Worksite Exercise Programs

Are they an effective control for musculoskeletal disorders of the upper extremities?

By Raymond W. McGorry and Theodore K. Courtney

MUSCULOSKELETAL DISORDERS (MSDs) have been associated with occupational and nonoccupational risk factors. Force, repetition, awkward (nonneutral) postures and vibration are among the physical risk factors for the development of MSDs [NIOSH(b) 1; NRC 1]; when found in combination, these factors have been reported to pose a greater risk than the application of high forces alone [Silverstein, et al(b) 343]. Serious workplace injuries due to repetitive motion resulted in an estimated $2.8 billion in direct costs alone in U.S. industry in 2002 (Liberty Mutual 1).

Recommended approaches for controlling work-related MSDs of the upper extremities (MSDUEs) have included engineering and administrative controls. Engineering controls include modification of the physical work environment such as workstation and tool redesign. Administrative controls include methods training, job enlargement, job rotation and work scheduling [OSHA 1; NIOSH(a) 1; GAO 1].

Worksite exercise programs have also been suggested and implemented specifically as a preventive measure against MSDUEs. For example, guidelines published by Worksafe Australia include exercise as a potential prevention strategy (NOHSC 1). More recently, the Health Council of the Netherlands encouraged the use of physical conditioning and selective training of muscle function as a control approach, in addition to "elimination of the causative strain" (Willems 1969).

The authors first conducted a review of the literature on the effectiveness of workplace exercise programs in 1995 (McGorry and Courtney 22; Table 1). It was concluded that the evidence was insufficient to support the use of worksite exercise programs as a sole intervention. However, the evidence suggested that some comprehensive multidisciplinary programs (including engineering and administrative controls) were effective in reducing incidence of work-related MSDUEs, and worksite exercise programs were included in several of these programs. Based on the review of the literature available at that time, the authors concluded that multidisciplinary interventions were the most appropriate approach to the control of work-related MSDUEs, and that no evidence precluded the use of an appropriately designed and monitored exercise program as part of a comprehensive effort.

A decade has passed since that initial review. In the interim, guidelines from occupational safety and health agencies in Australia and the Netherlands have suggested exercise as a prophylactic approach to MSDUEs (NOHSC 1; Willems 1969). This led the authors to consider whether more recent developments in the scientific literature support such recommendations. This article provides an updated review of the scientific literature on the efficacy of workplace exercise programs to provide readers with the most recent information available in order to make better-informed decisions regarding exercise as a control strategy for MSDUEs.

The New Literature

As defined for this review, worksite exercise programs take place on site at an office or manufacturing facility. They must include an upper extremity exercise component, although not necessarily to the exclusion of other exercises. Such programs are conducted during regular working hours, and are usually implemented with the goal of mitigating the

