# 102

# TRAUMATOGENS ASSOCIATED WITH CARPAL TUNNEL SYNDROME

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## BACKGROUND

Dorland's Illustrated Medical Dictionary defines "Traumato as a combining form denoting relativity to trauma or injury. Traumatogenic is defined as capable of causing trauma. Thus, traumatogen is an excellent description of forces or motions that can cause injury depending on their amount of exposure or dose."

The "worker disease" was first documented in 1717 by Ramazinni:

> Various and manifold is the harvest of diseases reaped by certain workers from the crafts and trades they pursue. All the profit that they get is fatal injury to their health. . . . That . . . I ascribe to certain violent and irregular motions and unnatural postures of the body, by reasons of which, the natural structure of the vital machine is so impaired that serious diseases gradually develop therefrom.

Although Ramazinni recognized the influences of forces on worker's muscular skeletal health, it was many years before the Science of Egonomics was developed and contributed to the relationship of design and disease. Ergonomics also works to determine permissible levels of work load that do not lead to injury. (P. Van Wely). Cumulative trauma disorders (CTDs) are now termed work related musculoskeletal disorders (WRMSD). The WRMSDs are physiological illnesses that may develop over a period of weeks, months, or even years as a result of prolonged mechanical stresses imposed on the musculoskeletal system, resulting in injuries recognized as physical ailments or abnormal conditions. These disorders may also be referred to as *repetitive strain injurys* (RSIs) (Kiesler and Finholt, 1988), *overuse injuries* (Green and Briggs, 1989), or *repetitive motion injuries*.

Cumulative trauma disorders (WRMSDs) are considered to be work related because they are more prevalent among the working population than the general public. Because of slow onset, both management and employees often ignore the microtrauma until the symptoms become chronic and permanent injury occurs (Putz-Anderson, 1988).

The development of such occupational illnesses in high risk industries has been recognized and monitored for some time. Although slight when compared with manual handling injuries, the RSI problem has been increasing consistently since the early 1980s (Green and Briggs, 1989) so that CTDs (WRMSDs) now represent a significant proportion of all workers' compensation claims (Brogmus and Marko, 1990; Brogmus et al., 1994). Several theories to substantiate this upward trend have been suggested, not least of which is a rise in symptomatic reporting as a result of increased public awareness.

## CLASSIFICATION OF MUSCULOSKELETAL DISORDERS

Three basic types of cumulative illnesses or musculoskeletal disorders to the upper extremity musculoskeletal system are classified according to the anatomical source of irritation: tendon disorders, nerve disorders, and neurovascular disorders. Tendon disorders are those ailments associated with

*Hamilton & Hardy's Industrial Toxicology,* Sixth Edition. Edited by Raymond D. Harbison, Marie M. Bourgeois, and Giffe T. Johnson.

overuse or unaccustomed use of a specific body part, examples of which include tendinitis, tenosynovitis, de Quervain's disease, and ganglionic cysts. Neurovascular disorders involve the compression of nerves and neighboring blood vessels. Thoracic outlet syndrome and vibration syndrome are commonly classified as neurovascular disorders.

Nerve disorders are attributable to repeated or sustained work activities that cause partial or complete loss of sensory, motor, or autonomic nerve function as a result of pressure against the nerve. Common examples of nerve compression disorders include neuritis, nerve entrapment syndrome, and carpal tunnel syndrome (CTS).

### Carpal Tunnel Syndrome

First described by Sir James Paget in 1865, CTS is the most common example of a nerve compression disorder. Other terms used to describe this disorder include *writer's cramp*, *occupational neuritis*, *partial thenar atrophy*, and *median neuritis*.

It is caused by restriction of the median nerve as it passes through the carpal tunnel, an anatomical space in the wrist bound on the palmar side by the inelastic transverse carpal ligament and on the dorsal aspect by the carpal bones. The 10 structures that transverse the carpal tunnel include the four tendons of the flexor digitorum superficialis, the four tendons of the flexor digitorum profundus, the flexor pollicis longus, and the median nerve.

Robbins (1963) suggests three possible alternatives by which the cross-sectional area of the carpal tunnel may be compromised, thus reducing the available volume through which soft tissue structures pass: (1) increase of volume of the contents of the carpal canal, (2) an alteration of the osseous trough, and (3) thickening of the transverse carpal ligament.

The tendons that form a bridge between metacarpals in the hand and the flexor muscles of the forearm are lubricated along their path by tenosynovium, which allows the tendons to glide against each other. Personal factors or occupational conditions that cause irritation to, or inflammation of, the tendons can result in swelling and thickening of the tenosynovium. Because the median nerve is fragile compared to the surrounding structures, it compresses as the tendons swell, producing symptomatic experience of CTS.

