Occupational risk factors associated with soft tissue disorders of the shoulder: a review of recent investigations in the literature

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Cumulative trauma illness currently accounts for over half of all occupational illness in the United States. From 1987 to 1989 there was a 100% increase in the reported number of cases of cumulative trauma illness (Bureau of Labor Statistics 1990). Shoulder region pain ranks second only to low back and neck pain in clinical frequency, and the occurrence of occupational shoulder illness is on the rise. This paper summarizes findings of a subset of recent epidemiologic, laboratory, and field studies conducted in order to identify occupational risk factors for cumulative trauma disorders (CTDs) of the shoulder region. These studies have identified the following risk factors as being associated with particular shoulder pain syndromes: awkward or static postures, heavy work, direct load bearing, repetitive arm movements, working with hands above shoulder height, and lack of rest. The paper begins with a discussion of several shoulder disorders, includes problems in studying cumulative trauma, presents results of recent studies, and concludes with suggested ergonomic controls that could help to reduce the incidence of shoulder disorders, by eliminating or reducing exposure to the associated risk factors.

1. Introduction

Musculoskeletal disorders (MSDs) are the prime disablers of working adults (Putz-Anderson 1988). The US National Institute of Occupational Safety and Health included MSDs on its list of the Ten Leading Occupational Disorders (NIOSH 1987). Kvarnström (1983) found that half of all long term sick leave within a large Swedish electronics manufacturing company was due to MSDs. Low back pain and wrist trauma have, deservedly, received much attention in the literature, due to the high prevalence and cost of disorders which affect these regions. However, the rise in occurrence of occupationally-associated pain and disorders of the shoulder region (Herberts *et al.* 1984), and the recognition that shoulder pain ranks second in clinical frequency to low back and neck pain (Cailliet 1981) should provide the impetus for increasing the concentration of efforts, including epidemiologic studies and ergonomic intervention development, in this area.

Recent studies have shown the prevalence of shoulder pain syndromes to be

elevated in many working populations. Herberts *et al.* (1984) found the prevalence of supraspinatus tendinitis in shipyard welders to be 18·3%, compared with 2% in clerks employed by the same company. The prevalence of rotator cuff (RC) tendinitis and/or bicipital tendinitis in grocery store checkers was found to be 15% in contrast to a 4% level in non-checkers (Baron *et al.* 1990). The prevalence of regular discomfort in the shoulder region in a population of chicken processing workers was found to be 9% (Buckle 1987). In that study the employees' lifetime prevalence of shoulder discomfort or pain was determined to be 42%. Punnett *et al.* (1985) found the prevalence of persistent shoulder discomfort in garment workers to be 19·6%. The prevalence of discomfort or pain in the shoulder region of newspaper employees composing and editing on computer terminals was reported to be 11% (Burt *et al.* 1990). From the wide variety of occupations represented in these studies, it is obvious that employees across a broad spectrum may be experiencing some form of shoulder pain syndrome.

Shoulder pain syndromes have, in the past, been classified as idiopathic. This is probably due to a number of factors, including poorly-defined diagnoses and broad categorization (lumping together) of different shoulder disorders, the multifactorial nature of their etiology, and the paucity of prospective cohort epidemiologic investigations of potential risk factors associated with shoulder pain. This paper presents a review of shoulder disorders which can stem from cumulative trauma and an examination of various occupational and personal risk factors associated with those disorders. Suggestions are included for engineering and administrative controls designed to help combat the rise in occupational shoulder disorders.

2. Shoulder disorders

This discussion is limited to specific soft tissue disorders (STDs) of the shoulder region which have been associated with occupational risk factors through epidemiologic research. However, achievement of this goal is difficult for a number of reasons. First, perusing the literature on shoulder disorders confirms that there are either too many names, or too few, for the various shoulder disorders (Anderson 1987). Frequently one disorder will have several names. On the other hand, when a worker presents a wide variety of symptoms, thereby making specific illness identification and classification difficult, researchers or clinicians may elect to identify the combination of symptoms as, simply, *shoulder pain syndrome*, more of a catch-all phrase than a specific identification. In such situations it is essential that symptoms be reported in detail so that there is a clear understanding of the nature of the condition under investigation.

The second obstacle to a concise discussion is a lack of agreement as to which illnesses are occupationally-induced. Putative testimony from case studies or educated speculation is not sufficient from a number of viewpoints, including worker compensation claims and development of ergonomic intervention controls. It is through epidemiologic study, however, that tangible evidence can be provided which relates exposure factor to shoulder disorder, even when there are a number of contributing factors, including the normal wear-and-tear of daily living. In such a situation, an occupational risk factor will tend to increase the severity or hasten the onset of a naturally occurring degenerative disorder. These various effects can be sorted out during data analysis.

Lastly, many epidemiologic studies simply refer to *shoulder–neck disorder*. A few

of these studies have been included in this review, but shoulder disorders remain the specific focus of this paper.

In spite of these complications, what follows is a compilation of information on shoulder disorders which have been discussed in the literature with references to occupational risk factors. These disorders are categorized as being related to tendons, muscles, nerves, or neurovascular involvement. A category for disorders with complex symptoms is also included.

2.1. *Tendon-related disorders*

2.2.1. *Rotator cuff tendinitis:* This disorder is also known as supraspinatus tendinitis, subdeltoid bursitis, subacromial bursitis, or partial tear of the rotator cuff (Rowe 1985). Symptoms of RC tendinitis include pain in the front of the shoulder, which is accentuated upon attempted abduction. Tendinitis is an inflammation of the tendon; the tendon may eventually fray, or calcify, or both may occur. This disorder has been associated with repetitive arm motions involving abduction or rotation which can result in repeated, cumulative microtrauma to the supraspinatus tendon (Owen 1969). Static tension in the tendon, occurring when the upper arm is abducted for a prolonged period of time, may also be a factor in the incidence of this disorder (Hagberg 1987). Due to increased tension, circulation decreases and the tendon is deprived of nutrients necessary for maintaining tendon health (Cailliet 1981).

2.1.2. *Calcific tendinitis:* The supraspinatus tendon is the tendon most often affected by this disorder (Owen 1969). Calcific tendinitis is regarded as a degenerative condition, and is frequently present by middle age. Activities such as repetitive abduction, especially with lateral rotation, may hasten the onset (Owen 1969). Clinical diagnosis includes relatively rapid onset, with restricted active abduction and tenderness in the subacromial area (Owen 1969). There may be swelling and pain in the region, which may subside when activity is suspended. However, pain and swelling return when activity is resumed.

