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Repetitive Motion Injuries

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The terminology of repetitive motion injuries has changed over the last several years. The term now used by the United States Department of Labor and the National Institute of Occupational Safety and Health (NIOSH) to describe adverse health effects of repetitive motion to the musculoskeletal system is *musculoskeletal disorders* (MSDs). When these injuries or disorders are considered to be work related, they are identified as work-related musculoskeletal disorders (WMSDs). Other common names used interchangeably over the years have included repetitive stress injuries (RSIs), repetitive stress disorders, cumulative trauma disorders (CTDs), and overuse syndrome. Musculoskeletal disorders refer to conditions that involve nerves, tendons, muscles, and supporting structures of the body. They do not include injuries resulting from slips, trips, falls, motor vehicle crashes, or similar causes (1,2).

A definition of WMSDs by the State of Washington Bureau of Labor and Industry that captures the full spectrum is as follows:

> Non-traumatic disorders of the soft tissues of the musculoskeletal system that can be caused or aggravated by work activities such as repetitive forceful motions, awkward postures, use of vibrating tolls or equipment, or by manual handling of heavy awkward loads. Examples include carpal tunnel syndrome, tendonitis, epicondylitis, hand–arm vibration syndrome, rotator cuff syndrome, cubital tunnel syndrome, and sciatica. Work-related disorders are primarily, but not exclusively, associated with the upper extremity and back (2).

Musculoskeletal disorders may affect soft tissue (muscle, tendon, ligament, bursa, cartilage, nerve, blood vessel, disk) or bone. Generally the symptoms do not arise from one acute episode of significant trauma but are the result of continual exposure to repetitive force and microtrauma that exceeds the ability of the body to recover and adequately repair structural damage. The terms RSI, MSD, and CTD are not a specific diagnosis but include both clinical entities and symptoms of pain.

The identification and prevention of repetitive motion injuries is a priority area in agricultural medicine. Upper-extremity MSDs are a priority area of the National Occupational Research Agenda for Musculoskeletal Disorders. Additionally, the U.S. Department of Health and Human Services Healthy People 2010 project has set a goal (Goal 20-3) to reduce the rate of injury and illness cases involving days away from work due to overexertion or repetitive motion (3–5).

For the purposes of consistency, MSDs will be used to refer to repetitive motion injuries arising from occupational exposures. The focus of this chapter is on diagnosis and treatment of common MSDs affecting the upper and lower extremities, based on available evidence-based medicine, determination of work-relatedness, ergonomic issues in agriculture leading to MSDs, and prevention through engineering and work practices that are applicable to agriculture. Although the neck and back are the body parts most commonly affected by repetitive motion injuries and are mentioned in this chapter, a detailed discussion of spinal injuries and conditions were addressed in Chapter 17.

Extent of Musculoskeletal Disorders in Agriculture

According to the 2001 United States Bureau of Labor Statistics Annual Report, MSDs accounted for 522,528 (34%) of 1,537,567 nonfatal occupational injuries and illnesses involving lost time. In agriculture, forestry, and fishing, MSDs accounted for 8,733 incidents (22%) out of 40,153 nonfatal occupational injuries resulting in lost work time. Presumably, the actual numbers are higher in agriculture than reported as family farms are excluded from occupational statistics, and agricultural injuries are commonly considered to be underreported in agricultural operations, even in farms with 11 or more employees where reporting is mandatory. In 1997, the median time away from work due to overexertion injuries was 6 to 7 days. The median time off work as a result of injuries or illnesses due to repetitive motion in agriculture was 17 days (4,6).

The U.S. Department of Labor National Agricultural Workers Survey reported that 11% of workers complain of musculoskeletal pain or discomfort during their first year of work and 19% of workers with 10 or more years of farm work make such complaints. The percentage reporting joint or muscle pain was highest in those working in multiple crops (20%) and lowest in horticulture (11%). The reported rate for tendonitis in the agriculture, forestry, and fishing industry in 2001 was 1.3 per 10,000 workers compared to 1.6 per 10,000 workers in all private sector workers. The reported rate for carpal tunnel syndrome was 1.1 per 10,000 workers in agriculture, forestry, and fishing, lower than the rate of 3.0 per 10,000 for all private sector workers. Farmers are among the civilian occupations with the highest risk for hand–wrist arthritis with odds ratios (OR) of 2.71 (95% confidence interval

