder.

Study characteristics. *Study population and design.* Country. Studies conducted in the US (6) and Nordic countries (18) accounted for 63% of the 38 included studies. All eight studies from Denmark were classified as positive effects (representing over one-third of all positive studies). It should be noted that seven of these eight positive studies were published after 2008, and originated from a common group of collaborators. Studies from Sweden were more often classified with null effects with one positive and five null. US studies were equivalently positive (three) and null (two)/inconclusive (one).

Occupational group. Nearly half (18) of the 38 included studies (3,137 of the 6,280 study participants in total)

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Table 1. Literature search strategy.

[Exercise		[Work		[Preventive Health Service		[Upper Extremity
OR		OR		OR		OR
Health Promotion		Workplace		Primary Prevention		Shoulder
OR		OR		OR		OR
Physical Fitness	AND	Occupational Injury	AND	Secondary Prevention	AND	Impingement Syndrome
OR		OR		OR		OR
Motor Activity]		Occupational Health		Early Medical Intervention		Shoulder Pain
		OR		OR		OR
		Occupational Exposure]		Physical Therapy Modalities		Bursitis
				OR		OR
				Therapeutics		Rotator Cuff
				OR		OR
				Rehabilitation		Shoulder Instability*]
				OR		
				Prehabilitat(ion)*]		

Note: MeSH terms were used in PubMed except where denoted by an asterisk, which were text words.

included occupational groups that perform computer work in office environments. The other half spanned a variety of occupational groups, including healthcare workers,[6,36,47] laboratory technicians,[25,37] musicians,[31] slaughterhouse workers,[26] shellfish gatherers,[46] construction workers,[8,10] and assembly workers.[3,41]

MSD diagnosis (Dx) inclusion criteria. Inclusion criteria for neck/shoulder symptoms or other musculoskeletal diagnosis of the study population were classified according to specific shoulder or neck/shoulder disorders (SNS), nonspecific neck/shoulder pain (NSNS), nonspecific musculoskeletal pain (NSM), undescribed symptom inclusion criteria (U), or asymptomatic (A).

Exercise program. *Exercise modality.* Of the 38 studies identified, 13 were classified as having components of general resistance training (RT) with external resistance from dumbbells, elastic bands, or machine resistance. Eleven included specific resistance training (SRT) exercises that targeted neck/shoulder function, 6 included general physical exercise (GPE) to increase cardiorespiratory and aerobic system demand, and nine included stretching (S) components. There were five studies classified as unstructured (U) programs in which the exercise modality was unclear or in which the program was aimed at counseling/raising awareness regarding the benefits of physical activity or in which no specific form of physical activity was prescribed (three of these were inconclusive). In five studies, the exercise was classified as a movement awareness (MA) modality (two of these were inconclusive). These were programs that did not represent strength training exercises, stretching/lengthening of muscle tissue, or GPE consistent with a primarily cardiorespiratory load. Counts across categories sum to more than 38 because some studies included more than one exercise modality (see Table 3).

Exercise environment. The primary exercise environment was classified as workplace-based (W) (66% of studies), home-based (H) (23%), or work-hardening clinic-based (C) (11%).

Study design. Study designs were documented (see Table 2) and formed the sole basis for grading the level of evidence. Unlike other systematic reviews,[59] we did not assess other sources of bias in grading the level of evidence. Of the 38 included studies, 17 were RCTs with complete randomization (Level I), 9 were control group trials with group or cluster randomization (RCT_{group}) or matched controls (RCT_{match}) (Level II), 4 were studies comparing two types of exercise (lacking a nonexercise control group) (Level IV), and 6 were cohort designs that did not include a control group (Level IV). Two studies used a nonparticipator control group design, without treatment randomization, and an obvious potential for selection bias.[60,61] These studies were both classified as Level IV. Four of the 13 null classified studies were Level 1, five were Level II, and four were Level IV.

Exercise program compliance. In 20 of 38 studies, compliance was reported in a way that a standardized percentage of prescribed exercise dose could be derived. Approaches to assessing program compliance (adherence) vary, and include confirmed attendance (A) in scheduled workplace exercise sessions (12 studies), unconfirmed diary (D) or self-report (5 studies), and other forms of recall (R) and self-rated compliance (3 studies). Where possible, we converted compliance as reported in the study to a percentage completion of the prescribed exercise "dose." This is reported as "%" in Table 2 and was based on the percentage of the total exercise sessions completed (or reportedly completed), or the percentage of prescribed exercise time completed. However, lacking the original data, our ability to standardize the calculation of program compliance across studies was limited, and in

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some cases, the estimates were reconstructed from reported summary data. An example is the reporting of percentages of participants completing 0–20, 20–40, and 40–60 minutes of weekly training as 39%, 18%, and 43%, respectively.[28] Using these summary values and midpoints of the ranges, our calculation would have yielded an overall compliance of 49%. However, the authors reported the actual training minutes completed as 66% of the 60-minute weekly total.[28] Similarly, some studies classified compliance based on a percentage of participants meeting an arbitrary minimum level of exercise completion. For example, Chan et al.[31] reported overall compliance (41%) as the percentage of the initial sample attaining the recommended minimum training level (two sessions per week). Their final analysis excluded (as being nonparticipators) those participants who completed (self-reported) fewer than the minimum. Similarly, Lundblad et al.[39] required 50% of the prescribed exercise sessions to be attended, and excluded (as nonparticipators) individuals failing to achieve this. This approach affects the actual dose of the exercise program in the treatment group relative to studies that did not drop participants from a final analysis, even when compliance with the prescribed exercise dose was low. Zebis et al.[25] defined "regular adherence" as participating in as few as one of three weekly exercise sessions (33% of the prescribed dose). They reported that 85% of participants attained regular adherence, when it was clear that far fewer than 85% of the exercise sessions were actually attended (only 63% attended 2–3 times/week and 15% attended 1–3 times/week). Their analyses did not exclude low-adherence participants.

Recognizing the limitations above, the average compliance in studies classified with positive and null effects were similar (66% vs 68%). Compliance, on average, was lower for home exercise (52%) than for exercise programs in the workplace (70%). Furthermore, compliance with home exercise must be assessed by self-documentation, and self-report of exercise compliance is known to be overestimated.[62] In 40% of positive studies, compliance was assessed by attendance, and in 15% it was by diary/recall/self-report. In 45% of positive studies it was unreported. Among null studies, compliance was assessed by attendance in 23% of studies and by diary/recall/self-report in 31%, and unreported in 46% of studies.

Related to compliance is the study attrition rate or continuation percentage – the percentage of initial enrollees who complete all phases of pre- and post-intervention assessment. When reported, continuation averaged 83% for positive studies and 82% in null studies.

Progressive training dose. In 20 studies, a progressive increase in exercise dose was reported. This was usually through increases in training load (L) or resistance (R), but included other approaches to increasing the training volume (V). The reporting of progressive increase in exercise dose was more common with RT modalities. Progressive training dose, through increasing training load, was reported in 75% of positive studies and 38.5% of null studies.

Duration of exercise intervention. The duration of the exercise program intervention period was reported in all studies. The median program duration was 12 weeks. The overall range was 3–104 weeks. One-year study periods represented 18.4% (7) of the studies. Another 57.9% (22) of studies were in the range of 8–16 weeks.

Exercise time. Exercise session frequency and duration were reported in 28 of 38 studies in a way that could be converted to weekly exercise time, independent of other aspects of exercise modality or intensity. The median was 85.2 minutes/week, and the range was 30–270 minutes/week. This excludes the study condition that evaluated 2 minutes of daily (10 weekly minutes) exercise.[27] In 12 of the 28 studies, the weekly exercise time was 60 minutes or less. In 10 of the 38 studies, the exercise program was not reported with sufficient detail to be converted to training time – usually because the prescribed exercise dose was reported as an RT set/repetition framework without the time to complete this.[3,10,32,36,41,44,56] Four of the 10 studies in which exercise time could not be reconstructed were among the five inconclusive studies. Two of the 10 were studies classified as null effects. The four positive studies among those 10 all incorporated a specific set/repetition RT framework.[3,10,32,56]

Cumulative exercise time was calculated as the weekly exercise time multiplied by the duration of the study period in weeks. Only two positive studies prescribed over 2,000 minutes of cumulative exercise time (52 weeks × 60 minutes, and 12 weeks × 270 minutes) over the study duration, while five null studies exceeded this total (see Fig. 1). The five null studies ranged from 12 weeks × 180 minutes/week (2,160 cumulative minutes) to 104 weeks × 50 minutes/week (5,200 cumulative minutes) to the maximum 52 weeks × 150 minutes/week (7,800 cumulative minutes). The 52-week/60-minute exercise per week study[21] exhibited low compliance among positive studies and the 12-week/270-minute exercise study was classified as Level IV (positive) for lacking a nonexercise control group.