2.1.3. *Bicipital tendinitis:* Persons affected with this disorder experience pain and tenderness over the bicipital groove during shoulder flexion, elbow flexion, and forearm supination (Hagberg 1987), or when the elbow and arm are extended and the forearm is supinated (Cailliet 1981). Rowe (1985) includes symptoms of pain in abduction. If pain becomes too severe, the shoulder may become immobile.

2.1.4. *Tendon tear:* Also known as strains, tears usually occur in the rotator cuff or in the biceps long head tendon. The symptoms of a cuff tear resemble those of supraspinatus tendinitis. With a complete tear of the supraspinatus tendon, abduction cannot be initiated. Rotator cuff tears are common in late middle age. Cumulative wear and tear from daily living, exacerbated by occupational stressors, leads to degeneration (Cailliet 1981). With the tendon in a weakened condition, a relatively minor injury can cause a tear (Cailliet 1981). Lifting in supination may cause a tear of the biceps tendon, while catching a load on outstretched arms, heavy lifting, or prolonged work in an overhead position may result in a tear of the rotator cuff (Owen 1969).

2.1.5. *Bursitis:* Affecting the subdeltoid bursa, bursitis is usually a secondary condition to rotator cuff tendinitis. The surfaces of the bursa can adhere to the

underside of the deltoid and the rotator cuff, which results in a form of frozen shoulder (an immobilization disorder). Additionally, calcium fragments in the surrounding tendons can penetrate the bursa, causing inflammation, swelling and pain (Cailliet 1981).

2.2. *Muscular shoulder pain—prolonged traumatic (occupational) shoulder muscle pain*

A person with pain in the shoulder area, with tenderness limited to the descending part of the trapezius muscle, may be diagnosed as having tension neck, cervicobrachial disorder, or myofascial syndrome (Hagberg 1987). In reviewing the pathogenesis of occupational muscle pain, Edwards (1988) discussed a variety of possible mechanisms, including mechanical trauma, fatigue, metabolic alterations, cramps, and myofascial pain. Mechanical trauma was referred to as ultrastructural damage which might be caused by eccentric contractions, heavy work, impact loads, or awkward postures. Edwards (1988) suggested that pain which occurred after work may be the result of muscle damage, while pain during work may be related to impaired muscle energy metabolism. In addition to these local mechanisms, Edwards (1988) suggested that a central mechanism may also be at work. Due to an imbalance between postural motor control and control over cyclic movements, muscles not directly involved in a task may still be active. Such a situation occurs, for instance, in electronics assembly wherein the hands and the fingers are moving and active, while shoulder and neck muscles performing postural duties may display unnecessarily high isometric activity. Static loads as low as 5% of maximum voluntary contraction (MVC) have been shown to result in fatigue (Sjøgaard *et al.* 1986).

2.3. *Nerve-related disorder—suprascapular nerve*

This disorder, named for the brachial plexus motor nerve which it affects, can be confused with bursitis. The condition can be due to inflammation in the shoulder area, and has been associated with occupations, such as letter carrier, which require workers to carry weight directly upon their shoulders (Feldman *et al.* 1983). Symptoms include weakness in the arm and pain in passive adduction.

2.4. *Neurovascular disorder—thoracic outlet syndrome (TOS)*

Also known as neurovascular compression syndrome, hyperabduction syndrome, cervicobrachial disorder (see syndrome disorders section below), brachial plexus neuritis, or costoclavicular syndrome, this disorder involves compression of the nerves and blood vessels located between the neck and the shoulder, known as the brachial plexus (Putz-Anderson 1988). Symptoms include numbness of the fingers, a pins-and-needles sensation, and a weak pulse at the wrist. When working with arms overhead, the pectoralis minor muscle or the scalene muscles of the neck may pinch those nerves and vessels which pass underneath those muscles. Additionally, work which requires pulling the shoulders back and down, such as standing at attention or carrying a stretcher, a backpack, or a suitcase may result in symptoms. This disorder is also associated with poor posture, such as drooping shoulders (Feldman *et al.* 1983), which may be an outward sign of localized or whole body fatigue. TOS can also be due to congenital factors such as arteriosclerosis, cervical rib, or abnormal muscles. Hall (1987) mentioned that some clinicians do not believe this syndrome exists. TOS is not often seen in clinical settings, it is difficult to diagnose, and the majority of patients do not present with objective clinical evidence of nerve damage.

2.5. *Syndrome disorder—occupational cervicobrachial disorder (OCD)*

The label OCD has been used to describe a pain syndrome complex with many and various symptoms of pain and discomfort, located primarily in the muscles in the shoulder and neck regions. Kvarnstöm (1983) listed symptoms including numbness and paresthesia in the neck, arms, and hands, headaches, irritability, forgetfulness, sleep disturbance, chronic fatigue, tendency toward depression, general weakness, and indisposition to work.

3. Occupational epidemiology

Occupational epidemiology is the multi-disciplinary study of the health effects of workplace factors to which human populations are exposed. These factors may be chemical, biological, or physical in nature (Gann 1985). This paper focuses upon physical factors. Through epidemiologic studies, researchers have discovered associations between specific physical factors and certain MSDs and STDs. It is often the case with chronic disorders that several factors may be implicated, including personal factors such as age, sex, and/or work technique. Experiments designed to explore underlying biologic mechanisms may be initiated following hypothesis confirmation through epidemiologic studies. Epidemiologic studies may also be designed to evaluate ergonomic intervention, in order to assess efficacy and side effects.

3.1. *Causality*

In epidemiologic studies, conclusions are made on the basis of causal inference, described by Kleinbaum *et al.* (1982) 'as being the logical development of a theory, based on observation and a series of arguments, that attributes the development of a disease to one or more risk factors'. Inference depends upon prior knowledge, intuition, insight, and uncertainty (probability). Epidemiologists often refer to 'risk factors associated with', rather than 'causes of', a particular illness because it is not possible to establish a basic link between cause and effect via inductive inference (Rothman 1986). Philosophical issues aside, it is still possible to build a strong case for causation between a risk factor and a disorder. Rothman (1986) defined a cause as 'an event, condition, or characteristic that plays an essential role in producing an occurrence of the disease'.

