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Stretching at Work for Injury Prevention: Issues, Evidence, and Recommendations

Scott Schneider, Column Editor

Reported by Jennifer A. Hess and Steven Hecker

Advocates of workplace stretching programs claim that enhanced flexibility can prevent work-related musculoskeletal injuries. While numerous companies have implemented stretching programs,[1,2] the efficacy and cost-effectiveness of these programs have not been demonstrated. Most reports of the benefits achieved by worksite stretching programs continue to be published predominantly in the popular literature or trade journals. These reports are based on uncontrolled or quasi-experimental in-house evaluations that rely on self-reported outcomes rather than objective measures.[3–5]

Furthermore, most studies, regardless of quality of design, seek only to answer one broad question: "Does stretching prevent injury?" This single focus eclipses more specific questions that should be asked about stretching, such as, "Who does stretching benefit, and in what situations?" Anecdotal evidence suggests that workplace stretching programs are increasing in popularity. There are a number of forums addressing whether such programs have a legitimate place as part of or as a complement to ergonomic analysis and intervention in reducing the toll of work-related musculoskeletal disorders.

The purpose of this report is to review studies that evaluate flexibility among working populations, or workplace stretching programs, or both, and to examine possible associations of flexibility and stretching programs with incidence of work-related musculoskeletal injury. While most studies remain equivocal about the role of stretching in injury prevention, they raise additional issues pertaining to flexibility and stretching that we also address.

To be included in this review, articles had to meet four criteria. They must 1) pertain to flexibility or stretching for the purpose of improving flexibility; 2) have been published in a peer-reviewed journal; 3) study populations of working adults rather than athletes or military recruits whose results may not generalize to a working population; and 4) include a control group if cross-sectional in design. Longitudinal studies by design would not require controls. The search was conducted in Medline using combinations of the keywords "stretching," "flexibility," "fitness," "exercise," "workplace," "industry," and "injuries" between 1975 and 2001. Several good studies that included stretching as part of a workplace exercise or fitness program, but that did not specifically quantify the effects of flexibility, were excluded from this review.[6–10]

Physiology of Stretching

Stretching programs are intended to reduce the incidence and/or severity of injuries by increasing flexibility. Flexibility is commonly defined as the range of movement possible around a specific joint or series of joints, and this definition is applied in most clinical studies. In biomechanics terms, flexibility refers to changes in the length of a muscle tendon unit brought about by alterations of its viscoelastic properties. Viscoelasticity is a measure of a tissue's ability to deform or change length when a load is applied over time and to resume its original size and shape when the force is removed, much like stretching and releasing a rubber band.

Several laboratory studies have demonstrated that stretching results in elongation of the muscle tendon unit, reductions in peak force, rate of force production, and tensile stress on the muscle tendon unit.[11–14] Therefore, stretching appears to alter the viscoelasticity of the muscle tendon unit, resulting in less stiff (i.e., more compliant) tissues. These changes increase the distance the tissue can stretch as well as the force required to tear the muscle tendon unit, making injury less likely. The presumption is that, for individuals with short or "tight" muscles, stretching increases flexibility by elongating tissues to a more physiologically normal range, promoting optimal function and reducing the risk of musculoskeletal injury.

Association of Flexibility with Pain and Injury in Workers

While it is commonly believed that those who are less flexible are more likely to have musculoskeletal pain and resultant injury, our search yielded only five studies that evaluated the association between flexibility and musculoskeletal pain or injury in working populations (see Table I). These studies focus on the low back region where the most common and costly musculoskeletal injuries occur. It should be noted that, while pain is generally considered a symptom, it is clinically common with back problems that no specific etiology can be found. Therefore, "back pain" is a frequently used diagnosis, and the term "back pain" has been used interchangeably with "injury" in many studies. Further, these