Studies classified with positive effect. The positive studies tended to more often involve SRT as an exercise modality with specific neck/shoulder disorders or nonspecific neck/shoulder pain as inclusion criteria. SRT was a component in 10 of the 20 positive studies and all five positive studies that included participants with specific neck/shoulder disorders. Only one null study[8] included SRT (in combination with stretching). That was also the study of longest duration (104 weeks), was a home-based exercise program, and reported low compliance.

Specific neck/shoulder disorders. Four Level I studies[4,10,29,32] and one Level IV study[3] were classified as having a positive effect of exercise related to specific neck/shoulder disorders.

Ahlgren et al.[29] evaluated three exercise programs for work-related trapezius myalgia in 126 women. The SRT treatment group used air resistance machines with rowing,

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Table 2. Summary of 38 relevant studies included in the review.

REF	PUBLICATION YEAR	POSITIVE (+), NULL (=), INCONCLUSIVE (?)	COUNTRY	OCCUPATIONAL GROUP/INDUSTRY	DX INCLUSION CRITERIA	EXERCISE MODALITY	ENVIRONMENT	STUDY DESIGN	COMPLIANCE	%	PROGRESSIVE	DURATION (WEEKS)
29	2001	+	Sweden	occupational neck/shoulder pain, trap myalgia	SNS	SRT	C	RCT	A	75%	L	10
43	2003	+	Turkey	office/computer workers	NSM	RT,S	W	RCT	-	-	-	8
6	2001	+	Norway	hospital employees	NSM	RT,GPE	W	RCTmatch	-	-	L	15
52	2004	+	Taiwan	keyboard users	U	S	W	RCTgroup	-	-	-	12
42	2010	+	USA	office workers	NSM	S	W	RCTgroup	-	-	-	3
21/22	2008	+	Denmark	office/computer workers	NSNS	GPE,SRT	W	RCT	A	47%	L	52
28	2012	+	Denmark	office/computer workers	NSNS	SRT	W	RCT	A	66%	L	20
25	2011	+	Denmark	laboratory technicians	NSNS	SRT	W	RCT	A	62%	L	20
4	2008	+	Denmark	female computer workers	SNS	SRT,GPE	W	RCT	A	85%	L	10
37	2011	+	Denmark	pharmaceutical lab technicians	U	RT	W	RCT	A	70%	L	8
27	2011	+	Denmark	employees w/frequent neck/shoulder muscle pain	NSNS	SRT	W	RCT	D	65%	L	10
26	2014	+	Denmark	slaughterhouse workers	NSM	RT	W	RCT	A	80%	L	10
56	2003	+	Finland	female office workers	NSNS	RT,S	H	RCT	D	62%	L	52
10	2003	+	USA	construction workers	SNS	SRT,S	H	RCT	-	-	L/R	8
32	2007	+	Hong Kong	Wcomp claimants w/rotator cuff tendinitis	SNS	SRT,S	C/W	RCT	-	-	L	4
34	2011	+	USA	beverage industry, tin mill laborers	A	S	W	cohort	-	-	-	12

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N	CONTINUATION %	EXERCISE SESSIONS PER WEEK	EXERCISE SESSION LENGTH (MIN)	WEEKLY TOTAL MINUTES	OUTCOMES	STATISTICAL SUMMARY* (NS – NOT SIGNIFICANT)
126	81%	3	60	180	S	VAS worst pain (trapezius myalgia) $P < 0.05$ (between group) 18%* decrease in SRT, 1% decrease in control group.
50	-	3	60	180	S	VAS rated pain (non-specific) $P < 0.001$ for exercise group, ns for control (within group); 39%* decrease in exercise group, 2%* decrease in control group.
65	78%	2	60	120	S	Pain index (composite) $P = 0.031$ (group × time) 39%* decrease for GPE, 29%* decrease for RT, 8%* decrease for controls.
178	87%	5,10	17.5	87.5	S	Pressure pain threshold improvement (trapezius) $P < 0.05$ for team exercise groups; Odds Ratios (relative to control group) 4.63 for 5 sessions/week, 7.06 for 10 sessions/week; ns for self exercise group at 5 sessions/week.
70	97%	400 (stretch 10x/hr)	0.21	83	S	VAS Pain Index (composite) $P < 0.001$ for two stretching groups (within group) difference from control condition pre–post; 10.8%* and 10.3%* decrease in pain.
549	80%	3	20	60	S,FC,LT	FOR CASES: Shoulder pain reduction in GPE and SRT not different from controls ns. FOR CONTROLS: Right shoulder pain increased in reference group greater than in GPE group (group × time $P < 0.05$).
449	62%	1,3,9	60,20,7	60	S,FC	FOR COHORT: DASH Disability score (upper limb) reduction (group × time), $P < 0.001$ for 3 sessions/week, $P < 0.05$ for 1 and 9 sessions/week; 4%*–6%* reduction in exercise groups relative to reference group. Pain in right shoulder $P < 0.05$, 4.5%*–7.8%* reduction in exercise group.
537	83%	3	20	60	S	Pain intensity (shoulder) $P = 0.07$ (group × time); 2%* decrease in SRT group. Pain intensity for neck $P < 0.001$; 6%* decrease in SRT group.
48	88%	3	20	60	S,FC	VAS worst pain/general pain (trapezius) $P < 0.0001$ (group × time). SRT reduced pain relative to control and GPE conditions by 35%* (worst pain) and 20%* (general pain) in SRT group.
40	95%	3	20	60	S,FC	Neck/shoulder pain $P = 0.02$ (group × time). RT group 21%* decrease relative to control group.
198	92%	5	2 or 12	35	S,FC	Worst neck/shoulder pain in previous week $P < 0.0001$ (group × time). SRT groups reduced by 14%* (2 min sessions) and 19%* (12 minute sessions) from control group. Tenderness score $P < 0.0001$ (group × time). SRT groups reduced by 13.1%*, 13.7%* (2, 12 min sessions) from control group.
66	92%	3	10	30	D,S,FC	Work Ability Index $P < 0.05$ (group × time). RT group had no change in Work Ability, control group decreased Work Ability by 5.5%*. VAS rated pain intensity in shoulder $P < 0.001$ for between group difference; SRT group reduced ~15%* from control group.
180	98%	3	set/rep completion	-	S;FC	Neck and shoulder pain and disability index change $P < 0.001$ (between group); 23%* decrease in exercise group 12%* decrease in control group.
92	92%	3-SRT, 5-S	set/rep completion	-	S	Shoulder Rating Questionnaire score $P < 0.001$ (group × time); symptomatic training group increased SRQ 14.6%*, symptomatic controls decreased 1.7%*. Pain rating $P < 0.05$; Disability rating $P < 0.05$.
103	91%	sets/repetitions specified	set/rep completion	-	RTW,FC	Return to work $P < 0.001$ (between group); 71.7% of workplace based training group returned to work 37.5% of controls. Shoulder pain and disability index $P = 0.034$ (between group).
95	82%	-	9 stretches, 15s each	30	IR	Injury rate $P = 0.01$; 8.5% for eligible population, 1.3% for stretching program participants.