Symptoms of CTS are usually experienced in the region of the hand served by the median nerve. This encompasses the second to fourth fingers, the base of the thumb on the palmar side, and the backs of the first four fingers on the dorsal side.

Acute CTS is often associated with nocturnal pain and tingling, episodic tingling during the workday, and gradual numbness, all of which may be encouraged by certain activities such as abnormal postures or repetitive or forceful hand motions. Symptoms usually diffuse shortly after the activity is changed.

As severity increases, the patient may experience aching, tingling, and what has been described as "painful numbness" in the fingers of the median distribution and deep in the palm. Perceptually, the patient may recall subjective feelings of uselessness related to the affected hand and wrist, mental sensation of swelling (although not apparent on inspection), clumsiness, and difficulty performing everyday tasks, such as unscrewing a bottle cap.

At the most severe level, patients with CTS may experience dull aching throughout the limb, which radiates not only distal to the site of compression, but also proximally. Patients may report pain throughout the forearm, upper arm, shoulder, and even the neck. Changes in coloration of the skin become more apparent, especially with exposure to cold. There may be excessive sweating in the palm and a possible mild degree of edema, which has been related to vasomotor imbalance. Wasting of the thenar muscles and mild weakness of the abductor pollicis brevis or opponens pollicis muscle may also be observed in severe cases.

### Incidence of Work-Related CTS

The Bureau of Labor Statistics, a division of the US DOL, has defined repetitive trauma disorders for the purpose of classifying work-related incidence of these occupational illnesses:

Disorders associated with repeated trauma include conditions due to repeated motion, vibration, or pressure, such as CTS, noise-induced hearing loss, synovitis, tenosynovitis and bursitis, and Raynaud's phenomenon.

Although repetitive motion disorders represent only a small, but growing percentage of total occupational injuries and illnesses involving lost work time in the United States (1994 = 4.9%), group classification has limited the analysis of incidence for individual disorders. Because of the increasing prevalence of musculoskeletal disorders, and in particular, debilitating nerve disorders such as CTS, the Bureau of Labor Statistics redesigned their survey in 1992 to report for the first time the diagnosis of specific repetitive motion disorders that commonly affect the shoulders, arms, and other upper extremity parts.

The limited data from 1992 to 1994 suggest that incidence of CTS involving lost workdays was between 36.0% (1992) and 40.8% (1994) of the total occupational illnesses. (Note: Back injuries are excluded from these data because the US DOL considers them as accidents rather than cumulative injuries.)

From 1981 to 1990, there has been a steady increase in reporting of WRMSD, with a brief accelerated increase in 1987 and 1988. Several theories on the escalating occurrence include increased employee awareness through media attention and employer training programs; increased reliance on computer terminals in the workplace without appropriate ergonomic education and application. In addition increased female populations in the workforce (females reporting CTS is approximately twice than that of male counterparts), and aging of the U.S. worker population may have also influenced the increase. The increased incidence of reporting is likely to be a result of a combination of these reasons. The whole picture will only truly be painted as more information becomes available from the Bureau of Labor Statistics' refined survey.

More than half of all incidents of CTS involving lost work days are attributable to the manufacturing industry. Massive downsizing of the manufacturing industries in favor of semi-automated processes during the 1980s is likely to continue in the foreseeable future; therefore, only through appropriate ergonomic intervention in the workplace to minimize known occupational factors will this problem be solved.

The recent slowing of occupational reporting of repetitive motion disorders has been further supported by the Bureau of Labor Statistics' 1996 announcement, which encouragingly revealed a decline in the number of occupational CTS cases for the first time in 15 years. It is speculated that the reduced incidence is in part a result of successful ergonomic interventions within specific high risk trades, including the meat industry, where incidence rates had fallen by 15.9%.

The Bureau of Labor Statistics reissued a table in 2009 that detailed the Incidence Rate for nonfatal occupational injuries and illnesses involving days away from work per 10,000 full-time workers by selected worker occupation and selected nature of injury or illnesses. The highest incidence rate was food servers, non-restaurant at 8.9. The next highest 4.6 and 4.4 for cooks, institution and cafeteria, and welders, cutters, solderers, and refrigeration, respectively. Those occupations with incidence rates between 2.4 and 2.9 in ascending order were: Butchers and meat cutters, roofers, labor and freights stock and material movers, hand, industrial machinery mechanic and automotive service technicians and mechanics. Those occupations with incidence rates between 1 and 2 were bus and truck mechanics and diesel engine specialists, maids and housekeeping cleaners, truck drivers heavy and tractor trailer and truck drivers light and delivery services. Those occupations with incidence rates below 1 were nursing aids, orderlies and attendants, construction laborers, carpenters, janitors and cleaners, except maids, and house-keeping cleaners (Bureau of Labor Statistics, 2008). In July 1997, National Institute for Occupational Safety and Health (NIOSH) published Musculoskeletal Disorders and Work Place Factors—A Critical Review of Epidemiologic evidence for WRMSD of the neck, upper extremity, and lower back. This publication is a comprehensive review of the relationship between musculoskeletal disorders and exposures to physical factors at work. Evidence for work relatedness of carpal tunnel is reviewed in Chapter 5. The thirty epidemiologic studies reviewed involved studies of populations exposed to a combination of work factors. There was evidence of positive association between highly repetitive work alone and in combination with other factors and CTS. There was evidence of a positive association and forceful work in CTS. There was insufficient evidence between CTS and extreme postures. However, there was strong evidence of a positive association between exposure to a combination of risk factors such as force and repetitiveness or force and posture. One of the important aspects of this review is that it begins to quantify the risk factors associated with CTS.