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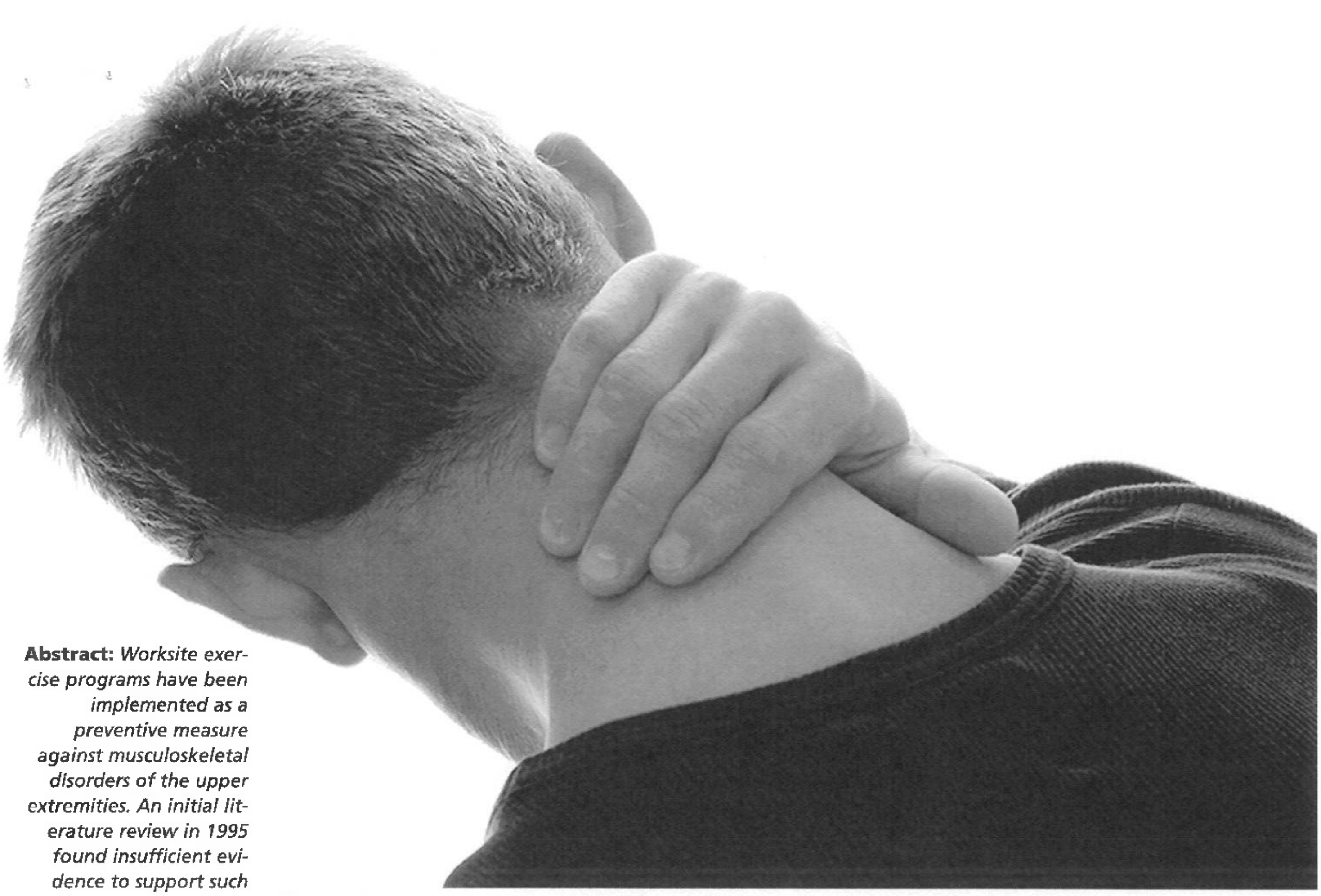

Abstract: *Worksite exercise programs have been implemented as a preventive measure against musculoskeletal disorders of the upper extremities. An initial literature review in 1995 found insufficient evidence to support such programs as a sole intervention, but found some evidence supporting their use as part of a comprehensive multidisciplinary program. This article provides an updated review of six other studies that have investigated the effects of these programs. Despite a decade of additional research, the results remain inconclusive. This lack of a consensus illustrates the need for well-designed studies with clearly defined interventions and effective control of confounding factors. More rigorous methods could improve the understanding of the role of worksite exercise.*

effects of static postures or repetitive motions involved in a worker's job. Participation may be mandatory or voluntary. The exercise programs may focus on specific joints or muscle groups, or may be more general in nature. Some programs involve a break(s) from the work routine, while other programs may take place at the beginning of the shift or workday. The exercise programs may be conducted on the shopfloor, in the office, at the worker's desk or in a common area.

Two online search engines were used to conduct the literature search: PubMed (www.ncbi.nlm.nih.gov/entrez/query.fcgi?DB=pubmed) and Ergonomics Abstracts Online (http://ergonomics.metapress.com). The criteria for inclusion in the review were: 1) the report was published in a peer-reviewed journal indexed by at least one of the above databases; 2) the exercise program included an upper extremity component; 3) the exercise program was conducted at the workplace; and 4) the study included at least one outcome measure related to upper extremity symptoms, disease or disability.

Satisfaction of all four criteria was required for inclusion in the review. The authors identified and reviewed five recent studies that have investigated the effect of a worksite exercise program, either alone or as part of a more comprehensive intervention, as well as one earlier study not included in the initial review. A summary of the results of the review is presented in Table 2.