(*Continued*)

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Table 2. (*Continued*)

REF	PUBLICATION YEAR	POSITIVE (+), NULL (=), INCONCLUSIVE (?)	COUNTRY	OCCUPATIONAL GROUP/INDUSTRY	DX INCLUSION CRITERIA	EXERCISE MODALITY	ENVIRONMENT	STUDY DESIGN	COMPLIANCE	%	PROGRESSIVE	DURATION (WEEKS)
50	2009	+	Canada	female university employees (computer users)	U	MA	W (fitness center)	cohort	A	74%	-	12
45	1998	+	Denmark	female "patients"	NSNS	SRT	C	RCTa	-	-	L	12
31	2014	+	Australia	musicians	U	RT,GPE	H	cohort	R	41%	other, no fatigue	12
3	2009	+	Brazil	male assembly line workers	SNS	SRT,S	W	cohort	-	-	L	8
48	2005	=	Finland	public administration employees (light work)	NSM	RT	W	RCTgroup	D	68%	V	15
51	2011	=	Taiwan	office workers, physical laborers	U	GPE	W	non-part control	A	68%	-	12
53	2003	=	Netherlands	office/computer workers	NSM	U	W	RCTgroup	R	74%	-	8
46	2011	=	Spain	shellfish gatherers	NSM	RT	C	cohort	-		V	8
47	2008	=	Sweden	female employees in dental healthcare	U	GPE	W	RCTgroup	D	100%	-	52
39	1999	=	Sweden	female workers (general)	NSNS	RT,MA	C/W/H	RCT	-	-	-	16
49	2011	=	Sweden	electronics industry, computer users	NSM	MA	W	RCT	A	83%	-	6
55	2003	=	Finland	female office workers	NSNS	RT	W	RCT	A	34%	U	52
35	2000	=	Sweden	female industrial workers	NSNS	RT	C/H	RCTa	-	-	-	24
8	2009	=	USA	construction apprentices	A	SRT,S	H	RCTgroup	R	50%	R	104
40	2011	=	Portugal	office/computer workers	NSM	U	W	non-part control	-	-	-	32
36	2001	=	Sweden	nursing aids, assistants	U	RT	H	RCTgroup	-	-	-	78
41	2011	=	USA	manufacturing assembly workers	NSNS	RT	H	RCT	-	-	L	26
38	1997	?	France	hospital, warehouse, office workers	U	U	W	RCTmatch	-	-	-	52

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N	CONTINUATION %	EXERCISE SESSIONS PER WEEK	EXERCISE SESSION LENGTH (MIN)	WEEKLY TOTAL MINUTES	OUTCOMES	STATISTICAL SUMMARY* (NS – NOT SIGNIFICANT)
52	87%	2	50	100	S,FC	Composite Musculoskeletal Fitness Score $P = 0.002$ (1.7 vs 2.07; pre vs post intervention); Perceived Stress scale $P = 0.018$ (26.1 vs 24.2 out of 40).
77	68%	3	90	270	S,FC,D	Activities of Daily Living score $P < 0.05$ (within group) for light and intensive exercise groups; Pain score $P < 0.05$ at completion (within group) for both groups. Between group differences not significant (ns).
144	35%	2	40	80	S,FC	Performance-related musculoskeletal disorder (PRMD) frequency $P < 0.05$ difference over time (12%* decrease); PRMD severity $P < 0.05$ (10%* decrease).
17	82%	2	set/rep completion	-	S	DASH score difference pre- post-intervention $P < 0.05$ (12.67%* decrease); DASH work score $P < 0.05$ (12.94%* decrease); Pain Rating Index $P < 0.05$ (18.2%* decrease).
53	100%	5–7.5x/wk	set/rep completion	190	S,FC	Intensity of pain in shoulder area (Borg CR-10 scale) difference between exercise and no exercise group ns after intervention. Significant differences reported for neck pain.
133	88%	3	60	180	S,FC	Shoulder pain–percent improving shoulder pain was 20.3% in exercise group 8.3% in control group, $P = 0.078$ (ns). Significant difference reported for neck pain.
268	82%	60 (3 min every 40 min)	3	180	S,LT	Severity of neck and shoulder complaints decreased over time (within group) in breaks + exercise and breaks only group. Between group difference not significant (ns).
19	100%	2	80	160	S,FC	Pain localization (for shoulder) difference ns pre- post intervention.
195	91%	2.5 hrs/wk		150	S,FC	Composite musculoskeletal symptom score ns ($P = 0.063$) differences between exercise group, reduced hours group, and reference group (group × time); upper extremity symptom score ns ($P = 0.062$).
97	60%	2	50	100	S,FC	Complaint indices for neck and shoulder and VAS rating of usual pain (within group) $P < 0.05$ for neck/shoulder index, but not for specific neck index or specific shoulder index (ns). No significant between group differences.
42	88%	5	21	100	S,D	Neck/shoulder pain intensity, coefficient for change in symptoms (linear mixed model) ns.
393	87%	3	30	90	S,FC,D	Neck pain rating (0–10) – between group differences not significant (ns) for RT, relaxation training, and control group.
77	90%	3	~20	60	S,FC	VAS rating of pain in neck or shoulder not different between strength, endurance RT exercise. Within group reduction in ratings of pain inconsistent over successive 4-week periods.
240	87%	5	10	50	S	Shoulder pain–Group assignment (exercise vs control) did not significantly predict new shoulder pain onset (ns) in regression model. Rate of new shoulder pain onset was 10.8% in exercise group, 17.9% in control group (14.4% overall).
50	48%	3	15	45	S	VAS rating of musculoskeletal pain in left and right frontal neck and left and right posterior neck not significantly different (ns) between groups. Shoulder not specified.
282	60%	≥2	set/rep completion	-	S	Rating of neck/shoulder symptoms (Nordic Musculoskeletal Questionnaire) – not significant (ns) (between-group changes in symptoms) for RT group, stress management group, and control group.
11	82%	set/rep specified	set/rep completion	-	D,FC	Disability index – 15 of 16 items in the index were not significant (ns) in non-parametric tests (between group).
620	85%	-	-	-	S	Shoulder disorder morbidity score (range: 0–13) $P = 0.03$; 2.7%* increase in control group, 1.3%* decrease in intervention group. Co-Intervention.

(*Continued*)

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Table 2. (*Continued*)

REF	PUBLICATION YEAR	POSITIVE (+), NULL (=), INCONCLUSIVE (?)	COUNTRY	OCCUPATIONAL GROUP/INDUSTRY	DX INCLUSION CRITERIA	EXERCISE MODALITY	ENVIRONMENT	STUDY DESIGN	COMPLIANCE	%	PROGRESSIVE	DURATION (WEEKS)
44	2012	?	U.K.	keyboard operators	NSM	U	W	cohort	-	-	-	12
30	2007	?	Netherlands	office/computer workers	NSM	U	H	RCT	D	56%	-	52
33	2004	?	USA	office/computer workers	NSM	MA	H	RCTa	-	-	-	52
54	2008	?	Netherlands	office/computer workers	NSM	MA	C	RCTa	A	80%	-	10

pressing, and pull-down (latissimus dorsi) exercises – clearly upper extremity movements emphasizing the shoulder. In the present review, the endurance training condition in that study was not classified as either general RT or GPE because the low rating of perceived exertion in arm cycling is not indicative of significant resistance or an aerobic exercise response. The coordination training group responded no differently than the nonexercising control group. The SRT group showed significantly greater reduction in reported pain (worst pain) than the control group.

Andersen et al.[4] compared 10 weeks of SRT (dumbbell front raise, lateral raise, reverse flies, upright row, and shrug exercises specific to shoulder muscle groups) to general physical exercise (stationary cycling at 50%–70% $VO_{2\ max}$) and a nonexercise control group with 48 keyboard/computer users diagnosed with clinical trapezius myalgia. After 10 weeks, the SRT group had significantly reduced ratings of pain relative to the GPE and control groups (whose pain ratings were not different).

Ludewig and Borstad[10] included 92 construction workers exposed to overhead work symptomatic for subacromial impingement and pain reproduction in multiple provocative tests. Their study design included asymptomatic workers who were assigned to a control group. The 8-week home exercise program included specific shoulder stretches (S) and specific strengthening movements (SRT) acting on scapular stability and the external rotators and selective activation exercises to limit upper trapezius recruitment during humeral elevation. The program resulted in a significantly improved shoulder disability score (Shoulder Rating Questionnaire) for the exercise group relative to nonexercising controls.

Cheng and Hung[32] described a specific 4-week workplace-based work-hardening program that included shoulder stretches, scapular control exercises, and isometric strengthening of the rotator cuff muscle groups (S and SRT). This study included employees with worker compensation claims for rotator cuff tendinitis. Comparison was made to a clinic-based program that also included exercise. Because the clinic-based work-hardening group received a standard treatment approach not under experimental investigation, this was classified as a control group. The workplace-based program resulted in significantly higher return to work and a significant reduction in shoulder pain and disability relative to the control group.