[CI], 1.27–5.36) by farmers, forestry, and fisheries occupation and OR of 3.6 (95% CI; 1.87–6.93) in the agricultural, forestry, and fisheries industry sector. A prevalence of 28% of hand and wrist pain and an OR of 1.72 (95% CI 1.34–2.21) was reported in a survey of New York farmers. The landscape and horticulture industry in Washington State is in the top 12 industries with the highest rates of musculoskeletal disorders in a Washington State–based review of the compensable workers' compensation cases from 1991 to 1999 (7–10).

Body Parts Affected and Common Conditions

Across all industries, the most common injuries are sprains and strains, followed by soreness and pain. The body parts most commonly affected are, in descending order, the back, neck, shoulder, wrist, knee, and multiple body systems. The mechanism most likely to result in an injury is overexertion, particularly while lifting. In a survey of migrant health centers in New York and Pennsylvania, joint and muscle strains were the most common type of injuries; they occurred most often in orchard work, and resulted from overuse, assuming an awkward position, and weight-bearing activity. Back, neck, and shoulder strains account for 39% of occupational health injuries at migrant health centers (6,11).

The California Farm Worker Survey from 1991 to 1996 reported the most prevalent types of injury events were overexertion and strenuous movement (13.5%). The body parts most commonly affected were, in descending order, the lower back, upper back, wrist, shoulder, knee, and neck. Cross-sectional studies of farmers in Ohio and Alabama have also reported sprains and strains as the most common types of injuries. Dairy farming is also associated with hand–wrist symptoms. Swedish research has identified three milking tasks (cleaning, premilking, and attaching) with high movement velocities and extreme positions (12–15).

A concern raised in a NIOSH conference regarding MSDs in children and adolescents is the impact of ergonomic hazards on the immature musculoskeletal system. Strains and sprains were one of the most common injuries in adolescents working on farms. Weeding by hand, washing and packing produce, loading and unloading produce, and tractor operation were five activities believed too strenuous for children and adults. A survey of North American fresh market vegetable growers and the children and adolescent workers reported low back (26%), foot and ankle (21%), knee (18%), and neck (16%) pain. Fresh market vegetable production requires soil preparation, planting, transplanting, weeding, hand harvesting, and product handling. Smaller operations often involve extensive and inefficient hand labor, and high levels of physical effort (see Chapter 12) (16–19).

Upper Extremity

Ergonomic risk factors for MSDs include repetitive motion, awkward posture, long duration of repetitive activity, lack of recovery time, forceful movement, vibration, uncomfortable conditions (cold, wet), and stressful work organization. Relatively few studies of sufficient quality exist to assess the work-site causative factors associated with MSDs other than back pain, hand/wrist/elbow MSDs, and knee/hip arthritis. Nonoccupational factors such as gender, age, work satisfaction, other additive occupational or recreational activities, and chronic medical conditions and lifestyle practices such as diabetes, hypothyroidism, arthritis, obesity, pregnancy, and alcohol use are potential confounding factors. There is general agreement that a combination of forces (force, repetition, posture, and vibration) is most strongly associated with carpal tunnel syndrome, tendonitis, and lateral epicondylitis, particularly high force and high repetition. There is also positive evidence for the association of force, repetition, and vibration alone or in combination with carpal tunnel syndrome. There is also positive evidence for force, repetition, and posture alone for tendonitis and force alone for lateral epicondylitis. There is insufficient evidence for posture alone as a risk factor for clinical diagnoses. Shoulder pain syndromes and shoulder tendonitis is positively associated with highly repetitive work and repeated or sustained work postures above 60 degrees flexion or abduction (16–22).

High repetition is considered to be a cycle time of less than 30 seconds or more than half of the cycle spent in an activity and greater than the recovery time. High force is considered to be 6 kg of force or greater. Frequency can also be determined by the work load index, which is the number of pieces handled per hour times the number of hours worked. Other determinants of work-relatedness include regular tasks requiring high force by the hand on the affected side, a job involving frequent, repetitive use of the same or similar movements of the affected hand or wrist, regular use of vibrating handheld tools, frequent or prolonged pressure over the wrist or base of the palm on the affected side, and regular or sustained tasks requiring awkward position (20–22).