Once an association is determined to exist between a disorder and a risk factor, and once that association has been determined not to be spurious (influenced somehow by confounding factors, chance, or bias), there exists a generally-recognized list of criteria which can be used to aid in evaluating the likelihood that the nature of the association is, indeed, causal (Mausner and Kramer 1985). Items in that list include the following: the strength and consistency of the association between the exposure factor and the health effect; the dose–response relationship in which it is expected that a rise in exposure level will result in an escalation in the number of cases, increased illness severity, or faster onset; the temporal relationship which requires exposure to occur prior to illness onset; and the biologic plausibility of the relationship. These items are referred to throughout this paper when discussing findings of specific studies.

A sixth point included with the ones just listed, specificity of association, refers to a risk factor being associated with a single effect. This is rarely the case with CTDs for at least two reasons. First, there is the multifactorial nature of chronic disorders. Factors may interact in such a way that one factor may cause one type of disorder for

one person and another type for someone else. For example, 'working overhead' may result in TOS in one worker and muscle soreness in another. Factors which could have effected this outcome are workstation design, the workers' anatomical constructions, and work technique. Second, risk factor definition may not be sufficiently specific. In the previous example, if the risk factor had been 'overhead work which induces interference of the brachial plexus by the pectoralis major', then the specificity criterion would have been upheld. Rothman (1986) refers to this criterion as 'useless and misleading', which it seems likely to be if strictly applied.

There is a challenge to confirming causal relationships between specific occupational risk factors and CTDs. Putz-Anderson (1988) presented CTD occurrence as a function of four general categories of occupational factors: exertion level, repetition (quantity and frequency), posture, and lack of rest (recovery time). In addition to workplace factors, non-occupational factors, such as age, gender, past history of acute trauma, and rheumatoid arthritis, have been shown to be associated with the occurrence of CTDs (Armstrong and Silverstein 1987). Sports and hobbies may also provide exposure to physical risk factors associated with shoulder pain (Hawkins and Kennedy 1980, Lehman 1988).

3.2. *Case definition*

Cases should be clearly defined in order for researchers to be able to generate meaningful results from epidemiologic studies. Official statistics on CTDs are often based upon International Classification of Disease (ICD) categorizations, which are considered to be too broad for epidemiologic analysis and risk factor determination (Buckle 1987, Anderson 1987). Researchers should present a list of objective criteria used for identifying cases of the illness of interest. These may include such items as type, location, onset, frequency, and duration of symptoms. Amount of time lost from work and time on restricted duty may also be important descriptors. It is extremely important that researchers fully describe how subjects were identified as cases in order for readers to understand fully the ailment under study and conclusions regarding the associated risk factors.

3.3. *Definition of exposure*

Equally important to a specific definition of the illness of interest is a precise definition of the exposure factors. The more precisely defined these factors are, the easier it is to test hypotheses about factor–disorder relationships, and the more meaningful the results will be. Jensen (1987), in a paper calling for consistency in back pain research studies, also mentioned the need for the use of compatible measures of illness frequency and the use of job characteristics, rather than job titles, as risk factor identifiers. When results are categorized by job characteristics, rather than job title, they are more readily generalizable to other jobs which contain similar characteristics. The value of a study's findings for ergonomic intervention, design, and implementation is also greatly increased. Hagberg and Wegman (1987) recommended representing exposure factors in quantitative terms, including information on postures, working heights, weights and frequency of handled objects, and any other parameters which would aid in characterizing the exposure levels of cases and controls.

4. Epidemiologic studies of shoulder disorders—observational studies

In reports of observational epidemiologic studies, risk factors are sometimes

presented as job characteristics and sometimes as job titles. This is how they will be presented here, as well, along with ways in which the studies' evidence meet one or more of the criteria of causality mentioned earlier.

4.1. *Exposure classified by job characteristic*

4.1.1. *Awkward postures:* TOS (Sällström and Schmidt 1984) and OCD (Kilbom and Persson 1987) have been associated with shoulder abduction. TOS cases were identified as those subjects who exhibited specific combinations and degrees of the following symptoms upon physical examination: positional paraesthesia, numbness, specific muscle weakness, pain, and/or dysfunction. Sällström and Schmidt (1984) found the prevalence of TOS symptoms to be higher in cash register operators and heavy industry workers, than in office workers performing word processing tasks. They felt that the common denominator, which set the first two groups apart from the office workers, was the awkward postures employees were often required to assume. In particular, cash register operation imposed a posture of 45° of abduction and extension on the right arm of operators.

Kilbom and Persson (1987) demonstrated that shoulder abduction was related to the onset of symptoms of OCD. In this prospective cohort study, which monitored a group of electronics assembly workers over a two-year period, the percentage of work cycle time with shoulders abducted to more extreme angles (>30°) was found to be an indicator of symptoms seen at the first year's follow-up. Symptoms, which the authors said would be diagnosed clinically as tendinitis and/or myofascial syndrome, were also associated with abduction from 0 to 30° after two years, signalling that even low levels of abduction can be detrimental to the musculoskeletal system. In addition to abduction, neck flexion parameters (percentage of work cycle time and number of flexions per hour), percentage of work cycle time in which arms were in extension, and number of shoulder elevations per hour were risk factors for illness in the first year of follow-up. At the two-year follow-up, the number of neck flexions was also found to be a risk factor.

4.1.2. *Static postures:* This characterization refers to tasks which require workers to sustain positions (whole body or extremities) for protracted periods of time. Herberts *et al.* (1984) reported on the earlier onset of supraspinatus tendinitis in shipyard welders, compared with plate workers at the same company. Cases were identified among employees with more than five years experience via questionnaire and physical examination. While prevalence of supraspinatus tendinitis was similar in the two groups, 18·3% in welders and 16·2% in plate workers, the mean age of the welders with tendinitis was 6 years less than that of the plate workers. The welders with pain averaged 12·9 years of work experience, while the symptomatic plate workers averaged 24·6 years. Both jobs were rated high in physical workload, but whereas the plate workers' jobs were dynamic in nature, welding was classified as an essentially static task.

Burt *et al.* (1990) investigated upper extremity CTDs in employees at a major newspaper. A questionnaire was used to identify cases, defined as those persons reporting 'pain, aching, stiffness, burning, numbness, or tingling in the shoulder region which lasted more than one week or occurred at least once a month within the past year'. Symptoms could not stem from an acute injury and had to have commenced during the current job. Findings included an 11% prevalence of shoulder symptoms. These symptoms were associated with the percentage of time spent typing

at computer terminals and with self-reported fast typing speed. Time spent typing can be thought of as time spent in a static sitting position with arms unsupported. Regarding the effects of typing speed, editors, reporters, and others who work at computer terminals often work under deadlines. Their typing techniques would be stylized by long periods of uninterrupted, rapid typing. Burt *et al.* (1990) hypothesized that the self-reported fast typing speed risk factor might actually be a reflection of the *effort* to type faster, which would result in increased static muscle loading.