Hilyer Study: Firefighters

Hilyer, et al conducted a six-month study of an exercise program emphasizing improved flexibility with 469 professional firefighters (Hilyer, et al 631). Participation was mandatory and group assignment was random, based on the fire station at which they worked. The control and exercise groups had 218 and 251 firefighters, respectively. The program was designed to promote flexibility of shoulder muscle groups as well as the low back and hamstrings. Four flexibility tests were conducted before and after introduction of the exercise program: 1) a sit-and-reach test for lumbar and hamstring flexibility; 2) a standing trunk rotation test; 3) a shoulder flexion/extension range of motion measurement; and 4) a knee flexion/extension range of motion measurement.

Comparisons of the flexibility test results showed a significant overall increase in flexibility among the experimental group and a particularly large increase in shoulder flexion and extension flexibility. At a two-year follow-up, no dropouts were reported from either study group. The two groups had no significant differences in injury rates or medical costs. However, the cost of lost time was significantly less—66.5% lower for the exercise group—suggesting a decrease in severity or associated disability when an injury did occur. Lost-time costs were not broken down by body part or nature of injury, which limits the ability to draw specific conclusions regarding program effectiveness for prevention of MSDUEs.

Genaidy Study: Meatpacking Plant

Genaidy, et al reported on the effect of short work breaks (microbreaks that included upper extremity stretches) on perceived discomfort among workers at a meatpacking plant (Genaidy, et al 326). Twenty-eight meat cutters participated in the study that evaluated effects of the intervention over a 2-week period. The workers were taught a psychophysical methodology that involved self-selecting stretching breaks based on discomfort in a body part. The workers were taught isometric static stretching techniques for the upper extremities, trunk and lower extremities, and were instructed to take breaks as often as necessary, but to limit break length to 2 minutes and no more that 24 total minutes per shift.

Statistically significant decreases were found in discomfort ratings reported for the shoulder, upper arm and lower arm after introduction of the program. Each shift, the workers took an average of 2.1 microbreaks with a combined duration of 48 seconds. The study lacked a control group, however, relying instead on a pre-test/post-test design; this increases the potential for a placebo effect to bias the results. The intervention period was very brief as well, and the number of subjects was small. In addition, the study did not include analysis of injury incidence or the cost effectiveness of the intervention.

Table 1

Exercise Study Characteristics & Findings, McGorry & Courtney, 1995

Study	Exercise Type	Outcome Measures	Positive Finding?	Statistical Significance
LaPorte, 1966 Industry: Post office Subjects: 40 letter sorters; 40 job and age-matched controls Study length: Single event	UE & other Other interventions: None	Visual fatigue Cognitive fatigue Hand MVE Tremor	N Y Y Y	NT NT NT NT
Hansford, 1986 Industry: Surgical products mfg. Subjects: 16 employees suture mfg. Study length: 2 weeks	UE only Other interventions: Exercise break tested vs. rest break; no other described.	Radial & ulnar artery flow velocity Radial & ulnar artery systolic blood pressure	Y N	Y, radial only N
Lutz, 1987 Industry: Surgical products mfg. Subjects: 33 employees in microswagging department Study length: 3 months	UE only Other interventions: Conservative therapy; job modification; workstation modification	Work-related medical visits, MSD symptom	Y	NT
Sawyer, 1987 Industry: Sports products mfg. Subjects: Approx. 15 racquet stringers Study length: 3 years	UE & other Other interventions: Job rotation; PPE; workstation modification	Case incidence Symptoms	Y Y	NT NT
Silverstein, 1988 Industry: Dental floss mfg. Subjects: 178 assemblers and packers Study length: 1 year	UE only Other interventions: Physical therapy	Body part discomfort	Y	N
Williams, 1989 Industry: Garment mfg. Subjects: 14 exercisers; 16 controls (similar jobs); company selected Study length: 10 weeks	UE only Other interventions: None	Hand MVE Phalen's Test Thermography	N N N	NT NT NT
Tadano, 1990 Industry: Telephone company Subjects: 500 operators Study length: 1 year	UE & other Other interventions: Physical therapy; work methods change; workstation modification	Case incidence	Y	NT
Thomas, 1993 Industry: Hardware mfg. Subjects: 7 symptomatic exercisers; 7 nonsymptomatic controls; company selected Study length: 8 weeks	UE only Other interventions: None	Motor NCV Hand MVE Body part discomfort	N I N	N N N