The meat processing industry is well known as a high-risk industry for MSDs, and before implementation of a voluntary participatory ergonomics program that was instituted in the early 1990s, the prevalence of repetitive motion injuries was as much as 75 times higher than the general industry rate. Cold is also considered to play an important role in the development of MSDs. Some of the highest incidences of carpal tunnel syndrome occur in frozen food workers and butchers. A four times greater risk of carpal tunnel syndrome occurs in frozen food workers than in those performing repetitive work in normal temperatures (23,24).

Lower Extremity

The best evidence of lower extremity repetitive motion injuries applies to hip and knee osteoarthritis. A strong positive association between frequent

bending of the knee and the development of osteoarthritis of the knee has been reported. Dairy farming, which is primarily milking and tractor driving, has been shown to have odds ratios (OR) ranging from 1.39 to 2.98 for hip and knee osteoarthritis. A study of Swedish farmers reported a dose-response association between the number of cows milked (OR 4.5; 95% CI 1.9–11.0) or working more than 5 hours per day (OR 13.3; 95% CI 1.2–145.0) and the onset of hip or knee disease (25–29).

Specific Ergonomic Forces Associated with Musculoskeletal Disorders

Agricultural work varies significantly with the type of commodity and associated work practices. Certain types of work practices are strongly identified as being at greater risk for repetitive injuries, such as manual harvest of small vegetables and fruits, meat processing, and dairy farming. A 3-year, NIOSH-supported study focusing on identifying priority MSDs in California nurseries reported upper extremity and back injuries as the most commonly reported injuries. Job tasks with the highest risk of MSDs were considered to be propagation (cuttings), canning (transport to field), field work (pruning, spacing, and weeding), and shipping. Job analysis identified highly repetitive gripping, high pinch forces, contact stress, and awkward posture associated with the use of non-power hand tools and material handling, which characterize those job tasks (30).

An assessment of California vineyards by the University of California Ergonomics Research Center found a high proportion of jobs involving repetitive heavy lifting, bending, and stooping. Hand harvest risk factors included highly repetitive handgrip; exertion of high force to carry full tubs; multiple awkward positions involving the shoulders, forearms, and trunk; highly repetitive cutting and reaching; and moderate forceful exertions involving the shoulders and arms. Grapevine pruning involves a high level of muscular activity associated with hand-powered professional pruning shears and has been associated with musculoskeletal hand disorders, in particular paresthesias of the dominant hand (31,32).

In the northeastern United States, research has been conducted on ergonomic hazards for apple harvest workers. This type of hand labor exposes workers to weight-bearing hazards and awkward postures. The result is that back, neck, and shoulder strain are among the most common occupational health complaints seen at health centers within this population. A posture, activities, tools, and handling (PATH) methodology for quantifying ergonomic hazard exposure developed for industry has been adapted for orchard work. This PATH methodology is a validated work-sampling tool for quantifying ergonomic risk factors in jobs involving nonrepetitive work. In 2001 a PATH assessment of 14 apple harvest workers showed that they spent nearly two-thirds of the harvest observation period (62.9%) reaching and picking and 78.5% of the time bearing weight. Full apple bags in this study weighed up to 42 lb (19 kg), and ladders ranged from 10 to 25 lb (4.54 to 11.34 kg). The common postures and posture-load combinations observed were the arm, shoulders, and elbows elevated with and without loads. Comparison to PATH assessments of jobs in construction and nursing show apple harvest work to be at least as hazardous (see Chapter 6) (11,33–38).

Selected Clinical Conditions

Characteristics of RMI and MSDs include the following:

1. Symptoms are related to intensity of use.
2. A condition may take years to develop and weeks to years to resolve.
3. Nonspecific symptoms predominate.
4. Specific syndromes can have nonoccupational causes.