4.1.3. *Heavy work:* Kvarnström (1983) examined risk factors associated with long term sick leave, due to OCD, in a large manufacturing company within a group of labourers and a group of white-collar employees. Cases were defined as those employees who took long term sick leaves (exceeding four weeks) for shoulder pain symptoms. These symptons included easy fatiguability in one or both shoulders, shoulder pain during work and aching at rest afterwards, and shoulder muscle tenderness upon clinical examinations. All long term sick leaves were taken by labourers, none by white-collar workers. In a matched study (for age and sex) of those long term cases, paired with controls from the same factory, cases were twice as likely as controls to classify their jobs as 'heavy work'.

Bergenudd *et al.* (1988) interviewed employees who had experienced shoulder pain lasting more than 24 h and which had occurred within the month prior to a sponsored physical examination. These researchers classified the overall physical nature of the employees' work as either light, moderate or heavy. To be categorized in the moderate or heavy groups required at least ten years of exposure to that level of work. Bergenudd *et al.* (1988) found that all lost time due to shoulder pain symptoms occurred within the moderate and heavy physical demand groups.

The prevalence of supraspinatus tendinitis in groups of welders and plate workers in Herberts *et al.* (1984), and mentioned above, was compared with that in office clerks within the same company. Although the clerks were older than the workers in the other two groups, the prevalence of supraspinatus tendinitis in clerks was less than 2%, which yielded a ratio of approximately 9·0, a strong indicator of the strength of association between heavy work and RC tendinitis. Heavy work imposes a high level of strain on the rotator cuff tendons by requiring substantial contraction levels in the muscles. Any existing damage will give rise to the opportunity for the concentration of stress in that area, which predisposes the affected area to tearing (Herberts *et al.* 1984).

In addition to problems from weights lifted by the hands and arms, direct weight-bearing has been found to be a contributing factor to shoulder MSDs. In a study of male letter carriers, Wells *et al.* (1983) found that while the prevalence of recurrent shoulder pain for meter readers and postal clerks was 7% and 5%, respectively, the prevalence for letter carriers with 11·35 kg shoulder bags was 13%. Recurrent shoulder pain was defined objectively, by a minimum score on a telephone questionnaire, in terms of onset, frequency, and duration of pain occurrence and impact on work and daily living activities. A 4·36 kg increase in bag weight elevated the prevalence for letter carriers to 23% within a matter of months. These prevalence values, adjusted for age, number of years on the job, height/weight ratio, and prior work experience, clearly demonstrate a dose–response effect of direct load-bearing on shoulder pain.

4.1.4. *Repetitive arm movement:* Hagberg and Wegman (1987) surveyed the results of several epidemiologic studies on exposure factors related to TOS and other shoulder disorders. They pooled results from several studies and calculated the ratio of the odds, or odds ratio (OR), to be 4·0 for having been exposed to repetitive arm movements, given that a person had TOS, to the odds of having been exposed, given that a person did not have TOS. Cash register operators and assembly line workers and packers were three groups of workers classified as being exposed to highly repetitive arm movements.

Punnett *et al.* (1985) calculated a prevalence ratio of 2·2 for symptoms of persistent shoulder pain in a cross-sectional study comparing exposure factors in female garment workers and female hospital employees. Cases were identified as those women who reported experiencing pain lasting for most days of a month, or more, within one year prior to the study. Finishers, one of the four garment worker jobs, performed hand-sewing and trimming tasks. These tasks required highly repetitive movements involving all joints of the upper extremities. The prevalence ratio for exposure in the finishers group, when compared with the hospital workers, was 4·0. The sewing machine operators group, with exposure to significant repetitive motion in the fingers and wrists, also had a significant prevalence ratio (2·0) for development of persistent shoulder pain when compared with the control group. These findings might also be appropriately categorized under the headings of 'static work' and/or 'awkward posture' exposure factors. Workers who perform fast, repetitive, fine finger and hand movements may habitually tense the entire arm while working. These workers may also tend to hunch over their work. These responses signal the need for a redesign of the task, the workstation, or both.

Kvarnström (1983), in his extensive study of long term sick leave due to OCD, also found cases to be concentrated in jobs with short work cycles, such as spray painters, assembly line workers, and winders. It is interesting to note that these jobs ran the gamut of physical demand, from heavy to light.

4.1.5. *Working at shoulder level:* Hagberg and Wegman (1987) included, in a survey of shoulder and neck disorders studies, three studies which associated exposure to elevated work heights with the prevalence of rotator cuff tendinitis. RC tendinitis was characterized by localized shoulder pain with tenderness over the humeral head. Results of two studies were pooled and an OR of 11 was calculated for the prevalence of RC tendinitis for work at shoulder height, compared with work below that level. The third study reported a similar OR. In that study, the investigators controlled some potential confounding by examining two similar groups of industrial workers, differing only in work height exposure, in an attempt to ensure that any differences in risk would be attributable to that particular factor.

4.1.6. *Lack of sufficient rest:* In their study of shoulder pain in newspaper employees, Burt *et al.* (1990) found that cases, on average, took fewer work breaks during busy days than did employees without shoulder pain symptoms. Kvarnström (1983) reported a prevalence ratio of 5·2 for long term sick leave due to OCD in assembly line workers and a ratio of 0·7 for serial assemblers, both in comparison to the rate of OCD in the population of company employees. The two jobs were reported to be essentially the same, with one notable exception. As part of the assembly process, serial assemblers also gathered parts and read instructions. During those activities, the shoulder muscles were allowed to rest. The assembly line workers experienced no

such breaks in their work cycle. In that same study, Kvarnström (1983) also determined that workers with OCD were more likely to be on a group incentive pay system.

Rest time, in the form of shorter breaks, also was found to be important for workers' health. In their two-year prospective study, Kilbom and Persson (1987) studied two groups of female employees who performed short cycle tasks, primarily soldering and assembly of circuit boards. They found that the percentage of the work cycle which these workers spent resting (micro-breaks of >2 s) was inversely related to the occurrence of tendinitis and myosfascial syndrome in the second year of employment. It is interesting to note that the benefits of those micro-pauses did not appear earlier (in the first year of follow-up). This is an indication that long-term research is essential for investigating certain exposure factors and potential intervention measures.