Notes: I = Inconclusive; MSD = Musculoskeletal Disorder; MVE = Maximum Voluntary Exertion; NCV = Nerve Conduction Velocity; NT = No Testing Described; UE = Upper Extremity.

van der Heuval Study: Computer Operators

van der Heuval, et al conducted an eight-week study comparing rest break alone versus exercise and rest break among 268 computer operators with upper extremity or neck complaints of at least 2 weeks duration (van der Heuval, et al 106). Volunteers were randomly assigned to one of two intervention groups where breaks were required by software-controlled work interruptions, or to a control group having no forced breaks.

In one intervention group, a 5-minute rest was imposed after every 35 minutes of work. In the second intervention group, 45 seconds of software-directed upper extremity and trunk exercises (specifics not described) started each 5-minute rest period.

Follow-up questionnaires were completed by 219 participants—74 from the control group, 79 from the break group and 66 from the exercise and break group. Self-reported complaint severity and frequency decreased for all three groups, but no significant between-group differences were found for symptoms or duration of sick leave. A significantly greater perception of recovery was observed for both intervention groups.

Melhorn Study: Aircraft Workers

Melhorn conducted a study of 212 aircraft workers to evaluate the effectiveness of three interventions: an exercise program, an ergonomics training program and a tool-vibration-dampening modification to a pneumatic rivet gun (Melhorn 1264). The study spanned 15 months with assessments conducted at the start and end of the 8-month study, and at a 7-month follow-up. The outcome variable, injury risk (0 to 7 scale), was a model constructed by combining physical measures, questionnaire data and noninvasive "nerve sensitivity testing."

A significant decrease in injury risk occurred among those in the ergonomics training program, but no main effect was observed for the program that included exercises for the upper extremities and back, or the tool modification. Significant effects of exercise were observed for covariate factors included in the risk model (dominant hand, number of parts processed), but the practical significance was unclear.

Eriksen Study: Postal Workers

Eriksen, et al reported results of a 12-week study with postal workers randomly assigned to one of three experimental groups or a control group (Eriksen, et al 383). Of the 1,061 worker volunteers who completed the pretest questionnaire, 472 worker volunteers completed the investigation of a worksite ex-

Table 2

More Recent Exercise Study Characteristics & Findings

Study	Exercise Type	Outcome Measures	Positive Finding?	Statistical Significance
Hilyer, et al, 1990 Industry: Municipal firefighters Subjects: 251 exercise; 218 control Study length: 6 months; 2 year f/u	UE & other Other interventions: None	Flexibility Injury rate Medical cost Lost time	Y N N Y	Y N N Y
Genaidy, et al, 1995 Industry: Meatpacking Subjects: 28 exercise (microbreak) Study length: 2 weeks	UE & other Other interventions: None	Perceived discomfort	Y	Y
Melhorn, 1996 Industry: Aircraft manufacturing Subjects: 212 total in 8 groups (2 control) testing 3 factors: rivet gun ergo training exercise Study length: 15 months	Mainly UE Other interventions: Pneumatic rivet gun modification; ergonomics training	Injury risk	N	N (some positive covariate effects)
Seradge, et al, 2000 Industry: Meatpacking Subjects: 286 exercise Study length: 1 year	UE only Other interventions: None	WC loss ratio Injury rate, MSD Injury rate, CTS	Y Y Y	NT NT
Eriksen, et al, 2002 Industry: Postal service (office workers) Subjects: 114 exercise; 94 exercise & health ed; 98 stress mgmt.; 166 control Study length: 12 weeks	UE & other Other interventions: General health education program; stress management training	Job stress Health complaints Lost time Subj. improvement	N N N Y	N N N Y
Van der Heuval, et al, 2003 Industry: Computer workers Subjects: 66 rest and exercise; 79 rest only; 74 control Study length: 3 months	UE only Other interventions: None, other than substitution of rest	Perceived recovery Complaint frequency Complaint severity Lost-time cost	Y Y Y N	Y N N N