Extrinsic risk factors of MSDs include motivation, job satisfaction, and monotony of jobs. Ergonomic factors include additive outside recreational activities, piecework, and overtime. Physiological factors of repetitive forceful work include muscle fatigue resulting in a reduced muscular activity to sustain the existing effort. If the effort exceeds 15% of maximal voluntary contraction, the muscle blood flow is reduced or cut off, leading to ischemia of tissues. This leads to biochemical changes resulting from anaerobic metabolism, accumulation of lactate and depletion of adenosine triphosphate (ATP) leading to and muscle pain and microtrauma. If there are not adequate rest cycles, the body's capacity is exceeded. Avoiding fatigue with many short rest periods during intense work can improve blood flow and counteract muscle fatigue. This can also affect other anatomic structures. One useful method of looking at upper extremity (UE) MSDs is to divide the upper extremity into the proximal UE (shoulder girdle and upper arm) and distal UE (elbow, forearm, wrist, and hand). The proximal UE affects the muscles and impingement of the rotator cuff while the distal UE exposures can affect muscle-tendon units or nerves. Categories of nerve entrapment units include tendon entrapment, peritendonitis, and epicondylitis. See Table 24.1 for categories of muscle-tendon unit conditions and Table 24.2 for specific clinical entities (39). Other upper extremity conditions that are not typically considered to be work-related are Dupuytren's contracture and ganglion cysts (39–43).

Diagnosis involves a careful occupational history, physical examination, and, infrequently, laboratory tests or imaging for MSDs, unless there is a history of trauma or unusual objective physical findings. Nerve conduction studies are critical in diagnosing nerve entrapment syndromes (40).

Treatment involves modification of the work to prevent the postural and repetitive activities that caused the problem; modification of the workplace ergonomic hazards or stressors; resting the injured part; splinting; physical

TABLE 24.1. Classification of muscle-tendon unit conditions.

Category	Definition	Clinical entity	Clinical findings
1. Tendon entrapment	Tendon entrapment of dorsal wrist compartment	1. DeQuervain's	1. Pain over affected compartment
2. Stenosing tenosynovitis		2. Intersection syndrome	2. Swelling, thickening 3. Crepitus
Peritendinitis	Extensor side of distal half of forearm affecting extensor tendons	Tendonitis	1. Acute inflammatory 2. Swelling, redness
Lateral/medial epicondylitis	Collagen degeneration and disorganized repair at flexor/extensor insertion at elbow	Tennis elbow and golfer's elbow	1. Localized tenderness at epicondyles 2. Pain with resisted maneuvers involving wrist

Source: Data from Rose et al. (40), Harris and Glass (41), Zuckerman et al. (42), Guidotti (43), and Fongemie et al. (44).

therapy modalities, including iontophoresis; progression to rehabilitation; and preventing deconditioning. Severe cases may require surgery (Tables 24.2 and 24.3) (39–43).

Shoulder Impingement

The rotator cuff is composed of four muscles: the supraspinatus, infraspinatus, subscapularis, and terres minor. The supraspinatus is the primary rotator cuff area involved in impingement and tears. Impingement is the primary cause of rotator cuff tendinopathy, calcification, and degenerative tears. Acromioclavicular osteoarthritis resulting in osteophyte formation often results in impingement. Repetitive overhead work, reaching, and throwing activities can begin the process of impingement beginning in the third decade. By the fifth decade, ischemia can lead to fibrosis and tendonitis and a weakened supraspinatus that is more susceptible to tears with lesser trauma (44).

Pain at night and with overhead activities is typical of shoulder impingement injuries. Clinical signs include painful arc, positive empty-can sign, lift-off sign, and Hawkins and Neer impingement signs. Radiographs may show acromioclavicular (AC) narrowing and inferior osteophyte formation. Magnetic resonance imaging (MRI) is indicated if a rotator cuff tear is suspected and may reveal impingement upon the supraspinatus tendon, supraspinatus tendinopathy, or partial or complete tear. Subacromial corticosteroid and lidocaine injection may give temporary or permanent relief. If impingement or tear is present, arthroscopy with subacromial decompression and repair is

TABLE 24.2. Common upper extremity musculoskeletal disorders (MSDs).