4.2. *Exposure classified by job title*

While not being as generally useful as information on job characteristics, information categorized by job title can provide specific information regarding particular jobs, as well as supply data for hypotheses formation regarding characteristics within a job title for examination in future research. The studies to be discussed are categorized as industrial, retail, of office work.

4.2.1. *Industrial work—welder:* Herberts *et al.* (1981), in an early study in their series on shipyard welders, compared the occurrence of RC tendinitis in experienced welders to that in office clerks and found a prevalence ratio of 9·0. A large ratio, such as this, indicates as relatively strong association between welding work and RC tendinitis. Within the welders, there was no indication of concentration of RC tendinitis within any particular age group.

4.2.2. *Retail employment—grocery store checker:* Baron *et al.* (1990) conducted a study of CTDs in female supermarket employees. Cases of rotator cuff and bicipital tendinitis were identified in those workers with positive results from both a questionnaire (regarding shoulder discomfort, not stemming from an acute injury, lasting at least one week or occurring at least once a month in the year prior to the study) and a physical examination (pain on positioning or palpation). Results from this study revealed that the risk to checkers (traditional cash register operation or scanning) of incurring a shoulder disorder was 3·9, when compared to the risk for other store employees. Within the group of checkers, working more than 25 h per week was a factor found to contribute significantly to the occurrence of shoulder tendinitis. This study demonstrated a dose–response effect between the number of hours of exposure per week and CTD occurrence. Scanning, when compared with cash register operation, also was found to be a strong risk factor for shoulder CTDs within the checker group.

4.2.3. *Office work—VDT operator:* Hünting *et al.* (1981) studied the prevalence of shoulder pain in workers who performed data-entry and word processing tasks at video display terminals (VDTs). Comparisons were made between traditional office work and three different types of typing situations; typewriter typing, interactive work at a terminal, and data-entry at a terminal. On a pain questionnaire which requested information on type and frequency of symptoms, only the data-entry

operators reported *daily* shoulder pain. The prevalence exceeded 10% in that group of employees. Each job within that group was described as 'full-time numeric data-entry with the right hand at work speeds of 12 000 to 17 000 strokes per hour'. The authors did not report the key stroke speed of the other keyboard jobs. Those rates may be assumed to be less, based upon the description of the work. A greater percentage of the data-entry group spent more than six hours per day working at a terminal (81%) as compared with the other job categories in the study (30–73%).

4.3. *Exposure—personal factors*

The goal of this paper is to alert ergonomists, industrial engineers, job-designers, workers, and physicians to occupational risk factors which have been associated with shoulder disorders. Personal risk factors should, however, not be overlooked, due to possible interactions with workplace risk factors. Some of the individual risk factors which have been associated with increased levels of shoulder disorders among certain populations are presented in Table 1.

Table 1. Individual risk factors associated with cumulative trauma illness of the shoulder complex

Factor	Illness	Study
Female sex	TOS, OCD, general shoulder	Sällström and Schmidt (1984), Kvarnström (1983), Bergenudd *et al.* (1988)
Job dissatisfaction	general shoulder pain	Burt *et al.* (1990)
Age*	OCD	Kvarnström (1983)
Social factors**	OCD	Kvarnström (1983)
Sports activities (swimming, tennis, baseball pitching)	painful shoulder, tendinitis, RC tear	Hawkins and Kennedy (1980)

*Also important to recognize are studies which show that age was not a risk factor for supraspinatus tendinitis (Herberts *et al.* 1981); for persistent shoulder pain (Punnett *et al.* 1985). This would lend more credence to illness occurrence being occupationally-induced, rather than being due to naturally occurring degeneration.

** These included being married, having a sick spouse, having children, working an alternate shift from the spouse's, and having few hobbies.

5. Epidemiologic studies of shoulder disorders—field and laboratory studies

Once risk factors have been identified through observational studies, steps can be taken toward reducing or eliminating worker exposure. However, knowing *what* is causing the problem is often not enough. There is also the question of *how* to be answered, and this question is best addressed through knowledge of anatomy and physiology, combined with laboratory or workplace research.

5.1. *Electromyography*

Researchers employ a variety of tools when investigating how the body reacts to certain exposures. Electromyography is a key physiologic measure used to study muscle activity. Electromyography is the process of monitoring the low level electrical discharges emitted during motor unit activation. Electromyographic voltage (EMG) is a reflection of both the number of motor units recruited and the

rate at which they fire. Surface electrodes monitor and combine this information from several motor units to give a picture of the activity in a particular muscle. EMG data are most often used either to estimate the level of activity in a muscle (as a percentage of the EMG recorded at MVC for that muscle) or to assess the level of muscular fatigue during or after task performance. Activity level is of interest when researchers want to know which, and when, muscles are recruited to perform particular tasks. Fatigue development is of interest because of the detrimental effects to physiology and performance which can occur in the long and short terms.

5.2. *Localized muscle fatigue*

Muscle fatigue is the result of sustained exertions of a specific muscle or muscle groups. These exertions may be an extended series of repeated, short cycle contractions or they may be low- or moderate-level contractions sustained for prolonged periods of time. Most of the experimental evidence regarding the physiologic basis of fatigue points to decrement in the muscle excitation-contraction coupling (Wiker *et al.* 1989). This is generally considered to be a result of the build-up of waste products and the shortage in the supply of nutrients within the muscle due to impaired blood circulation during a fatigue-inducing exertion.

Fatigue has been associated with jobs which run the gamut of physical demand from heavy, such as welding (Herberts *et al.* 1984), to light, such as word processing (Erdelyi *et al.* 1988). Fatigue can cause discomfort, pain, and interference with fine motor control, one result of increased postural tremor. Appraisal of fatigue, via measurement of postural tremor (increase in amplitude; concentration of spectra at 10 Hz), EMG signal (increase in amplitude; shift to lower mean frequency), and subjective reporting, have all been described in the literature (Wiker *et al.* 1989), with varying degrees of success and consensus. EMG has been shown to be affected by posture (muscle length), contraction level (inconsistent results below 10% MVC), percentage of cycle time which the task fills (questionable results below 50%), muscle temperature, time delay between contraction and measurement (rapid recovery), and length of data collection time (some amount between 3·4 and 87 s seems necessary; Wiker *et al.* 1989).