Notes: CTS = Carpal Tunnel Syndrome; MSD = Musculoskeletal Disorder; NT = No Testing Described; UE = Upper Extremity.

ercise program. A group of 114 workers completed the exercise program, the goal of which was to improve muscular capacity, strength and flexibility while maintaining the heart rate at 70 to 80% of maximum. Exercises of the neck, back, arms and shoulders, adapted from an aerobic dance program, were performed for one hour twice a week. A group of 94 workers received health education training as well as exercise during a 2-hour session conducted once per week; 98 received stress management training; and 166 controls received no interventions.

No significant difference in self-reported duration of sick leave, pain or subjective health assessment based on pre-test and post-test questionnaires was observed for any experimental group as compared to the control, in a study that was hampered by a very high dropout rate. Because the results were not specific to body part, effects specific to the upper extremities could not be determined.

Seradge Study: Meatpacking Plant

Seradge, et al reported on a one-year study of an upper extremity exercise program with 286 workers at a meatpacking plant [Seradge, et al(c) 150]. The 3-minute "carpal tunnel decompression exercise" program was developed based on the authors' observations from a previous study of in vivo carpal tunnel pressures measured in 92 subjects (102 hands) with carpal tunnel syndrome (CTS) [Seradge, et al(b) 855]. The tunnel pressures were recorded during a series of wrist and finger movements; following the experimental activity, carpal tunnel pressures were found to decrease for the final 15 minutes of data collection.

The exercise program was the only intervention introduced during the study period and it was mandatory for all production workers. The program was performed once daily at the beginning of each shift. The authors noted a decrease in MSDUE cases reported (exclusive of CTS), from 40 to 25 (37%), and a decrease in CTS cases reported from 55 to 22 (45.4%) during the year of the exercise intervention as compared to the previous year's reports. The workers' compensation loss ratio (the ratio of compensable medical and lost-time cost to insurance premium) improved by 16.5% over the one-year period. Although these results are encouraging, the study was not controlled, which introduces the potential for confounding by other factors. The statistical significance of the results was not reported.

Discussion

A literature search identified six articles investigating the effectiveness of worksite exercise programs in addition to the eight articles previously reviewed (McGorry and Courtney 22). Five of the six newly reviewed studies (the exception being the Melhorn study) found a positive main effect for at least one of the outcome measures following the introduction of an exercise intervention. Participant flexibility improved in one study (Hilyer, et al 631). The study conducted by Genaidy, et al showed a positive effect for the sole outcome measure of perceived discomfort. Ambiguous or negative results were found for the exercise intervention groups in three studies (van der Heuval, et al 106; Melhorn 1264; Eriksen, et al 383).

The results with respect to the more pertinent and direct outcome measures of disability or injury cost varied greatly across the studies. Of the six articles reviewed, the Hilyer, et al study with a cohort of firefighters provided the strongest support for worksite exercise programs (Hilyer, et al 631). Participants not only demonstrated improved flexibility, but also showed significant reduction in lost-time costs. However, injury and cost data were not reported by body part, so it is impossible to conclude with confidence that the effect was observed specifically for the upper extremities.

The other study that reported a positive effect on upper extremity disease in general and on CTS specifically was the worksite exercise intervention instituted at a meatpacking plant [Seradge, et al(c) 150]. Results of this study must be considered with great care since it was conducted without a control group and the results were reported without significance testing. In contrast, van der Heuval, et al and Eriksen, et al found no significant effect of an exercise intervention on sick leave (van der Heuval, et al 106; Eriksen, et al 383).

Research Implications

Looking across all 14 studies reviewed, the authors noted a high degree of variability in study methods and outcomes that might account in part for the mixed results. More rigorous and consistently applied methods could improve the understanding of the role of worksite exercise. Good experimental design principles include random assignment of subjects to conditions, the use of control group(s), variables that are objectively measurable and are directly relevant to the desired health outcomes, and the application of statistical hypothesis testing. [For further exploration of the components and attributes of good experimental design, see Courtney (33).]