Disorder	Clinical features	Tests/radiographic findings	Treatment
Impingement syndrome	1. Positive impingement signs 2. Nighttime pain	1. Positive lidocaine injection test 2. AC arthropathy 3. MRI-supraspinatus tendinopathy	1. NSAIDs 2. PT 3. Subacromial injection 4. Subacromial decompression
Biceps tendonitis	1. Often anterior manifestation of impingement 2. Positive Speed's/Yrgasen's signs	1. Often unremarkable 2. Possible calcification of bicipital tendon	1. NSAIDs 2. PT 3. Steroid injections may cause tend on rupture
Acromioclavicular (AC) arthritis	1. Tender AC 2. Positive crossover	1. AC osteophyte 2. Narrowing of AC joint	1. NSAIDs 2. Judicious steroid injection 3. Resection distal clavicle in severe cases
Carpal tunnel syndrome	1. Nighttime symptoms 2. Tinel's/Phalen's signs 3. Thenar atrophy is severe	1. Positive EMG for median entrapment 2. MRI not indicated	1. Nocturnal splint 2. Steroid injection 3. Carpal tunnel release
Lateral epicondylitis	1. Lateral elbow pain 2. Pain opening doors/holding objects	1. Occasional calcification 2. X-rays usually not indicated	1. PT/iontophoresis 2. NSAIDs/forearm strap 3. Steroid injection tendon sheath 4. Rare lateral epicondylar release
DeQuervain's tenosynovitis	1. Pain pinching 2. Positive Finkelstein's test	Not indicated	1. NSAIDs 2. Thumb spica splint 3. Steroid injection 4. Release of first dorsal compartment

EMG, electromyogram; NSAID, nonsteroidal antiinflammatory drug; PT, physical therapy.
Source: Data from Rose et al. (40), Harris and Glass (41), Zuckerman et al. (42), and Guidotti (43).

TABLE 24.3. Management strategies.

1. Work modification
   - Proper working posture to keep the affected area at a neutral position
   - Improve lighting
   - Decrease work hours
   - Decrease repetitive motion tasks
   - Decrease certain hazards such as working over head or squeezing on a tool
2. Workplace hazard modification
   - Proper equipment, chairs, etc.
   - Proper tools
   - Modify computer programs to decrease key strokes
   - Mechanization
3. Resting the injured part
4. Splinting
   - Night splints
   - Day splints to allow the person to work
5. Antiinflammatory medications
   - Nonsteroidal antiinflammatory drugs (NSAIDs)
   - Cox-2 inhibitors (far more expensive than NSAIDs)
6. Injections
   - Joint
   - Tendon sheaths
7. Physical therapy
   - Range of motion
   - Iontophoresis
   - Teach active exercise and conditioning programs
8. Surgery (in severe and resistant cases)

Source: Data from Rose et al. (40), Harris and Glass (41), Zuckerman et al. (42), and Guidotti (43).

diagnostic and usually the definitive treatment. Differential diagnosis includes AC arthritis, bicipital tendonitis, rotator cuff tear, labral tear, and glenohumeral arthritis (44,45).

Carpal Tunnel Syndrome

Classic carpal tunnel syndrome (CTS) is a focal nerve entrapment of the median nerve at the carpal tunnel of the wrist resulting in a complex of clinical symptoms and signs in the distal distribution of the median nerve. The criteria in the NIOSH case definition for work-related CTS are the following:

1. Symptoms suggestive of CTS (paresthesias, hypoesthesia, or pain in distribution of the median nerve)
2. Objective findings such as positive Tinel's sign, Phalen's sign, or decreased sensation in the distribution of the median nerve or abnormal electrodiagnostic testing
3. Evidence of work-relatedness (see Chapter 25)

Classic symptoms are paresthesias and pain with repetitive activity, nocturnal awakening relieved by "flicking" the wrist, and, in later stages, dropping objects, hypoesthesia in the median distribution, and thenar atrophy resulting in weakness of the abductor pollicis longus and opposition (46,47).

Tinel's and Phalen's signs and two-point discrimination lack sensitivity and specificity for the diagnosis of CTS. Electrodiagnostic testing is the gold standard but is 90% to 95% sensitive and may be false negative if performed before 4 to 6 weeks of when symptoms begin. Nonsteroidal antiinflammatory drugs (NSAIDs) are not considered to be effective, whereas nocturnal splinting, work-site modification, and steroid injection may be of satisfactory benefit. In long-standing cases with abnormal sensation and motor weakness, carpal tunnel release is the preferred initial treatment. Nonoccupational causes must be considered including metabolic conditions causing peripheral neuropathy (diabetes, hypothyroid conditions, vitamin B_{12} deficiency, chronic alcoholism), arthritis, cervical radiculopathy, and myofascial pain conditions (47).