Nonspecific neck/shoulder pain (NSNS). Ylinen et al.[56] enrolled 180 female office employees with nonspecific neck pain through clinical referral in a 12-month RCT study of exercise. In addition to stretches (S), the exercise programs included training of the neck flexor muscles lifting only the mass of the head (endurance condition) and incorporating added resistance with elastic bands (strength condition). This

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N	CONTINUATION %	EXERCISE SESSIONS PER WEEK	EXERCISE SESSION LENGTH (MIN)	WEEKLY TOTAL MINUTES	OUTCOMES	STATISTICAL SUMMARY* (NS – NOT SIGNIFICANT)
17	33%	5	multiple times daily	-	S	VAS rating of pain before typing $P = 0.009$ (within group), 9.1%* decrease; VAS rating of pain after typing $P < 0.001$ (within group), 20%* decrease. Co-intervention of ergonomic workstation modifications.
466	68%	n/a	n/a	-	S,D	Because physical activity was not increased in treatment group, conclusions can not be drawn.
93	75%	-		-	S	No differences between combined intervention group and relaxation exercise group, (group × time) significant effect of time for both groups–reduced VAS pain ($P < 0.01$) and DASH ($P < 0.01$). Cannot discern effect of exercise. Co-intervention.
88	95%	12, 18	-	60	S	No difference (ns) between postural and strength/fitness exercises, but did not test vs non-exercise group. Within group effect of exercise not reported. Cannot discern effect of exercise.

Notes: See section "Study Characteristics" for description of abbreviations. Statistical summary (*denotes difference in pain symptoms expressed as a percentage of the full pain scale range).
Abbreviations: Dx Inclusion Criteria: SNS, specific neck/shoulder; NSM, nonspecific musculoskeletal; NSNS, nonspecific neck/shoulder; A, asymptomatic; U, undescribed. Exercise modality: SRT, specific resistance training; RT, resistance training; GPE, general physical exercise; S, stretching; MA, movement awareness; U, undescribed. Environment: W, workplace; H, home; C, clinic. Study design: RCT, randomized control trial; RCTgroup, RCT with randomization by group; RCTmatch, randomized to treatment with matched controls; cohort, cohort time series design (no control group); RCTa, RCT with alternative treatment control group. Compliance: A, attendance at session; R, recall; D, diary. % calculated: see text for calculation of % compliance with exercise dose. Progressive: R, training resistance increased; L, training load increased; V, training volume of training increased. Duration (weeks): number of weeks of exercise between baseline and follow-up. Continuation %: percentage of enrolled subjects not lost to dropout (completers). Outcomes: S, symptoms; D, disability; LT, lost work time; RTW, return to work time; FC, functional capacity.

study was classified as positive for the shoulder because the neck and shoulder pain and disability index was significantly improved in both the endurance and strength training groups relative to controls.

A number of studies of an SRT program with dumbbell resistance similar to that of Andersen et al.[4] have been conducted with workers symptomatic for nonspecific neck/shoulder pain. In these related studies,[21,25,27,28] the authors identified those symptomatic for neck/shoulder pain ("cases") using a validated pain questionnaire[63] based on a cut-off pain intensity of 3 on a 10-point scale. In the Andersen et al study,[28] this was done after enrollment of 449 office workers with controlled progression of training intensity over 20 weeks and the SRT training assigned to groups receiving one weekly session of 60 minutes, three weekly sessions of 20 minutes, and nine weekly sessions of 7 minutes. Results were reported for 158 cases, and a positive effect on pain reduction was found for cases in all groups relative to controls and for those completing the program. The greatest pain reduction was observed in the three weekly (20 minutes) training session group. However, 44% of "completers" exercised less than 20 minutes/week, and in the one session/week group 51% did not achieve 20 minutes/week of exercise. (This could have been achieved by completing as few as a single 60-minute session every 3 weeks.) Thus, compliance with the prescribed exercise dose is problematic in interpreting the effect of the actual exercise dose on pain reduction.

In another study,[25] these authors administered a dumbbell SRT program (three weekly sessions of 20 minutes) in a 20-week RCT with 537 laboratory technicians stratified by symptomatic cases or asymptomatic (non-cases) for neck/shoulder symptoms and reported a null *preventive* effect (no reduction in neck/shoulder pain symptoms among asymptomatics) and a positive rehabilitative effect (reduction of ache, pain, discomfort among symptomatic cases). However, with 28% of the study population presenting as shoulder cases at baseline, the positive rehabilitative finding appears to have broad application in this occupational group. The authors concluded that 20 weeks was insufficient for detection of a preventive exercise effect.

Andersen et al.[21,22] studied 549 office workers in an assessment of a one-year program with three weekly SRT or GPE exercise sessions of 20 minutes on symptomatic cases and asymptomatic participants. Among the cases, a significant reduction in neck pain rating was observed after four months in both the GPE and SRT groups relative to those in the nonexercising group (group × time interaction). Symptomatic cases in the exercise group showed no significant reduction in shoulder symptoms relative to the nonexercising controls. However, among asymptomatics, a statistically significant

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Table 3. Classification of studies by exercise modality, inclusion criteria diagnosis, and evidence grade (see Table 2 legends).

DX INCLUSION CRITERIA	EVIDENCE GRADE*	EXERCISE MODALITY						
		SRT	RT	S	GPE	MA	U	
Specific neck/shoulder	+ I	4,10,29,32		10,32	4			
	+ II							
	+ IV	3		3				
	= IV							
	= II							
	= I							
Non-specific neck/shoulder	+ I	21,25,27,28	56	56	21			
	+ II							
	+ IV	45						
	= IV		35					
	= II							
	= I		39,41,55			39		
Non-specific musculoskeletal	+ I		26,43	43				
	+ II		6	42	6			
	+ IV							
	= IV		46				40	
	= II		48				53	
	= I					49		
Undescribed	+ I		37					
	+ II			52				
	+ IV		31		31	50		
	= IV				51			
	= II		36		47			
	= I							
Asymptomatic	+ I							
	+ II							
	+ IV			34				
	= IV							
	= II	8		8				
	= I							
TOTAL Counts	+ I	8	4	4	2	0	0	18
	+ II	0	1	2	1	0	0	4
	+ IV	2	1	2	1	1	0	7
	= IV	0	2	0	1	0	1	4
	= II	1	2	1	1	0	1	6
	= I	0	3	0	0	2	0	5

Notes: *Evidence graded at Level I, II, IV and indication of positive effect (+) or null effect (=). Level I indicates RCT; Level II indicates RCT with matched control group or group-level randomization; Level IV indicates case series design, nonparticipant control group design, or RCT with alternative treatment control group.

preventive effect (group × time interaction) was reported, with the exercise groups reducing the development of shoulder pain relative to the nonexercising group.

In a study of otherwise healthy employees with frequent neck/shoulder pain, Andersen et al.[27] compared groups performing a 2-minute daily SRT exercise session and a 12-minute daily SRT session to a control group. The SRT program was reduced to a single exercise consisting of a lateral raise (shoulder abduction) with resistance tubing in which a single versus multiple set session structure accounted for the difference in exercise time. Both the 2- and 12-minute daily exercise groups showed reduced neck/shoulder pain intensity

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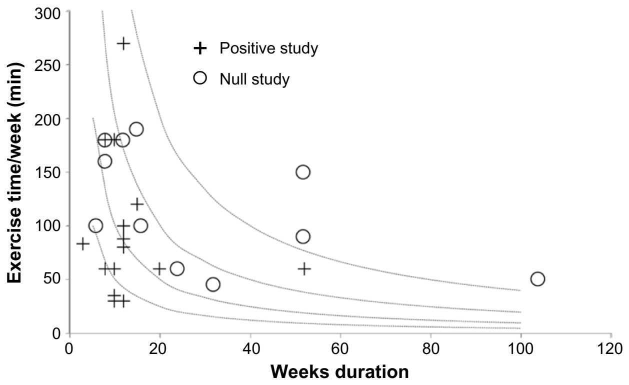

Figure 1. Cumulative exercise time (time/week × number of weeks) in the 28 studies for which exercise time could be reconstructed. Contour lines show equivalent cumulative exercise times of 500, 1,000, 2,000, and 4,000 minutes.

and less palpable tenderness relative to a control group after 10 weeks.