Only 7 of the 14 studies reviewed used a concurrent control group. The others either used pre-test/post-test designs or were not controlled. For outcome measures, studies reported one or more of the following: five studies reported physical measures (e.g., flexibility, maximum voluntary exertion); seven reported subjective measures (e.g., body part discomfort, perceived recovery); and seven reported a measure directly relevant to injury or disability (e.g., injury rate, lost time, medical cost). Nine of the 14 studies employed statistical testing.

Only three of the studies used a randomized, controlled design with statistical testing of outcome measures directly related to injury or cost (Hilyer, et al 631; Eriksen, et al 383; van der Heuval, et al 106). Of these, only the Hilyer, et al study reported a positive effect, showing a significant reduction in lost time. The ability to generalize these results is limited, however, since outcomes were not reported by body part and because firefighters may not be representative of the general work population due to rigorous fitness-for-duty requirements. The Eriksen and van der Heuval studies reported nonsignificant effects of their respective interventions on lost time. These studies were of shorter duration (approximately three months), and the Eriksen study, in particular, was hampered by a high dropout rate.

Fitness/Wellness Programs

This literature review did not include employer-sponsored wellness or fitness programs. However, it is plausible that such programs could help workers be less prone to work-related injury, require less medical care, use less sick time and, ultimately, be more productive. It is widely held within the physical rehabilitation community that poor physical conditioning increases the risk of injury, whether in the sports arena or the workplace.

Employer-sponsored fitness programs can range from the fully equipped on-site fitness centers to off-site programs subsidized by the employer. The goal of these programs is to promote general fitness and health. Participation is typically voluntary and takes place outside of working hours. When properly used, such programs would be expected to produce a positive general effect on employee health, but the literature does not support their efficacy from an economic (cost-benefit) or injury/disability perspective.

As a case in point, Proper, et al showed that providing a series of seven health promotion consultations produced significant improvements in cardiovascular and respiratory function [Proper, et al(a) 34]. However, this study and others (Nurimen, et al 85; Tsai, et al 475) have not clearly demonstrated the cost effectiveness of such programs in terms of reducing medical utilization or absenteeism. Several comprehensive reviews are available on this topic [Proper, et al(b) 75; Proper, et al(c) 106; Aldana 296; Dishman, et al 344]. In addition, some recent studies have evaluated the application of exercise specifically as a treatment approach for diagnosed CTS [Garfinkel, et al 1601; Rozmaryn, et al 171; Nathan, et al 840; Seradge, et al(a) 7; Akalin, et al 108]. Results are still inconclusive.

More rigorous and consistently applied methods could improve the understanding of the role of worksite exercise.

Reflections on Practice

Based on the results of these two literature reviews, the authors offer the following considerations for SH&E professionals evaluating the implementation of a worksite exercise program as a control strategy for MSDUEs.

First, consider the nature of the tasks that workers perform. Observe working postures realizing that static postures of the head and trunk or upper extremities maintained for long periods can be detrimental just as are highly repetitive movements. The first approach should always be to modify the job or workplace to better accommodate the worker.

Participants should be screened for medical conditions for which the exercise may be contraindicated. Additional time should be allocated for exercising, and time should not be diverted from rest breaks or other existing recovery pauses. Exercises should not be embarrassing to perform or disruptive to the workplace. Active exercises that could aggravate existing conditions should be avoided (McGorry and Courtney 22).

If jobs require maintaining the shoulders or arms at non-neutral postures, the program should emphasize active and passive range of motion exercises to promote stretching of soft tissues and circulation to that body part. Exercises should promote passive and active movement of the affected body part without significant loading. Resistive exercises, typically used for strengthening, are generally not appropriate as part of a worksite program as they can potentially increase exposure (OSHA 14).

The intention of this article is to provide an unbiased review of the literature and should not be considered an endorsement of any exercise program. In the end, ergonomic interventions should be based on a thorough job and worksite evaluation by an appropriately trained and credentialed professional. Finally, before implementing a workplace exercise program, a healthcare professional with the appropriate training should be consulted.