Another important aspect of the developing research is CTS case definitions. The CTS case definition in Prevalence and Incidence of CTS in the United States working populations: Polled analysis of six prospective studies (Dale) was that both CTS hand diagrams and electrodiagnostic study results consistent with median nerve mononeuropathy of the wrist. More specifically; the carpal tunnel symptoms case definition required that subjects report symptoms of tingling, numbness, burning, or pain in one or greater than one of the first three digits (thumb, index, and long finger) on a hand symptom diagram. In addition, electrodiagnostic study results consistent with median nerve mononeuropathy at the wrist were required.

### Social and Economic Costs

It is estimated that the economic burden of CTS on the U.S. industry presently exceeds $2 billion per year (Palmer and Hanrahan, 1995). A significant share of this expense is attributable to CTS surgery, which is estimated to cost between $400 and $500 million a year. A proportion of these surgeries are performed because of symptomatic recurrence in which a patient's recovery may be encumbered as a result of deficient procedures (Kern et al., 1993).

Cases of CTS also have the longest recuperation period for any reported occupational injury or illness category. More than 36% of work-related CTS cases involve more than 1 month of lost work time, with a median recovery period of 18 days, compared to the overall median for all occupational injuries and illnesses of 6 days (Box 102.1).

When determining the cost of worker injuries, it is usual to add the expenses associated with medical intervention and workers' compensation insurance premiums. However, the total costs might be as high as five times the actual direct costs (Box 102.1).

With cost-effective surveillance, workers at risk may be identified and the incidence of CTS prevented or reduced; thus the social and economic impact would be significantly lessened.

### Occupational Factors Associated with CTS Prevalence

It is often difficult to identify a specific cause of CTS because many risk factors may interact simultaneously to bring about

**BOX 102.1 DIRECT AND INDIRECT COSTS ASSOCIATED WITH CTD INCIDENCE**

**Direct Costs (20%)**

Medical expenses
Workers' compensation premiums
Lost and light duty workdays

**Indirect Costs (80%)**

Loss of injured worker's production
Time lost of employee paid by employer
Time lost by uninjured employees
Temporary help
Reporting and retraining
Reporting and claims
Management time
Worker/management discussions
Litigation costs

the condition. It is also difficult to isolate occupational factors from leisure activities, and individual susceptibility further compounds the problem. Studies identified the following factors as being contributory to the development of musculoskeletal disorders:

1. *High task repetition.* Silverstein et al. (1986) classified a job as highly repetitive if the cycle time is <30 s or if more than 50% of the time involves performing the same kind of fundamental cycle. The more repetitive the task, the more rapid and frequent are the muscle contractions, which become less efficient and hence require increased effort, therefore, demanding greater time for recovery.
2. *Forceful exertions.* As muscle effort increases in response to high task load, circulation to the muscle decreases, causing more rapid muscle fatigue.
3. *Posture.* Awkward postures overload muscles and tendons, load joints in an asymmetrical manner, and impose a static load on the musculature (Van Wely, 1970).
4. *Mechanical pressure.* Frequent or continuous use of tools with hard or sharp edges or short handles can cause compressional ischemia, impeding nerve conduction.
5. *Vibration.* Vibrating tool operation also affects myelinated nerve fiber activity and parasympathetic activity, which depresses peripheral nerve conduction (Murata et al., 1990; Murata et al., 1991).
6. *Exposure to cold.* Working in a cold environment or handling cold tools affects circulation to the digits, reducing tactile sensitivity, thereby increasing hand force.
7. *Gloves.* Use of gloves reduces tactility, thereby increasing the amount of force exerted to hold or manipulate a given object.
8. *Insufficient recovery time.* Recovery time can exceed work time for jobs where physical demands are high. Deprived of sufficient recovery time, soft tissue injuries may occur.
9. *Lead.* Constant contact or exposure to lead has been shown to impair maximal motor and sensory nerve conduction velocities of the median nerve (Araki et al., 1986).
10. *Organic solvents.* Chronic exposure to n-hexane, xylene, and toluene correlates with suppressing activity of myelinated fibers in the peripheral nervous system (Murata et al., 1994).
11. *Underreporting.* A selective loss of symptomatic employees may occur in high risk jobs, a form of healthy worker effect (Morgenstern et al., 1991).
12. *Psychosocial factors.* Kiesler and Finholt (1988) suggest that job dissatisfaction leads to increased reporting of WRMSD.