Nonspecific musculoskeletal pain in unspecified regions. An RCT with 66 slaughterhouse workers symptomatic for musculoskeletal pain in the shoulder, elbow/forearm, and/or hand concluded that three weekly RT (shoulder, arm, and hand) sessions of 10 minutes for 10 weeks prevented deterioration in the Workability Index (WAI) compared to a nonexercise control group receiving ergonomic training.[26] The exercise group maintained a similar WAI of 39–40 during the 10 weeks of exercise, while the nonexercising group's WAI decreased by 2.3 units. The small change on the 49-point scale left both groups still within the broad classification of "good workability" and, while statistically significant, does not appear to be a determinant of meaningful change in work ability. Since the control group was given ergonomics training, it is questionable whether that information sensitized this group (differentially from the exercising group) to report lower workability and whether this confounds the effect of exercise.

The inclusion criteria in Oldervoll et al.[6] was nonspecific pain in the neck/shoulders/low back for at least three months in the last year and recurring within the previous month. Their study compared dynamic RT (12–15 repetitions) and aerobic capacity training (GPE) in two weekly 60-minute sessions to a nonexercising control group. A composite pain index score for neck, shoulders, and low back decreased at 15 weeks in both RT and GPE groups relative to the control group. No difference was found between the exercise groups. Omer et al.[43] included patients with positive diagnostic criteria for neck pain, shoulder and back pain, arm pain, or carpal tunnel syndrome (CTS). Results were not reported by specific diagnosis. The eight-week exercise program was not described in detail but included stretching and strengthening (RT) exercises conducted three times weekly in 60-minute sessions. The rated pain (visual analog scale) was reported as having decreased significantly ($P < 0.01$) in the exercise group, but not in the control group. Specific benefit to the neck/shoulder could not be discerned.

Two studies (positive at Level II) included only stretching exercises without combining stretching with RT.[42,52] In the study by Marangoni,[42] office workers with regionally nonspecific neck, shoulder, or upper limb musculoskeletal pain (44% reporting pain in shoulder at baseline) stretched for 10–15 seconds every six minutes (equating to 83 minutes/week in 400 microsessions) for three weeks. A composite pain index score (summed over painful regions) decreased in the stretching groups relative to the control group. Pain was not broken out by musculoskeletal region, so specific benefit to neck/shoulder musculoskeletal symptoms cannot be interpreted.

The second stretching-only study classified as positive (Level II)[52] reported a statistically significant effect for a twice-daily (35 total daily minutes) stretching exercise program on shoulder soreness and pressure pain threshold after 2–3 months. Participants (computer users) were not described with respect to baseline musculoskeletal symptom criteria. Effects were not consistent in contrast with a self-exercise and a once-daily stretching exercise group. Further, the twice-daily stretching group was supervised by a physical therapist in contrast to the other groups, possibly confounding the effect of exercise dose (once vs twice daily) with the presence of a physical therapist group leader.

Another study that did not describe pain/symptom inclusion criteria was an eight-week kettlebell training program (RT) with three weekly 20-minute sessions.[37] The program resulted in a significant reduction in neck/shoulder musculoskeletal pain intensity among laboratory facility employees known to have high prevalence of musculoskeletal pain. Though present musculoskeletal pain was not described as an inclusion requirement, participants averaged between 3 and 4 (out of 10) in baseline pain intensity.

Four of the positive studies classified as Level IV evidence were cohort case series designs without a control group.[3,31,34,50] Gartley et al.[34] compared injury rates among stretching program (90-day) participants to that of all employees (nonparticipants) at the worksites. Calculated odds of a nonstretching participant experiencing an MSD was 7.69 times that of a stretching program participant. The analysis compared lost time among program participants to lost time among nonparticipants at the facility. This design risks a selection bias. Tamim et al.[50] evaluated a 12-week Tai Chi program with female university administrative staff. Musculoskeletal *fitness* scores and perceived stress and psychological well-being improved significantly; however, no symptoms of musculoskeletal pain/discomfort were included as outcomes. The high accessibility of the program during lunch hours was a reported strength of the intervention. The program evaluated by Chan et al.[31] addressed upper limb MSDs of performing orchestral musicians. Performance-related musculoskeletal pain/symptom severity decreased significantly after a 12-week exercise program including both RT and GPE. The authors reported less than 10% participation in the program (50 participants in their final analysis out of 576 musicians in eight orchestras)

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and excluded 21/71 musicians for completing less than the minimum two sessions/week.

Randlov et al.[45] (classified as Level IV) compared two training programs of differing intensities (light vs intensive SRT). Light training was defined as one set of each of seven exercises per session. Intensive training was five sets. The intensive exercise treatment also progressively increased training resistance. Improvements were reported in both groups in ratings of pain; however, the reduction in pain rating was maintained in the intensive training group, whereas the light training group saw pain ratings return to original levels from 6- to 12-month follow-ups. Camargo et al.[3] (Level IV) evaluated an eight-week program based on stretching and strengthening exercise components[7,9,10] administered to 17 assembly workers with subacromial impingement syndrome. DASH (disabilities of the arm, shoulder and hand) scores from pre- to post-intervention improved significantly (12.67 point reduction from initial score of 22.32), and DASH work scores improved similarly. Pain rating indices also decreased significantly.

Studies classified with null effect. Several studies reported a null effect of exercise specific to shoulder outcomes. Tsai et al.[51] concluded that 12 weeks of general physical fitness exercise, GPE (emphasizing aerobic exercise), was effective based on reductions in neck, wrist, and back pain to office workers and laborers with undescribed symptoms. However, a statistically significant reduction in symptoms was not found for shoulder pain. Similarly, the RCT cross-over design by Sjogren et al.[48] reported a significant reduction in neck symptoms, but not shoulder, after 15 weeks of light RT consisting of six dynamic movements at 30% of one repetition maximum. In an eight-week cohort study of the effect of RT on musculoskeletal disorders of 19 shellfish gatherers, Rodriguez-Romero et al.[46] reported reductions in back pain, but no change in pain for the neck, shoulder, or upper or lower extremities. In a 32-week study of 50 office workers, Macedo et al.[40] reported no difference between exercisers and nonparticipating controls on reports of neck pain but reported positive benefit in back and wrist pain. The exercises appeared to be highly unstructured, described as emphasizing employee enjoyment, including stretching and "playful and recreational activities" on an individual basis, as well as in pairs and in groups. Compliance with this program was not reported.

Borstad et al.[8] followed 240 asymptomatic construction apprentices, assigned (by group) to either an exercise or control group, over two years. Onset of new shoulder pain (14.4% overall) was not statistically different between the groups, indicating that the SRT/S exercise program did not have a preventive effect. Compliance with the program was reportedly low, perhaps attributable to the long study period.

Hagberg et al.[35] reported significant increases in shoulder strength, increases in arm motion performance, and decreases in rating of perceived exertion (RPE) over a 4–24-week RT rehabilitative exercise program for nonspecific neck/shoulder pain in female industrial workers. The trial lacked a nonexercise control group and compared two types of exercise: a strength-based (5 second maximal contractions) and an endurance-based (two-minute contractions at 25% of maximum) exercise program. No differences in pain rating between the two treatment groups were found, and differences in reported pain from baseline (assessed at four-week intervals) were inconsistent. This study was classified at Level IV and a null effect.

Other studies reported no effect of exercise relative to a nonexercising control group. Van den Heuvel et al.[53] randomly assigned exercise described as "four physical exercises lasting 45 seconds each" every 35 minutes to 268 office workers using computers. The specific exercises were not described, but appear to have included stretches. The three minutes of exercise was part of a five-minute work break (every 35 minutes) given to office workers with upper limb musculoskeletal complaints. After eight weeks, no differences were found relative to a group who simply took a five-minute rest break prompted by software interruption. There were also no significant differences between groups in pre- post-intervention complaints of, or missed time due to, neck or upper limb disorders. A cross-over design study of a video-based six-week Qigong training program (classified as MA) concluded that the exercise slightly reduced neck disability among 42 office workers.[49] However, no change in neck/shoulder pain intensity was found. Compliance with this program was reportedly high, with 83% of the group sessions attended. This may, in part, reflect a reduction in work time to accommodate participation in the program, which was prior to employees' lunchtime.