TABLE I

Studies examining the relationship between flexibility and pain/injury

Author(s), year(s)	Design	Population	Predictor variable	Measurement tools	Outcome variable	Reliability/validity	Analysis methods
Bergquist-Ullman et al., 1977[18]	1-year randomized, controlled prospective study	217 Swedish manufacturing employees with acute LBP; control population of 35-year-old healthy males	Range of motion in flexion of low back	Modified Schober, flexion, lateral flexion and extension	LBP assessed by patient history and physical examination	Validity cited from other studies, not directly measured	Stratified by vocation, Chi-square, no p-values for ROM provided
Cady et al., 1979[16], 1985[17]	4-year prospective longitudinal study	1652 firefighters, subgroup of 320 firefighters aged 40–49	Total spine flexibility (range of motion)	Measurement technique not stated	Back injury incidence and cost calculated from workers' compensation records	Not reported	Mahalanobis D-square, multiple regression, means variances
Biering-Sørensen, 1984[19]	1-year prospective longitudinal study	928 Danish residents: 449 men, 479 women aged 30–60	Range of motion in flexion of low back and hamstrings	Modified Schober, fingertip-to-floor distance, hamstring length, questionnaire	Low back trouble assessed by questionnaire	Coefficient of variation for Schober = 4.83% ($p < 0.001$)	Student t test, ANOVA, Chi-square, Mann-Whitney
Troup et al., 1987[20]	1-year prospective longitudinal study	2981 working men & women from various professions: nursing, clerical, fire service, teaching, unskilled labor, physiotherapy, and other occupations	Lumbar range of motion in flexion and extension	Fluid goniometer, questionnaire	LBP assessed by questionnaire	Not reported	ANOVA, Chi-square, and discriminant analysis
Battié et al., 1990[15]	4-year prospective longitudinal study; pain history reported retrospective	3020 aircraft manufacturing employees	Lumbosacral range of motion in flexion	Modified Schober, sit-and-reach test, side bending, and questionnaire	Future and prior LBP assessed by questionnaire, company records, and workers' compensation records	Modified Schober and sit-and-reach interobserver and intraobserver reliability ($r = 0.97$), both cited from other studies	Student *t* test, ANCOVA, Cox proportional hazards, regression model

studies were conducted to find tools for predicting workers at risk for low back pain (LBP), rather than purely for the purpose of understanding the role flexibility plays in injury.

One such study evaluated aircraft manufacturing employees over a four-year period.[15] No statistical difference in flexibility was found between those who eventually reported back pain and those who did not. There was a significant relationship between limited forward flexion and reports of current or previous back problems. However, the authors concluded that since the magnitude of flexibility differences between those with a history of back problems and those without were small, the results were not significant, and flexibility was not a meaningful metric for predicting risk of injury.

Los Angeles firefighters were evaluated to explore the relationship between fitness measures, occupational injuries, and claim costs.[16] Firefighters were placed into one of three fitness categories using a scoring system for flexibility, strength, exercise diastolic blood pressure, heart rate, and physical work capacity. The most fit were found to be substantially more flexible than the least fit. A subgroup of 320 healthy firefighters was examined specifically for flexibility, strength, work capacity, and percent body fat.[17] An association was found between flexibility, fitness, and work injury where those with either greater flexibility, strength, or work capacity had much lower back and total injury costs. In terms of flexibility, total back injury costs were almost six times greater for the group with the least flexibility versus the most flexible firefighters ($50,086 versus $8,831, respectively).

Swedish auto manufacturing workers with acute LBP were evaluated to determine prognostic factors for acute and subacute LBP.[18] The study results indicate that forward flexion was decreased in subjects with acute low back pain compared to a population of healthy males. However, 89 percent of these individuals also reported an increase in pain during forward bending, making it unclear whether reduced flexibility was the cause or result of injury. The range of motion (ROM) in extension and lateral flexion was not different from that found in a healthy population. There was no evidence of a relationship between ROM and duration of back pain over the year of observation, and the authors concluded that ROM was of no prognostic value for assessing the course of LBP.

Objective risk indicators for LBP were evaluated in working-age people from a Danish municipality.[19] At the one-year follow-up, men experiencing their first episode of LBP were significantly *more* flexible (in flexion) than men with no history of LBP, suggesting that joint laxity may be a cause of LBP. Women experiencing their first episode of LBP tended to demonstrate less back flexibility, while women with recurrent LBP had significantly tighter hamstrings.