Taken as a whole, the literature specific to worksite exercise programs implemented as a control for MSDUEs is not very compelling.

Conclusion

Despite a decade of additional research on exercise programs, the results of this review concur with the conclusions of the previous review. Taken as a whole, the literature specific to worksite exercise programs implemented as a control for MSDUEs is not very compelling. This finding may reflect the lack of a focused, sponsored, peer-reviewed research initiative in this area by funding agencies that would influence the development of stronger studies.

The most positive support for exercise continues to be in those studies in which exercise was included as part of a more comprehensive ergonomics program approach to controlling MSDUEs, including engineering and administrative controls. The lack of a consensus across multiple research studies illustrates the continued need for well-designed, prospective studies with clearly defined interventions and effective control of confounding factors. ■

References

Akalin, E., et al. "Treatment of Carpal Tunnel Syndrome with Nerve and Tendon Gliding Exercises." *American Journal of Physical Medicine and Rehabilitation.* 81(2002): 108-113.

Aldana, S.G. "Financial Impact of Health Promotion Programs: A Comprehensive Review of the Literature." *American Journal of Health Promotion.* 15(2001): 296-320.

Courtney, T.K. "Applying Research in Reality: A Rationale and Systematic Approach." *Professional Safety.* 42(1997): 33-38.

Dishman, R.K., et al. "Worksite Physical Activity Interventions." *American Journal of Preventative Medicine.* 15(1998): 344-361.

Eriksen, H.R., et al. "Improving Subjective Health at the Worksite: A Randomized Controlled Trial of Stress Management Training, Physical Exercise and an Integrated Health Program." *Occupational Medicine (London).* 52(2002): 383-391.

Garfinkel, M.S., et al. "Yoga-Based Intervention for Carpal Tunnel Syndrome: A Randomized Trial." *Journal of the American Medical Association.* 280(1998): 1601-1603.

Genaidy, A.M., et al. "Active Microbreak Effects on Musculoskeletal Comfort Ratings in Meatpacking Plants." *Ergonomics.* 38(1995): 326-336.

General Accounting Office (GAO). *Worker Protection: Private Sector Ergonomics Programs Yield Positive Results.* GAO/HEHS-97-163. Washington, DC: GAO, 1997. <http://www.gao.gov/archive/1997/he97163.pdf>.

Hansford, T., et al. "Blood Flow Changes in the Wrist in Manual Workers after Preventive Interventions." *Journal of Hand Surgery.* 11A(1986): 503-508.

Hilyer, J.C., et al. "A Flexibility Intervention to Reduce the Incidence and Severity of Joint Injuries among Municipal Firefighters." *Journal of Occupational Medicine.* 32(1990): 631-637.

Laporte, W. "The Influence of a Gymnastic Pause upon Recovery Following Post Office Work." *Ergonomics.* 9(1966): 501-506.

Liberty Mutual Insurance Co. "Liberty Mutual Workplace Safety Index, 2004." Boston: Liberty Mutual, 2004.

McGorry, R.W. and T.K. Courtney. "Exercise and Cumulative Trauma Disorders: The Jury Is Still Out." *Professional Safety.* 40(1995): 22-25.

Melhorn, J.M. "A Prospective Study for Upper-Extremity Cumulative Trauma Disorders of Workers in Aircraft Manufacturing." *Journal of Occupational and Environmental Medicine.* 38(1996): 1264-1271.

Nathan, P.A., et al. "Effects of an Aerobic Exercise Program on Median Nerve Conduction and Symptoms Associated with Carpal Tunnel Syndrome." *Journal of Occupational and Environmental Medicine.* 43(2001): 840-843.

National Occupational Health and Safety Commission (NOHSC). *Guidance Note for the Prevention of Occupational Overuse Syndrome in the Manufacturing Industry.* 2nd ed. NOHSC Publication 3105. Canberra, Australia: Australian Government Publishing Service, 1996.

National Research Council (NRC). *Musculoskeletal Disorders and the Workplace: Low Back and Extremities.* Washington, DC: National Academy Press, 2001.