5.3. *EMG and shoulder pain*

Studies have demonstrated a connection between shoulder pain and EMG activity level, or median spectrum frequency. Erdelyi *et al.* (1988) found that female word processors who were experiencing shoulder pain at the time of their study, manifested as symptoms of local tenderness and reduced mobility upon clinical examination, had higher EMG activity in the trapezius muscle than did their pain-free counterparts, when performing a standardized typing task. In a study of fatigue in the infraspinatus muscles during coil winding, Suurküla and Hägg (1987) found that workers who experienced symptoms, characteristic of OCD, at the time of their study, exhibited a lower mean level of zero crossings (an analysis technique with an interpretation similar to that of the median spectrum frequency) when compared with pain-free workers, during brief test contractions. In a plant where workers performed assembly and soldering of circuit boards, Christensen (1986) found the static (resting) activity level of the deltoid muscles of workers who had experienced shoulder pain within the last year to be significantly higher than the level of workers who had no pain the previous year. While these studies demonstrate consistency of association, they cannot show whether elevated EMG levels are a precursor or a

result of shoulder pain. This illustrates the need for longitudinal laboratory or field research which can confirm temporal relationships between exposure factors and illnesses.

5.4. *Static work*

5.4.1. *Elbow angle during seated work:* Arm position has been investigated by many researchers, regarding shoulder discomfort and CTDs. Erdelyi *et al.* (1988) found that EMG levels in the trapezius were lowest in females performing keyboard work when their elbows were bent at an angle of 105° (the angle between forearm and vertical upper arm), in conjunction with the use of armrest supports. This condition was compared with elbows unsupported at 90 and 105°. It is interesting to note, however, that subjective ratings from the participants showed the 105° position without support to be the most comfortable, followed by the 90° position, with the 105° arm support condition rated third.

Chaffin (1973) demonstrated the dependence of time to fatigue upon elbow angle and hand-held weight. Smaller elbow angles (the angle between upper arm and horizontal forearm) were shown to resist fatigue longer than extended positions. This paper and the previous one offered recommendations for correct elbow angles, but unless one reads carefully, their suggestions may at first appear to be in conflict. One recommended extended elbow angles, the other reduced angles. However, in noticing that each author fixed a different part of the arm, the reader can see that the first paper addressed the issue of table height, while the second addressed the horizontal distance between worker and workpiece. Table heights should be relatively low for typing (Grandjean, 1988, advocated providing an adjustable distance of 71–87 cm from the floor to keyboard home row), while assembly work and the like should be positioned close to the worker (Putz-Anderson, 1988, recommended a working space located 10–35 cm from the table edge).

5.4.2. *Shoulder flexion/extension and abduction:* Herberts *et al.* (984) investigated shoulder muscle response to increases in hand-held weight and arm elevation. In examining activity of the medial and posterior deltoid, the infraspinatus, trapezius, and supraspinatus muscles, they determined that the infraspinatus was the muscle which was most sensitive to a 1 kg increase in hand weight. They observed a 35% and a 41% increase in EMG activity with the arm in flexion and abduction, respectively. The medial and posterior deltoid muscles were most reactive to an increase in humeral elevation from 45 to 90° both with a one kg hand load. Activity in both muscles increased roughly 100% in abduction. The medial deltoid was also as sensitive in flexion. The authors noted that the supraspinatus did not appear to be reactive because that muscle was already very active at 45° of shoulder abduction.

Laboratory studies have shown that even slight shoulder flexion can make a significant difference in time to fatigue. Chaffin (1973), who studied fatigue as signalled by increases in EMG power in the low frequency range (4 to 30 Hz), presented results which demonstrated the effects of height and weight on fatigue onset for a seated operator. Vertical heights of 5, 30, and 57 cm, measured hand to tabletop and with no weight other than the arm, were associated with average times to fatigue of 20, 9, and 5 min, respectively. Chaffin (1973) reported fatigue onset occurrence for 30, 60, 90, and 120° of abduction as 68, 25, 10, and 7 min, respectively.

Wiker *et al.* (1989) also examined the association of arm elevation and fatigue,

For comparison, they employed postural tremor and self-report metrics, as well as EMG, and found the first two techniques to be more sensitive to changes in elevation than measures of EMG amplitude and mean power frequency.

5.4.3. *Hand-held weight:* In each of the position/fatigue conditions presented in Chaffin (1973), increment weight was shown to significantly reduce fatigue onset time. As mentioned above, Herberts *et al.* (1984) found the infraspinatus muscle to be highly sensitive to small increases in hand held weight with the arm in an elevated position. Wiker *et al.* (1989) discovered that hand-held weights as light as 0·95 kg could induce fatigue in a task requiring repetitive arm movement.

5.5. *Repetitive work*
While too much time in one position can be harmful to workers, the other end of the spectrum, highly repetitive, short work cycle tasks may be just as detrimental.

5.5.1. *Repetitive arm flexion/extension:* Hagberg (1981) studied subjective reporting of perceived exertion and EMG activity in the trapezius, biceps, and anterior deltoid muscles of six healthy, female subjects performing, for one hour or until completely fatigued, a repetitive flexion/extension task (0–90–0°), with hand-held weights between 0 and 3·1 kg and a work cycle of 4 s. The activity in the trapezius was found to closely correspond to the shoulder joint load. The author mentioned that this correlation was higher than for the anterior deltoid, even though the anterior deltoid is considered to be the primary shoulder flexor. He concurred with previous researchers in concluding that the anterior deltoid may be oversized for the tasks it performs. Through symptoms reports from subjects 24 h after task performance, the author was able to make a connection between residual neck pain, in the descending part of the trapezius muscle, and repetitive arm flexion. Additionally, some subjects were found to have residual tenderness over the rotator cuff even after 48 h.

5.5.2. *Repetitive work—light load:* In a group of workers who performed repetitive electronics assembly tasks, EMG activity in the deltoid, infraspinatus, and trapezius muscles was measured at specific times throughout the workday, in order to detect signs of fatigue (Christensen 1986). At the same time that EMG measures were taken, employees were asked to rate their work subjectively in terms of fatigue. In this set of workers, the prevalence of neck and/or shoulder pain was found to be 72%. The author found no change in EMG activity levels, but subjective ratings revealed a perceived increase in fatigue as the day progressed. The author suggested that the method of EMG analysis, while quite adequate for describing activity level, may not have been appropriate for gathering evidence of muscular fatigue.

5.5.3. *Repetitive work—forceful work:* Suurküla and Hägg (1987) studied EMG zero crossings and fatigue during coil winding in participants with and without shoulder pain. Between the two groups, they found a strong difference in the infraspinatus muscle and a similar, but weaker, trend in the trapezius. Those with pain demonstrated a lower mean quantity of zero crossings. However, the authors were unable to determine if local muscle fatigue in those with pain was due to their pain, or a precursor of it.