A study to assess the predictive value of various pre-employment screening tests assessed flexibility in 2,891 British workers from a variety of backgrounds.[20] Those with LBP, while restricted in both flexion and extension, were significantly less mobile in *extension* than in flexion compared to those without back pain. In fact, loss of lumbar extension was the measure most frequently associated with aggravation of LBP. A significant association was also found between decreased spinal flexibility and reports of back problems over the following year. When considering frequency of symptoms, those with chronic back pain had the least mobility in combined sagittal flexion and extension.

Workplace Stretching Programs

Our search identified three studies that specifically evaluated the efficacy of workplace stretching programs (see Table II). A workplace stretching program designed to prevent muscle strains was implemented among pharmaceutical manufacturing employees.[21] A statistically significant increase in flexibility measurements for all body regions tested was found after two months of stretching. Participants' perception of physical conditioning, self-worth, attractiveness, and strength also increased significantly. The greatest physiological improvements in stretching occurred for back flexibility and shoulder rotation, especially in those who attended more than 13 sessions.

A flexibility program among municipal firefighters evaluated the incidence, cost, and severity of joint injuries in stretchers versus nonstretchers.[22] Subjects who participated in the program were significantly more flexible than controls after six months of stretching. In the 2–year follow-up, there were 48 injuries among stretchers and 52 injuries among controls (not significantly different). The total dollars spent because of injury (i.e., time loss plus medical costs) was $85,372 for stretchers versus $235,131 for controls ($p = .056$). The authors reported this as a statistically nonsignificant result. However, a breakdown of costs revealed that time-loss costs for stretchers were significantly lower than controls ($45,597 versus $147,581, respectively; $p = .026$), while medical costs were not significantly different between the groups ($39,775 stretchers versus $87,550 controls; $p = .191$).

An intervention study with manual handling workers looked at strength in conjunction with flexibility.[23] One group of workers received progressive resistance strength training alone, while another group received progressive strength training in conjunction with trunk flexibility exercises (pre- and post-strength training). Flexibility improved in those who performed strength training and stretching, but not in those who performed only strengthening exercises. Low back flexibility did not improve in the groups performing only resistance training. Additionally, flexibility combined with strength training resulted in higher percentage increases in static and dynamic strength than did strength training alone.

TABLE II
Workplace stretching programs

Author(s), year(s)	Design	Population	Predictor variable	Measurement tools	Outcome variable	Reliability/validity	Analysis methods
Hilyer et al., 1990[22]	6-month controlled pre-test–post-test intervention study	469 municipal firefighters aged 24–63 from 4 fire districts (exper = 251, control = 218)	Range of motion in low back, hamstrings, and shoulders	Sit-and-reach test for low back, flexometer for shoulder, and goniometer for knee flexibility	Incidence of MS injury, time loss, and treatment costs from worker records over 2 years	Sit-and-reach (r = 0.98), trunk rotation (r = 0.90–0.98), cited from other studies	ANCOVA, Chi-square, *t* tests
Genaidy et al., 1994[23]	6-week within-subject factor design	28 manufacturing employees: 16 subjects, 12 controls divided among 3 plants	Trunk range of motion, dynamic/static strength, flexibility	Sit-and-reach, trunk rotation	Strength, flexibility, perceived exertion	Not reported	ANOVA
Moore, 1998[21]	One group pre-test–post-test design	60 manufacturing employees aged 23–59 years	Range of motion in trunk and shoulders	Sit-and-reach, body rotation, shoulder rotation	Incidence of injury based on self-reports to company nurse, level of flexibility, and self perception	Sit-and-reach (r > 0.84), body rotn (r = 0.75–0.92), shoulder rotn (r = 0.85–0.98), shoulder flexometer (r = 0.90–0.98), cited from other studies; knee extension: no reliability cited	Paired *t* test

Discussion

The reviewed studies evaluated numerous parameters such as acute and chronic low back pain and ranges of motion in flexion, extension, and side bending. They included standard clinical tests for flexibility, such as the Modified Schober and the fingertip-to-floor test, combined with self-report questionnaires, physical examinations, and work records. With such diverse methodologies and data sources, it is not surprising that there are contradictions in the findings. In spite of these limitations, we draw from this review several specific areas requiring further study.