NIOSH(a). *Elements of Ergonomics Programs.* DHHS/NIOSH Publication 97-117. Washington, DC: U.S. Department of Health and Human Services, Centers for Disease Control and Prevention, NIOSH, 1997. <http://www.cdc.gov/niosh/97-117pd.html>.

NIOSH(b). *Musculoskeletal Disorders and Workplace Factors.* DHHS/NIOSH Publication 97-141. Washington, DC: U.S. Department of Health and Human Services, Centers for Disease Control and Prevention, NIOSH, 1997. <http://www.cdc.gov/niosh/97-141pd.html>.

Nurminen, E., et al. "Effectiveness of a Worksite Exercise Program with Respect to Perceived Work Ability and Sick Leaves among Women with Physical Work." *Scandinavian Journal of Work and Environmental Health.* 28(2002): 85-93.

OSHA. "Ergonomics Program Management Guidelines for Meatpacking Plants." Washington, DC: U.S. Department of Labor, OSHA, 1993. <http://www.osha.gov/Publications/osha3123.pdf>.

Proper, K.I., et al(a). "Costs, Benefits and Effectiveness of Worksite Physical Activity Counseling from the Employer's Perspective." *Scandinavian Journal of Work and Environmental Health.* 30(2004): 34-36.

Proper, K.I., et al(b). "Effectiveness of Physical Activity Programs at Worksites with Respect to Work-Related Outcomes." *Scandinavian Journal of Work and Environmental Health.* 28(2002): 75-84.

Proper, K.I., et al(c). "The Effectiveness of Worksite Physical Activity Programs on Physical Activity, Physical Fitness and Health." *Clinical Journal of Sports Medicine.* 13(2003): 106-117.

Rozmaryn, L.M., et al. "Nerve and Tendon Gliding Exercises and the Conservative Management of Carpal Tunnel Syndrome." *Journal of Hand Therapy.* 11(1998): 171-179.

Sawyer, K. "An On-Site Exercise Program to Prevent Carpal Tunnel Syndrome." *Professional Safety.* 32(1987): 17-20.

Seradge, H., et al(a). "Conservative Treatment of Carpal Tunnel Syndrome: An Outcome Study of Adjunct Exercises." *Journal of the Oklahoma State Medical Association.* 95(2002): 7-14.

Seradge, H., et al(b). "In Vivo Measurement of Carpal Tunnel Pressure in the Functioning Hand." *Journal of Hand Surgery.* 20(1995): 855-859.

Seradge, H., et al(c). "Preventing Carpal Tunnel Syndrome and Cumulative Trauma Disorder: Effect of Carpal Tunnel Decompression Exercises: An Oklahoma Experience." *Journal of the Oklahoma State Medical Association.* 93(2000): 150-153.

Silverstein, B.A., et al(a). "Can In-Plant Exercise Control Musculoskeletal Symptoms?" *Journal of Occupational Medicine.* 30(1988): 922-927.

Silverstein, B.A., et al(b). "Occupational Factors and Carpal Tunnel Syndrome." *American Journal of Industrial Medicine.* 11(1987): 343-358.

Tadano, P. "A Safety/Prevention Program for VDT Operators: One Company's Approach." *Journal of Hand Therapy.* 3(1990): 64-71.

Thomas, R.E., et al. "Effects of Exercise on Carpal Tunnel Symptoms." *Applied Ergonomics.* 24(1993): 101-108.

Tsai, S.P., et al. "Injury Prevalence and Associated Costs among Participants of an Employee Fitness Program." *Preventative Medicine.* 17(1988): 475-482.

van den Heuvel, S.G., et al. "Effects of Software Programs Stimulating Regular Breaks and Exercises on Work-Related Neck and Upper-Limb Disorders." *Scandinavian Journal of Work and Environmental Health.* 29(2003): 106-116.

Willems, J.H. "Repetitive Strain Injury: A Report from the Health Council of the Netherlands." *Ned Tijdschr Geneeskd.* 146(2002): 1969-1970.

Williams, T.L., et al. "Exercise as a Prophylactic Device Against Carpal Tunnel Syndrome." *Proceedings of the Human Factors Society 33rd Annual Meeting.* Santa Monica, CA: Human Factors Society, 1989. 723-727.