5.6. *Rest*

Be they minutes or only seconds long, rest breaks have been shown to have positive impact on workers. Hagberg and Sundelin (1986) studied the effects of length of work session and induced and spontaneous rest breaks (simply removing hands from the keyboard) on the EMG levels of the trapezius muscles in healthy, female, professional word processors. They found an inverse relationship between the number of spontaneous pauses taken and the static and median activity levels in the trapezius muscles. In terms of discomfort in several body regions, subjects ranked the test sessions in the following order from least to most discomfort: 3 h session with induced pauses, a 3 h session with only spontaneous pauses, and a 5 h session with only spontaneous pauses. Grandjean (1988) recommended the total amount of rest in the work cycle to be a minimum of 15%. That may be increased to as high as 30% for tasks with high physical demands.

Wiker *et al.* (1989) studied fatigue as a function of a number of task characteristics, including percentage of work cycle, for a Fitts' reciprocal movement task using a lightweight stylus tool. They examined task performance lengths of 20 or 40 s within a 60 s work cycle. The differences in effects were manifested in measures of postural tremor and in self-reports of residual discomfort at the global level and in individual shoulder muscles (upper trapezius, medial deltoid, biceps, and triceps).

Even breaks as brief as fractions of a second may be of benefit to workers. Veiersted *et al.* (1990) studied interindividual differences in EMG patterns for employees performing identical machine-paced tasks. All employees were pain-free at the time of the study, but some had experienced shoulder pain in the past. The researchers tallied the number of EMG gaps (activity below 0·5% MVC, lasting at least 0·2 s) during performance of three different machine-controlled tasks. They found that workers who had experienced pain in the past registered far fewer micropauses during their work session than did the other group of workers. As has been pointed out before, studies such as this cannot establish the temporal relationship between the study parameters. However, they do supply ideas for future research of a longitudinal nature.

6. Discussion

6.1. *What is known*

From the observational epidemiologic studies discussed earlier, there appears to be substantial evidence implicating awkward and static postures, heavy work, repetitive arm movements, and insufficient rest as risk factors for various soft tissue shoulder disorders, including thoracic outlet syndrome, occupational cervicobrachial disorder, rotator cuff and bicipital tendinitis, and persistent or recurring general shoulder pain. Occupations such as welder, grocery store checker, and certain VDT workstation operators seem to carry increased risks of shoulder disorder occurrence for workers. Results of experimental studies indicated that elevated levels of muscular activity, both at rest and during work activities, were associated with shoulder pain, as were fewer occurrences of low levels of activity (micropauses in muscle activity). Whether these experimental results were the cause or the outcome of pain was not established.

Clearly what is needed, now that this more general knowledge exists, are specifics regarding exposures and effects related to occupational shoulder disorders.

6.2. *Yet to be discovered*

From study to study, uniformity in identifying cases and describing risk factors is clearly lacking, based upon the sample of recent studies highlighted in this paper. As mentioned earlier in the text, this also seems to be a problem for other occupational disorders (i.e., back pain) which are considered to be the result of cumulative trauma. There seem to be at least three reasons why these problems exist. The existing disease classification systems are inadequate for these occupational disorders; symptoms are not always easily recognized and may come and go as work varies; and measurement tools are not always adequate or available for thorough quantitative analysis.

6.2.1. *Effects:* Tools used for identification of cases vary between studies. In the studies included in this paper, researchers relied on questionnaires, physical examinations, amount of time on medical leave, or some combination of those methods to identify cases of various shoulder disorders. Each of these methods places different levels of restriction on who is categorized as a case. Questionnaires can be subject to errors in recall, as well as other subjective judgements. Physical examinations may exclude workers who do not have symptoms on the day of the exam. The amount of time for medical leave is a function of personal factors, company and societal norms, as well as symptom severity.

Criteria used to classify cases also varied. As an example, in two studies symptoms were required to persist for more than one week, or occur once very month during the previous year. In another study, pain had to last more than 24 h and occur within one month prior to the study. In yet another, cases were identified as those persons who experienced pain for most days of a month or more within the previous year. Uniformity in case identification methodology would yield more powerful study results and allow for legitimate comparisons between studies.

6.2.2. *Exposures:* Within studies, exposure is classified by job title or by job characteristic. Classifying by title, in essence, expresses some qualitative, unknown combination of physical exposures. This method may be beneficial as a first attempt to identify problems, but in no way contributes information regarding how to reduce exposure (other than eliminate the problem jobs). There is a need to define quantitatively how much is too much abduction or flexion, how fast is too fast, and how often is too repetitive.

Definition of exposure by objective, quantitative physical description, if properly specified, will establish exposure limits based upon the identified dose-response curve. This will require observation of workers across the spectrum of exposure, including reference groups. Quantification should express the level, duration, and variation of the exposure (Winkel and Westgaard, 1991). Many studies concentrate on one aspect of a single risk factor. This is important, as quantitative assessments are still lacking. But it is characterization of the interactions of the various risk factors which will provide the best tools for designing safer work environments. Tanaka and McGlothlin (1989) described a conceptual model, based upon knowledge of the interactions of physical risk factors, which could be used to determine safe operating limits for work involving the wrist. A similar working model could be constructed for the shoulder.

6.3. *Future activity*

Future research in this area should be designed along more uniform lines, not at the

expense of creativity or good research practices, but in an effort to supply information regarding effect–exposure relationships which can eventually become standards, widely respected and utilized as guidelines for workstation designs, and not merely useful information for the single plant or department directly involved in a given study. Standards for both case definition and physical exposure measurements should be established. There should remain room for flexibility, as new measurement devices are developed. Currently video systems with kinematic analysis features probably provide the best method for quantifying position, repetition, and rest measurements for the shoulder. Standardized questionnaires can be used to gather information of a longitudinal nature, especially regarding variations in work and workers symptoms. A complementary combination of observational tools may be most beneficial.

Longitudinal surveillance studies in which employees would be screened for symptoms and exposure at the time of employment, and monitored periodically thereafter could provide important temporal and dose-response information relating exposures and effects. Such studies would also provide important information regarding positive or adverse effects due to changes in the workplace, especially ergonomic interventions. At this point, there are few intervention studies in the literature upon which ergonomists can draw applicable information.