Flexibility and Optimal Range of Motion

Several studies found reduced low back flexion in subjects with acute or chronic LBP.[15,18] One study found decreases in extension in those with LBP, while another found that men with hypermobile low backs were more likely to experience LBP.[19,20] These contradictions highlight the issue of a beneficial "functional" range of motion. It seems reasonable that individuals at either end of the mobility spectrum, regardless of the axial plane or direction, may be at an increased risk for injury.

Muscles exert more force in the middle of the joint range of motion. Since less force is produced at the end ranges, it follows that muscles, ligaments, and joints are less stable and more susceptible to injury when muscles are too long or too short, especially if the worker is in a biomechanically disadvantageous posture such as bending or lifting a load. This raises several questions: "Is there a healthy functional range of motion? How much flexibility is too great or too little? Which workers really need to enhance their flexibility?" Perhaps placing hypermobile workers in a stretching program puts them at greater risk of injury, while strengthening exercises would be appropriate. Hypomobile individuals, on the other hand, might benefit from greater flexibility, but these individuals have not been evaluated as a separate population.

Stretching at Work

The three studies that evaluated workplace stretching programs demonstrate that stretching improves flexibility. However, one study lacked a control group,[21] while two studies failed to correlate improvements in flexibility with meaningful outcome measures such as injury incidence or severity.[21,23] Additional studies are needed to more clearly define the contribution of stretching programs to injury prevention. The enhanced strength demonstrated by manual handling workers who stretch is an important finding in the real world of workers who bend, lift, carry, pull, and push over many hours a day.[23] The current narrow focus on flexibility might be overlooking this valuable aspect of stretching that could contribute to reducing injuries related to worker fatigue.

The decreases in injury severity and associated costs found in firefighters are an important aspect of stretching at work.[22] Others have noted the cost savings from decreasing injury severity and time loss. A review of job site physical therapy exercise programs indicates that the greatest costs associated with work injuries are from worker absence and time-loss compensation rather than medical care.[24]

Further, workers with back injuries have a diminished likelihood of returning to work if they are off work for longer than six weeks.[25,26] Those off work for longer than six months have less than a 50–percent chance of ever returning to productive employment, and for those whose disability lasts longer than a year, the likelihood drops to 25 percent. Given these findings, reducing time loss and injury severity is as meaningful to workers and employers as is injury prevention. If reduced severity is indeed a product of stretching programs, this may be as significant an outcome as reduction of injury incidence.

Stretching, Flexibility, and the Sports Connection

Workers are sometimes referred to as "industrial athletes," and sports literature is frequently cited in the debate over the effectiveness of stretching at work. However, studies conducted among athletes are equivocal in their findings. Many studies in the sports literature have demonstrated that stretching before or during an athletic activity helps reduce the incidence of strains and sprains.[27−33] However, a roughly equal number have shown that stretching either has no effect on injury rates or may actually increase the risk of musculoskeletal pain or injury in athletes.[34−40]

Further, it is questionable to rely on studies relating flexibility and stretching among elite, college-aged athletes who train vigorously, to workers whose age, physical condition, training practices, and daily physical demands differ significantly. It may be erroneous to assume that industrial athletes behave in the same way as elite athletes, and there is a need for further studies specific to working populations. Perhaps, given differences in athletes and working populations, the outcome of rigorously evaluated workplace stretching programs might also be substantially different.

Criteria for an Effective Workplace Stretching Program

Even researchers who are highly critical of the proposed benefits of stretching recognize that all methods of stretching are not equal.[41] Since businesses continue to implement these programs, it seems appropriate to include some guidance regarding design, in order to enhance the potential for an effective program. The following criteria, summarized in Table III, are based on a review of the literature and current American College of Sports Medicine recommendations.[42] A preliminary aerobic warm-up (e.g., walking in place) for five minutes prior to stretching is advantageous for preventing injury and increasing the effectiveness of stretching. Stretching programs should be designed by job description or the body region most at risk for injury. This may mean concentrating stretches on several body regions such as the lower back, wrist, or shoulder, rather than performing a brief

TABLE III

Criteria for an effective workplace stretching program

- Warm-up for 5 minutes prior to stretching
- Exercises should be tailored to commonly performed job duties
- Stretch regularly: 2–3 days/week, minimum
- Perform stretches correctly:
  - Use static or PNF stretches
  - Hold stretch 15–30 seconds
  - 3–4 repetitions per muscle group
  - Stretch bilaterally, emphasize tight muscles
- Intensity should be to a position of mild discomfort
- Trained instructors should lead and monitor classes
- Compliance should be monitored
- Stretch at appropriate work times throughout the day
- Company commitment to work time and program overhead costs

total-body routine. For example, in construction, where there is a high incidence of low back injuries, it may be beneficial to devote a large portion of the routine to stretching the low back in flexion and extension as well as stretching the hamstrings and other related muscles. Conversely, office workers may benefit more from a focus on the neck, shoulder, and upper extremity.