Schwarz et al.[47] examined the effect of 2.5 hours of weekly GPE compared to equivalent reduced working hours (37.5-hour work week) and no reduced work hours over one year among a homogenous sample of healthcare professionals. The reduced work hours group received no reduction in monetary compensation. The specific exercise was at the choice of the individual so long as it met the criteria of vigorous activity of 55%–89% max HR (consistent with GPE classification). The group × time interaction effect on a composite musculoskeletal symptom score did not reach statistical significance ($P = 0.06$) but a trend toward a benefit of the exercise program was evident. The authors discussed the fact that reduced work hours were not offset by proportionate reduction in expected productivity and that this might have increased work demands. All groups (including controls) reported regular levels of exercise at baseline, which may have contributed to ceiling effects with regard to health improvement. All groups (even the controls) increased physical exercise over the study period, suggesting a possible contamination bias.

Three additional studies of RT were classified as having a null effect on nonspecific neck/shoulder pain. Lundblad et al.[39] evaluated a Feldenkrais technique program (classified as MA) and a group-based physiotherapeutic intervention (classified as RT) that included group-based exercise and exercises to be practiced at home by female employees working

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with nonspecific neck shoulder symptoms. These programs were compared to a nonexercise control group over a 16-week period. Specific complaint indexes in the neck and shoulders, ratings of pain, and work disability did not change differentially over time between exercise and control groups. The 40% dropout rate in this study appears to be high. Compliance with the exercise among the non-dropouts was not reported, beyond meeting a minimum of 50% exercise participation. Maher et al.[41] evaluated a 26-week rehabilitative RT program using elastic band resistance on 11 manufacturing assembly workers with nonspecific neck shoulder pain. The sample size was too small for parametric statistical testing, and the single statistically significant finding (nonparametric) was reported in the form of a response to an individual disability question from a 16-question index. Viljanen et al.[55] reported no effect of a one-year, three-times-weekly, 30-minute dynamic dumbbell strength training (RT) intervention or a relaxation training intervention relative to a control group on reductions in neck pain in symptomatic female office workers. However, notable about this study is that it was the lowest *reported* compliance of the studies reviewed. After 12 weeks, participants had completed 39% of strength training sessions; after one year, this had fallen to 34%. Compliance with the relaxation training fell more precipitously – from 42% at 12 weeks to 22% at one year.

Studies classified as inconclusive. Five studies were classified as inconclusive, three of them because ergonomic co-interventions were part of the experimental treatment and were believed to confound the effect of exercise.[33,38,44] Povlsen[44] evaluated a 12-week rehabilitation program that included physiotherapeutic exercise to improve flexibility and strength that emphasized the hand, wrist, and forearm. The study lacked a control group (Level IV), and the program included ergonomic workstation modifications. Rating of pain decreased both before and after bouts of typing as a result of the overall program. Because of the ergonomic modifications (co-interventions), it is not clear whether the effects can be attributed to exercise. LeClerc et al.[38] included an exercise program component in a matched control group trial (Level II) including hospital, office, and warehouse workers. Shoulder morbidity score (based on pain intensity/duration and disability) decreased significantly in the intervention group relative to controls. The exercise, described only as "physical training in an exercise room" appeared to be the emphasis of the intervention, but the intervention also included ergonomic program components. Feuerstein et al.[33] compared an ergonomic intervention with a combined ergonomic and stress reduction group. This study incorporated exercise insofar as active muscle relaxation and diaphragmatic breathing were part of the stress reduction intervention. Both treatment groups exhibited significant reductions in symptoms (DASH) and functional limitations. This study was classified as inconclusive with regard to the breathing exercise because no differences could be detected between the ergonomic intervention group and the combined treatment group. The interventions reduced pain but could not be attributed to the deep breathing relaxation response exercises. Because the ergonomic intervention alone reduced pain equivalently suggests that the relaxation exercises may not have been effective.

Bernaards et al.[30] evaluated "work style" and "lifestyle physical activity" interventions over a one-year period on the reduction of neck and upper limb symptoms among 466 computer users in the workplace. The lifestyle physical activity intervention counseled participants to incorporate moderate to heavy intensity physical activity into the lifestyle. The authors found reductions in pain attributable to the work style intervention but none that could be attributed to the physical activity (counseling) intervention. However, the physical activity counseling did not actually increase (self-reported) physical activity. Lacking a measurable increase in physical activity as a result of the intervention, the effect of the exercise intervention cannot be determined.

An RCT with an alternative treatment control reported no difference between 10 weeks of Mensendieck/Cesar exercises (postural/MA) and a strength and fitness exercise program standard to physiotherapy.[54] No statistically significant differences were reported between exercise therapy approaches, and results for within-group time effects were not reported. A benefit of exercise relative to no exercise cannot be discerned.

Discussion

A 2009 systematic review by Coury et al.[13] concluded that no workplace exercise programs had positive effects on controlling *shoulder* pain but that strong evidence supported the effectiveness of exercise on *neck* pain.[13] This conclusion was based on interpreting results of nine studies reporting both neck and shoulder symptoms and classifying them distinctly from neck/shoulder symptoms, as is reported in several studies. Our review more broadly considered neck/shoulder outcomes, and we did not differentiate distinct neck from distinct shoulder-related symptom outcomes in studies reporting "neck/shoulder" pain or disability. Of nine studies identified for shoulder or neck/shoulder pain in the 2009 review, six[21,29,39,48,52,53] overlapped with our review (which included only studies subsequent to 1997). We classified three of those studies as null[39,48,53] and one as positive[21] – in agreement with the earlier review. However, two studies classified as null for neck/shoulder in the 2009 review we classified as positive.[29,52] Additionally, eight other studies published prior to 2009 included in our review, but not in the Coury et al review,[13] we classified as positive, which included subacromial impingement[10] and rotator cuff tendonitis[32] diagnoses. We also identified 10 studies that were classified with a positive exercise effect, with post-2009 publication dates. Therefore, based on more recent evidence we conclude that workplace exercise programs have had positive effects on shoulder pain and related outcomes, at least in the short term. There is evidence (some at Level I) of positive effects of workplace exercise on the shoulder specifically,

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and several studies for more broadly defined neck/shoulder symptoms.

Our review of the available literature since 1997 suggests very little evidence that exercise (of any modality) is effective as a strictly *preventive* intervention for shoulder disorders, as defined by the prevention of new shoulder symptoms/pain onset among asymptomatic employees. Only the study by Andersen et al.[21] showed a reduction in new shoulder symptoms in an exercise group relative to a nonexercising control group. A stronger case can be made for workplace exercise for tertiary prevention[64] and therapeutic intervention for at least shorter term relief of neck/shoulder symptoms among workers with existing neck/shoulder pain or symptoms.

A recent review by Verhagen et al.[59] concluded that for arm, neck, and shoulder pain, there is very low quality evidence that exercise leads to similar levels of pain as nontreatment control in the short and long term. In a comparison of exercise to *active treatment controls*, their review concluded, from four studies, that "regular" exercises reduced pain in the short term (less than 3 months) more than "specific" exercises. Importantly, the Verhagen et al.[59] review more broadly included arm, neck, or *shoulder*-related outcomes, and the studies in our review of the neck/shoulder exhibit only partial overlap with those four. Included among those four studies was that of Ahlgren et al.[29], who compared SRT and a coordination training exercise modality against a nonexercise control group. The coordination exercise protocol was a form of body awareness training (a "specific" exercise in the Verhagen et al review nomenclature) and the "strength" and "endurance" exercise conditions apparently represented the "regular" exercises described in the Verhagen et al.[59] framework. A second study overlapping with the present review was of van Eijsden-Besseling et al.[54], which compared "regular physiotherapy" and a Mensendieck/Cesar therapy (a "specific" exercise modality in the Verhagen et al.[59] nomenclature). The strength and fitness exercises delivered by the physiotherapists in the "regular" exercise group were not clearly described. The authors reported no difference between the groups assigned to the two exercise programs. In our review, the van Eijsden-Besseling et al.[54] study was classified as inconclusive. It is important to clarify that the "specific" exercise conditions,[59] however that term was derived, is different from specific (anatomically targeted) resistance training (SRT) in our framework, which was the exercise modality associated with the most positively classified studies in regard to the reduction of neck/shoulder pain over these 38 studies. The present review is consistent with previous review findings, suggesting a benefit of (specific) RT exercise over coordination training/movement awareness exercise for control of pain in the shorter term.[59]

Exercise modality. Drawing conclusions about the exercise modalities and their efficacy for the control of neck/shoulder pain is difficult because of the nonstandardized outcomes in the studies (symptoms, pain, disability, or lost work time), the nature of the neck/shoulder symptoms of the study population, and the combination of exercise modalities in several studies. The wide range of exercise program designs across these studies is a reflection of the multifaceted benefits of exercise to overall health and the nonspecificity of musculoskeletal pain (beyond specific neck/shoulder pain) that these programs were, in many cases, addressing. Though our review focused on the neck/shoulder outcomes reported, many studies included programs designed to address broader musculoskeletal health.