7. Conclusions

Bechtol (1980) suggested that human upright posture is to blame for most chronic shoulder pain. If this is so, then he has described the nature of the endemic level of chronic shoulder pain. Many epidemiologic studies, however, point to specific occupational factors which appear to be more prevalent in groups of workers who suffer from chronic shoulder disorders. The mounting evidence against awkward static working postures, highly repetitive motions, and heavy lifting should move employers to initiate engineering controls in order to eliminate or at least reduce worker exposure to these factors. A list of generally-applicable engineering and administrative controls appears in table 2. Engineering controls, those changes which adapt the workplace to the employees, are always preferable to administrative controls. The latter, which usually involve only changes in administrative procedures, should be considered temporary measures, to be superseded by permanent engineering controls when those are devised (Putz-Anderson 1988). Notice that the benefits from control measures listed in table 2 may extend beyond the reduction of shoulder CTDs.

Table 2. Engineering (E) and administrative (A) controls designed to reduce worker exposure to risk factors associated with shoulder CTDs.

1. Repetition—*Do not design tasks at either end of the repetition continuum. Eliminate tasks which require fast, highly repetitive arm movements and those which hamper volitional arm movements, thereby imposing static postures.*

Benefits: • Reduction in the repetitive nature of a job should reduce both the high level of wear and tear of tendons and tendon sheaths and the level of subjective fatigue of the worker.
• Reduction of high speed arm movements may reduce risk of tendinitis (Chaffin 1973).
• Eliminating static postures reduces localized muscle fatigue and byproducts of fatigue (residual muscle pain, reduced nutrient supply to

muscles and tendons), and lowers risk for developing joint, ligament, or tendon damage (Grandjean 1988).

Implementation: • (E) Design sequential tasks, rather than short cycle repetitive ones (Putz-Anderson 1988).

• (A) Reduce workers' exposure to highly repetitive tasks or to tasks which require static postures by interspersing these tasks with less extreme tasks which require different motions and employ different muscles.

• (E or A) Reduce speeds of very fast movements (Chaffin 1973). Solomonow and D'Ambrosia (1987) reported that cyclic exercise rates which exceed 1 Hz pose high risks for joints and soft tissue, while those less than 1/6 Hz may cause fatigue and contribute to muscle ischemia.

• (A) Eliminate or modify those piece rate incentive pay schemes which are shown to encourage high speed arm movements (Chaffin 1973).

• (A) Instruct workers to relax non-essential muscles. For example if they are performing detailed work with hands and fingers, they should be reminded to relax their shoulders, which they may tend to tense or raise over time.

• (E) When using keyboards, use forearm supports or rests (Putz–Anderson 1988).

2. Posture—*Minimize shoulder flexion and abduction.*

Benefits: • Take advantage of peak shoulder strength, which occurs when flexion and abduction are minimized (Chaffin (1973), and reduce loading on the shoulder due to the weight of the arm.

• Reduce stress on brachial plexus (Putz–Anderson 1988).

• Reduced muscle activity and tendon loading, which improves nutrient flow and increases time to fatigue (Chaffin and Andersson 1984).

• Task performance can be more precisely controlled, use less energy, and be more quickly performed when hands are closer to the body (Grandjean 1988).

• Impingement on soft tissue in the area of the rotator cuff is reduced.

Implementation: • (E) Keep work close to the body and below shoulder height. When standing, heavier work should be positioned between hip and waist height, light work about waist height, and detailed work 50–100 mm above elbow height (Grandjean 1988). For typing, home row keys should be at elbow level (Grandjean 1988).

• (E) If arms must be abducted or flexed, then minimize the percentage of the work cycle time during which these postures occur and reduce the number of times they occur.

• (E) To reduce abduction, use inline tools for horizontal surface at elbow height and for vertical surfaces below waist height; use pistol grip tools for horizontal surfaces below waist height and vertical surfaces at elbow height (Armstrong 1983).

• (E) Design workstations for adjustability including provision of height-adjustable tables for sit/stand options and chairs with adjustments for seat pan angle and backrest height.

3. Force—*Minimize hand-held weight.*

Benefits: • Reduced muscle activity, fatigue, and associated problems.

• Gain more precise control and coordination from muscles which are not heavily loaded (Grandjean 1988).

Implementation: • (E) Use articulating arms or other tool suspension devices where possible (Putz-Anderson 1988).

• (E) Use fixtures to hold parts (Putz-Anderson 1988).

• (E) Provide and urge use of carts, dollies, and mechanical lifting aids when moving or transporting parts.

• (E) Static loading should not exceed 15–20% of maximum strength (Grandjean 1988).

—*Reduce or eliminate forceful or heavy work.*

Benefits: • Reduce localized muscle fatigue and associated problems.
• Reduce energy consumption (Grandjean 1988).

Implementation: • (E) Reduce or eliminate direct load bearing activities (time spent and amount of weight).
• (A) As an interim measure in certain limited situations, it may be acceptable to consider establishing a temporary job rotation system to reduce exposure, provided the alternative jobs significantly reduce shoulder loading, and provided there is no increase in the number of workers who would be subjected to injury.
• (E) Supply proper, well-maintained tools to reduce forceful effort.
• (E) Ensure that parts can be assembled with ease.

4. Rest—*Require employees to take rest breaks.*

Benefits: • Reduced fatigue, including postural tremor and residual discomfort, and increased concentration (Grandjean 1988).
• Rest pauses tend to increase output (Grandjean 1988).
• New skills are acquired more easily if rest breaks are allotted during training (Grandjean 1988).

Implementation: • (E) Design jobs so that workers can take breaks when needed or design breaks into the work cycle.
• (A) Eliminate or modify piecerate incentive pay systems which are shown to induce rest break-aversion in workers.
• (A) Teach workers to take micro- and mini-breaks within task cycle. This may be aided with biofeedback so that they can learn to relax their muscles, which even for brief periods of time has been shown to be beneficial (Melin 1987).

For the present, enough is currently known about many of the risk factors associated with shoulder CTDs to enable employers to begin to take immediate action to reduce worker exposure. It should be kept in mind that employees are a valuable resource for ideas regarding workstation and job redesign. Their input should be included in an employer's solutions to this growing occupational health problem.

For the future, quantitative guidelines should be devised so that workstations can be designed or modified to meet the health considerations of employees. Future work in the area of shoulder CTDs should concentrate on gathering information with which to generate dose–response curves for use in job and workstation design. These curves would supply designers with guidelines on repetitive movement and other job parameters such as acceptable ranges of abduction and flexion; tool and parts weights, and job cycle times. This new information would lead to the development of sound engineering controls for use in combatting this growing health concern.

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