There are several types of stretches: static, ballistic, or proprioceptive neuromuscular facilitation (PNF). PNF, where a muscle is contracted for about 20 seconds, relaxed, and then stretched, probably provides the greatest stretching effect. Static stretching is also very effective and is simpler to perform.[43] Ballistic stretching, where the individual bounces the muscle being stretched, has been shown to cause injury and should be avoided. The appropriate number and duration of stretches is another consideration. Overall, stretches should consist of three to five repetitions per muscle group, and each should be held for approximately 15 to 30 seconds to bring about the physiological changes that result in lengthening of muscles, tendons, and ligaments.[11] Symmetry in range of motion between body sides is essential for preventing injury; therefore, workers should be encouraged to stretch each side of the body equally and to pay special attention to muscles that are tighter on one side than the other.

Adherence to a regular stretching program is important for increasing flexibility and for reducing the number and per capita cost of musculoskeletal injuries.[2,7] Injury incidence was found to be lower only among individuals who exercise three or more times per week. For some individuals, it may be more advantageous to stretch at times other than first thing in the morning. For instance, a sedentary worker may benefit from stretching periodically throughout the day or just prior to some exertion.

The logistics of administering a stretching program will impact its success. Time and money constraints are important factors to consider when developing a program. Management must be willing to invest worker time on a daily basis even though savings may not be realized for a year or more. Qualified exercise leaders are essential to instruct and monitor workers on proper methods of stretching. Training a supervisor or other worker to lead stretching classes is one strategy used successfully by some businesses, while others employ an exercise physiologist.[7]

Conclusion

Basic science research has shown that stretching can alter viscoelastic properties by decreasing stiffness and increasing tissue compliance of the musculotendinous unit, leading to reduced risk of injury. However, epidemiological and intervention studies, focusing on working populations, have demonstrated equivocal findings pertaining to flexibility and injury. The methodological variations mentioned in this review — differences in design, populations, measurement tools, outcome variables, and use of control groups — explain much of the diversity in these study findings. The few available studies specific to workplace stretching programs, while suggesting that stretching at work enhances worker health and decreases the severity and cost of treating musculoskeletal injuries, fail to definitively prove the case for or against stretching. More information is needed to clarify the relationship between levels of flexibility, injury, and the need for regular workplace stretching. However, while these studies have shortcomings (and there continues to be a need for well-designed, prospective, controlled studies that correlate flexibility with the incidence and cost of injury), they have raised some important questions.

- Is stretching beneficial for those with hypermobility, normal ranges of motion, or only for those with hypomobility? Could stretching be detrimental for some workers?
- In terms of the low back, should stretching focus on flexion or extension?
- Is stretching beneficial only for the low back? (No references were found that specifically addressed stretching for the prevention of neck, shoulder, knee, or wrist injuries in working populations.)
- While findings are contradictory in young athletes, could the benefits of stretching in older workers be more consistent or substantial?
- Is there an ideal time of shift for stretching? For example, should workers stretch at the start of their shift or just prior to some exerting task?
- What constitutes a quality stretching program? Are 5 or

10 minutes sufficient to stretch the entire body? How many repetitions are needed to gain maximum benefit? Are all stretches equally effective?

The heated nature of this debate has made it difficult to generate a thorough dialogue about the role of stretching, and it is not enough to say that stretching at work does or does not work. Finally, stretching is only one component of injury prevention. As others have observed: "Fitness for most physical activities requires a combination of endurance, strength and flexibility, musculoskeletal timing and coordination."[17] These other aspects of musculoskeletal health as well as an ergonomically optimized work environment must not be overlooked in an effort to find a quick fix.

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