Several program designs that targeted specific neck/shoulder symptoms include components from more than one exercise modality, most commonly SRT and stretching.[3,8,10,32] An attribution of one specific exercise modality to the positive effect in such a study is not possible, and it may not be useful to draw conclusions about the efficacies of various exercise modalities in isolation when the most effective program combines modalities. Nonetheless, most studies include exercise modalities consistent with our framework, and general trends across the exercise modalities can be observed. The most compelling evidence, by way of studies classified with a positive exercise effect, supports SRT as a therapeutic intervention for specific shoulder neck/shoulder disorders (ie, trapezius myalgia, subacromial impingement syndrome, and rotator cuff tendinitis) as well as nonspecific neck/shoulder pain and symptoms. The evidence in support of the use of general RT is mixed, with four Level I positive studies, one Level II and one Level IV positive study, but seven null studies (three with Level I evidence). Among the six positive Level I/II studies including stretching components, four of the programs combined stretching with SRT or RT.[10,32,43,56] Another study reported a positive effect only on a composite musculoskeletal symptoms index that was nonspecific to any musculoskeletal region.[42] Another did not report inclusion criteria symptoms/diagnosis, and the outcome was a measure of soreness prevalence and not intensity.[52] An additional null study[53] did not describe exercises sufficiently to be classified definitively, but clearly *included* stretching exercise, and may have been exclusively stretching-based. No positive Level I studies were found in which stretching was the sole exercise modality. We interpret this evidence as indicating that general physical exercise (defined by activities higher in cardiorespiratory demand, ie, "aerobic exercise") and stretching, in the absence of RT, are less effective than SRT as workplace-based exercise to reduce neck/shoulder symptoms or pain. There were no Level I or II positive studies on neck/shoulder pain reduction including what we collectively grouped as *movement awareness* modalities (eg, deep breathing/relaxation, Tai Chi, and Qigong).[33,49,50,54] These studies were generally downgraded in evidence because they either lacked a control group or combined the exercise with other interventions. There were two Level I null studies of these modalities. Higher quality positive studies of these modalities are needed to more adequately demonstrate their efficacy.

Exercise dose. The multiple varied exercise modalities make it difficult to interpret study findings with regard to how

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much workplace exercise is beneficial, ie, a minimum effective exercise dose – considering frequency, duration, and intensity. We were able to reconstruct the exercise program *time* in the majority of studies. In the aggregate, there does not appear to be a relationship between longer weekly exercise *time* and positive effects. It could be concluded that the opposite trend was evident and that little benefit is evident beyond 90 minutes/week of exercise. Studies with 90 min or more of weekly exercise were more likely to be classified as null (73% of null studies for which exercise time could be reconstructed) than as positive (only 31% of positive studies involved more than 90 minutes of weekly exercise). One-half of the positive studies involved weekly exercise of 60 minutes or less. Median weekly exercise time over positive studies was 70 minutes and for null studies was 100 minutes. Minimum effective exercise time is important from a physiologic standpoint and, in a workplace exercise program, from a cost/benefit standpoint to the employer if the exercise program takes place on paid time. Our findings differ somewhat from the conclusion of a recent review of interventions for upper extremities (UE) CTDs of computer users.[65] These authors created symptomatic and asymptomatic best practice models using occupational therapy principles. For symptomatic computer users the authors suggest "…stretching, range of motion, strengthening and posture exercise involving shoulders, forearms, wrists and digits of the hand" (p. 167) with a specific exercise dose of three weekly sessions of one hour – primarily based on Omer et al.[43] In our review, that study[43] represented the second highest weekly exercise dose (in terms of exercise *time*) among the studies we classified as positive. Importantly, our review, unlike that of Goodman et al.[65], does not address distal upper limb conditions, was not limited to occupational computer users, and had the benefit of more recent studies. Nonetheless, our review does not justify three hours of weekly exercise as a recommendation for the shoulder.

The distribution of exercise session frequency and duration has been addressed in few studies other than Andersen et al.[28] who concluded that in distributing one hour of exercise time, three weekly sessions of 20 minutes appears to be preferable in reducing neck/shoulder pain relative to a single, weekly 60-minute session or nine 7-minute session per week. The authors note that compliance (adherence) was lower for the single, longer weekly exercise session and that training load progression (gains in shoulder strength) were inferior in the 7-minute sessions. However, the definition of "regular adherence," defined by participation in at least 20 minutes/week of exercise (only one-third of the prescribed program dose), combined with the differential adherence across the three programs obscures an assessment of the actual positive dose–response.

Program duration. Silverstein et al.[66] conducted a one-year prospective study of workplace exercise on musculoskeletal symptoms and reported no effect of the exercise program on neck and upper limb symptoms. The authors suggested that one year might be insufficiently short to assess an effect on discomfort reduction among employees working with discomfort for years. If that observation was a call for longer duration studies, it has not been answered. Our review of 38 workplace exercise studies (relevant to the shoulder or neck/shoulder) dating back to 1997 (nearly 10 years after Silverstein et al.[66]) includes only two studies even *reporting* a duration longer than 52 weeks.[8,36] These studies were both classified with null effects. Further, the cumulative exercise time in Silverstein et al.[66] (14 minutes daily exercise for 52 weeks) exceeds that of all but three of the studies for which we could estimate this – all three of which were classified as null.[8,47,55] The challenges in conducting workplace studies of longer duration are clear, and the lack of any reported, let alone positive, studies that have followed workplace exercise beyond one year makes it difficult to draw conclusions about longer term effectiveness on neck/shoulder pain. The present review reveals clear differences between studies of shorter versus longer duration. Of the 20 studies we classified as positive, only 2 were trials longer than 20 weeks duration, while over half (7 of 13) of the classified null studies exceeded 20 weeks. This is consistent with a differentiation of shorter term and longer term outcomes and an observed absence of evidence for longer term effectiveness.[59] Studies of longer duration are more difficult to conduct and perhaps result in less publication bias, such that null studies of longer duration are more likely to be published. This is speculative, but consistent with a recognized publication bias against null studies with small sample size[59] (also less difficult to conduct).

Compliance. Variation in studies with regard to program compliance, when this was even reported, creates challenges in interpretation of exercise program effectiveness.[67] The studies are not standardized in reporting the handling of noncompleting dropouts (intention to treat), or in describing actual compliance with the prescribed exercise dose for participants completing baseline and follow-up assessment study phases. The ability to interpret exercise program compliance is also critical to conclusions regarding training dose. Compliance was self-reported in 40% of studies for which we could extract this information, and some studies set arbitrarily low thresholds of acceptable/unacceptable compliance without assessing the effect of low compliance on exercise dose. For instance, Andersen et al.[28] reported a positive effect of a 60 minutes/week (prescribed) exercise program, but 39% of participants reportedly attended only one-third of that exercise dose (a single 20-minute session). Andersen et al.[27] reported that adherence to the training doses was no different (66%) between a 2-minute and a 12-minute daily exercise bout, in spite of the sixfold difference between exercise session times. If the compliance percentage is accounted for, the actual exercise dose averaged only 78 seconds/day in the 2-minute daily exercise group.