Lateral Epicondylitis

Lateral epicondylitis is a persistent aggravating clinical entity. It is most common between 35 and 60 years of age, rarely occurs before age 20, and is seven times more common than medial epicondylitis. Causative physical factors include forceful gripping, throwing, lifting with palms up, forceful wrist extension, and repeated blunt trauma to the elbow. Poor overall conditioning may predispose to lateral epicondylitis due to fatigue of the shoulders and increased use of the wrists. The standard treatment has been use of the forearm strap, physical therapy (PT), and corticosteroid injection if inadequate response. Recent studies have indicated that steroid injections offer short-term pain relief but no greater or even poorer long-term results than PT. Surgery is reserved for severe cases, resulting in limitation of activities of daily living persisting at least 6 months and recalcitrant to nonoperative treatment. Long-term results are not encouraging, as 5% are resistant to conservative treatment, 40% observe prolonged minor discomfort, and 25% recur within 5 years (48,49).

Regulatory Issues in the United States

In 1997 California became the first, and remains the only, state in the United States with a regulation that targets ergonomic risk factors and repetitive motion injuries [Cal/OSHA GISO 5110, Repetitive Motion Injuries (RMIs)]. The regulation specifies that if two or more workers performing the same tasks had diagnosed RMIs in the same workplace within the last 12 months, a three-step ergonomics program must be implemented. A United States OSHA Ergonomics Standard was proposed and accepted but was rescinded

by the United States Senate in 2001 and cannot be considered again as an OSHA standard. Washington State had passed a similar ergonomics standard, but that was repealed by voter initiative in 2003. As of early 2005, the U.S. approach to decreasing MSDs, outside of California, is now through an industry-specific ergonomics guideline consultative voluntary program and the workers' compensation system rather than mandated regulatory programs (50–53).

Prevention and Medical Management

A key in prevention of MSDs is early recognition. Clues to early diagnosis can be found in the workplace in the following ways:

1. Review of company injury logs for cases typical of repetitive motion injuries
2. Assessment of jobs or work conditions that cause worker complaints of pain symptoms, fatigue, or paresthesias
3. Frequent references to physical aches and pains related to certain types of work assignments by workers visiting the clinic
4. Job tasks involving activities that are known to be associated with MSDs

Astute clinicians may be able to identify patterns and help bring them to the attention of employers so ergonomic preventive strategies can be developed at the work-site through safety committees, musculoskeletal symptoms surveys, and work-site evaluations for ergonomic risk factors.

Preventive strategies include the following:

1. Providing proper tools that decrease pressure points and vibration by providing adequate padding
2. Reducing activities with high repetition or increase recovery time
3. Evaluating work-sites and practices to ensure proper body positions
4. Engineering ergonomic hazards—the preferred strategy but it is often not feasible economically (54,55)

When an injury or pain disorder does occur, temporary restrictions that decrease the amount and duration of ergonomic hazards and increase the rest cycles, job rotations that alternate time spent in activities involving alternative movements and postures, and recovery time allowed each hour can be provided along with work practice modification. Shorter and more frequent breaks are more effective than less frequent but longer breaks (Table 24.3).

Further Research

Recommendations through National Occupational Research Agenda (NORA) specific to the prevention of upper extremity MSDs in agriculture include further research on the ergonomic impact and design of tools and

equipment, such as pruning shears for nursery workers and lift handles for buckets. The National Institute of Occupational Safety and Health publications such as *Easy Ergonomics: A Guide to Selecting Non-Powered Hand Tools* and *Simple Solutions: Ergonomics for Farm Workers* are valuable and free resources with specific preventive recommendations. The unique conditions of agricultural work, such as variable weather, the awkward positions required by the natural positioning of produce in the field, and the physical characteristics of living or perishable product that affect work conditions, also require further research into cost-effective engineering and work-design and remain an ongoing challenge (NORA) (55,56).

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