To the extent in which compliance was reported in the reviewed studies, an obvious trend did not emerge with

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respect to exercise modality and compliance. However, among the 20 studies for which we could reconstruct compliance, an inverse trend was apparent between study duration and reported compliance. Over 40% of the variation in compliance (percentage of exercise completed) may be explainable by program duration (in weeks). Other authors have noted key differences between short- and long-term exercise compliance[67] as well as the complexity of the multiple factors that affect exercise compliance[68,69] and its measurement validity.[70] Our definition of *workplace exercise*, to be broadly inclusive of eight studies of home exercise administered with workplace oversight, allows a comparison of the home exercise environment to the workplace exercise environment. Compliance appeared to be notably higher when exercise was performed at the workplace as opposed to the home environment. This suggests that the workplace may have advantages to the promotion of exercise for work-related neck/shoulder pain.

Study populations. Other than identifying study populations by occupational group, these studies reveal little about the differences in work environments and work cultures across various occupations. Studies have included a variety of occupations, but the study populations in half of the articles reviewed were computer/office workers. This may be representative of the composition of the modern workplace; or it may also reflect the relative convenience of enrolling and following a larger number of workers at a single study site, with homogenous workplace exposures and work organization characteristics, which allows exercise breaks to be scheduled into the workday. Workplace physical exposures for computer users in office work, as well as their effect on neck/shoulder pain, are quite different from those of the construction worker, assembly line worker, and other occupations.

Country. The eight Danish studies deserve mention for the positive effects they report in regard to resistance training (RT and SRT) exercise modalities. Of the Danish studies, seven were positive and one inconclusive. All studies from Denmark included RT/SRT (six studies) or RT (two) studies. Thus, the high percentage of positive findings that evaluated SRT may be somewhat confounded with their being conducted in Denmark (62% of studies classified as positive Level I/II evidence with SRT exercise modality were Danish studies). The positive findings in these studies may relate to superior aspects of the exercise program or the study designs. Alternatively, this trend may reflect other sociocultural factors in the Danish workplace that may not be completely generalizable across cultures. Ideally, the evidence in support of workplace exercise of the SRT modality would be more evenly represented across countries of origin.

Psychosocial and cultural factors influence acceptance of workplace exercise and, accordingly, have played a role in exercise program design and adoption. As a US example, Lee et al.[71] reviewed exercises from 14 documented exercise programs for computer users. The criteria they adopted for exercise suitability considered exercises that could be performed at the employee's workstation, most while still sitting in their chair. The authors presumed that less conspicuous exercises would result in less embarrassment and compliance would thus be improved. Consistent with this interpretation outside the US, van den Heuvel et al.[53] (Netherlands) reported that 25% of exercise study participants reported an *expectation* of embarrassment from exercising in the presence of coworkers. These psychosocial aspects of the work environment create significant constraints to exercise program design and challenging barriers to adoption of workplace exercise. This may be particularly problematic if the more effective exercises (eg, SRT) are also the more conspicuous. It is also possible that, as workplace health/exercise promotion has become more common since the early 1990s,[71] changing social and cultural norms may lessen potential embarrassment.

The importance of proximity and accessibility to exercise equipment may be more relevant to RT modalities, and its effect on compliance is evident in these studies. In the study by Ylinen et al.[56], a home exercise program was designed because employees were reportedly unwilling to visit health clubs. The relatively low compliance with that study, and of home programs overall, suggests advantages of exercise in the workplace. When employees could exercise in the workplace with equipment (eg, dumb bells, resistance tubing, or bands for SRT) in designated areas in close proximity to, yet physically separated from, their workstation, Zebis et al.[25] reported "regular" compliance with exercise for 85% of participants. Others have emphasized that accessibility to exercise classes was important to participation and that participants indicated that a significant reason for participation was that the exercise was easily accessible at the workplace.[50] Workplace programs may be a compromise in the trade-off between exercise programs in a health club setting, requiring more travel to and from specialized equipment, and the convenience of home-based programs that appear to exhibit inferior program compliance.

In the studies reviewed, we found little information describing administrative aspects of the exercise programs that affected participation incentive. In home programs, it was assumed that the time burden was borne by the employee, and, not unexpectedly, compliance was substantially lower with home exercise. When exercises were performed in the workplace, the expectation of productivity compromise and/or paid versus unpaid work hours was often unclear. In several studies, the exercises were reported as being conducted during or before lunchtime breaks[43,49,50] or at the beginning or end of the shift,[34,51] but it was not necessarily clear if this was during compensated time. In other cases, it was clear; for example, when one-third of participants report a negative expectation of a loss in productivity due to the scheduled exercise breaks as part of that program.[53] In many cases, employees were clearly given flexibility to exercise during normal work hours, or were prompted by scheduled work breaks, and were compensated during that time.[3,21,25,29,36,42,48,53] In these studies, voluntary program participation is assumed. A notable exception, and

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interesting observation on program compliance, is a study of "mandatory" exercise (GPE meeting criteria of 55%–89% maximum heart rate for 2.5 hours/week).[47] These authors reported over 100% compliance (as self-reported), by virtue of exercise time exceeding the targeted level. This study (classified as a null finding in our review) concluded: "When it was mandatory to spend the reduced work hours on physical activity, the increase in physical exercise was even greater … it follows that interventions involving a modest reduction in work hours seem to be more effective when the time is spent on physical exercise" (p. 187). The concept of a 2.5-hour (~6%) reduction in workweek hours so that workers can exercise may be unrealistic in the US without demonstrating to employers that the 6% can be made up elsewhere. A consideration rarely described in these studies is the added job demands and musculoskeletal stress when administratively reduced work time for exercise is not accompanied by a proportionate reduction in expected work output.[47,66]

The findings of this review suggest areas of future research related to workplace exercise efficacy for control of neck/shoulder disorders, and how future research could be improved. We suggest that future research address (1) exercise modality – studies that adequately describe the type of exercise activity and exercise stimulus; (2) compliance – studies that evaluate the degree to which compliance/adherence affect workplace exercise program efficacy. Mandatory exercise participation in research may not be feasible, and introduces ethical considerations. However, participation incentives should be described and the effects of incentives on workplace exercise participation and compliance could be studied; (3) exercise program duration – longer term studies are still needed to address the extent to which short-term benefits (reduction in pain/symptoms) persist over the longer term when workplace physical demands are constant; and (4) exercise time/dose – studies are needed to determine minimum effective exercise dose – the least amount of exercise time resulting in positive effects on pain/symptom outcomes. Finally, it is suggested that outcomes and instruments for measuring neck/shoulder pain and symptoms be standardized to improve comparability across studies and better facilitate meta-analysis.

Conclusion

In a review of 38 relevant studies published since 1997, we find little evidence that workplace exercise is effective as primary prevention of work-related neck/shoulder pain. More evidence has emerged to support SRT for improving neck/shoulder outcomes as a tertiary prevention approach, for the control of existing symptoms. A number of Level I RCT studies provide evidence that workplace exercise can be effective in the relief of neck/shoulder pain, and to a lesser extent disability, at least in the shorter term. Benefits of workplace-based exercise programs have been demonstrated for workers with specific shoulder and neck/shoulder disorders and nonspecific neck/shoulder pain. Prior reviews of workplace exercise have made a distinction between positive effects on shorter term versus longer term outcomes. The present review confirms that longer duration studies continue to be less likely to demonstrate significant reductions in pain or work disability. Prior reviews have placed less emphasis, or none at all, on exercise modality and exercise program compliance (adherence). These appear to be important considerations in workplace exercise programming, and it is suggested that future studies report exercise program compliance such that actual exercise dose or completed exercise time can be discerned. As workplace health protection and health promotion become more integrated, increased consideration may be given to SRT exercise (relative to GPE designed for cardiorespiratory challenge) to reduce neck/shoulder musculoskeletal pain and disability.

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Author Contributions

Conceived and designed the article: BDL. Analyzed the data: BDL, RBD. Wrote the first draft of the manuscript: BDL, RBD. Contributed to the writing of the manuscript: BDL, RBD. Agree with manuscript results and conclusions: BDL, RBD. Jointly developed the structure and arguments for the paper: BDL, RBD. Made critical revisions and approved final version: BDL, RBD. Both authors reviewed and approved of the final manuscript.

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