When two or more of the preceding risk factors are present, the risk of trauma is dramatically increased. Odds ratios of developing WRMSDs appear to be multiplicative. Jobs that combine high force and high repetition may pose the greatest risk (Silverstein et al., 1986).

### Personal Factors Associated with CTS Prevalence

It is widely recognized that several medical and postoperative conditions can predispose a patient to CTDs. For reasons that are unclear, hypothyroid and hyperthyroid patients, postmenopausal women, and posthysterectomy patients are more susceptible to musculoskeletal disorders. Increased incidence among these patients may be because of altered hormonal balances causing connective tissue changes similar to an inflammatory response. Other medical conditions associated with an increased incidence of WRMSDs include rheumatoid arthritis, hypertension, diabetes mellitus, kidney disorders, lipoma, amyloid disease, myxedema, acromegaly, gout, cystic fibrosis, body mass index, pregnancy, use of oral contraceptives, alcoholism, and a variety of endocrine problems.*

*Robbins, 1963; Chabon, 1985; Pascual et al., 1991; Nathan et al., 1994; Osorio et al., 1994; Werner et al., 1994; Chammas et al., 1995; O'Riordan et al., 1995.

Nonmedical personal factors have also been positively correlated with increased reporting, which might be indicative of CTS prevalence among the general population. Tanaka et al. (1995) determined, based on self-reported CTS findings, that race (odds ratio—4.2, whites higher than nonwhites), gender (odds ratio = 2.2, females higher than males), and age (odds ratio = 1.03, risk increasing per year) might predispose individuals to musculoskeletal disorders of the hand and wrist. Furthermore, Radecki (1994) discovered 75% of female and 40% of male CTS patients had a positive family history suggestive of hereditary traits.

### Traumatic and Nontraumatic Causes of CTS

Median palsy can be produced as a result of traumatic compression of the median nerve resulting in CTS symptoms. Based on the in-depth anatomical studies of the carpal tunnel (Robbins, 1963), the following identifiable sources of traumatic and nontraumatic causes of CTS were developed. This has helped establish a foundation as to potential causes of hand–wrist musculoskeletal disorders.

**Traumatic causes are as follows:**

1. Hematoma caused by hemorrhage in the palm
2. Carpal dislocation: forward dislocation of the lunate bone
3. Recent fracture of the distal end of the radius
4. Immobilization of a Colles fracture in the position of the acute volar flexion and ulnar deviation (Cotton-Loder position)
5. Healed fracture of the distal end of the radius with excessive new bone formation or with an unreduced bone fragment, resulting in tardy median nerve palsy
6. Deformities of the carpal bones caused by recent or old fractures or gross traumatic arthritis of the wrist

**Nontraumatic causes are as follows:**

1. Tenosynovitis
2. Calcium deposit
3. Ganglion
4. Leri's pleonosteosis
5. Neuromass of the median nerve at the wrist
6. Pseudoneurosis of attrition of the median nerve in the carpal tunnel
7. Aberrant artery closely accompanying the median nerve in the carpal tunnel, beating against the nerve
8. Abnormally low muscle belly of the sublimis of the long finger contracting against the nerve
9. Accessory bundle of the flexor brevis minimi digiti originating proximally from the antebrachial fascia and passing as a bridge over the nerve

## MEDICAL DIAGNOSIS OF UPPER EXTREMITY MUSCULOSKELETAL DISORDERS

Conservative surveillance techniques report that the occupational incidence of disorders associated with repeated trauma increased by 1500% between 1983 and 1996 (US DOL). This increase equates to an average annual increase of 24%, based on previous year's data. Such dramatic growth prompted attention by the research and medical communities. As a result, a repertoire of clinical and quantitative diagnostic utilities for upper extremity musculoskeletal disorders was developed.

Because of the nature of nerve disorders, such as CTS, two patients for whom symptomatic experience is similar may be suffering from two quite different disorders or from neurological irritation at two different sites along a nerve path. Therefore, the clinician must be confident in findings of the diagnostic tests before prescribing an appropriate course of treatment, surgical, or otherwise. A full diagnosis contains several parts.

### History

The first and most important information is the patient's experience: how the problem started, how it progressed, and what activities encourage symptomatic trauma. The patient can offer a level of insight not found in any quantitative measures, the benefits of which should be fully utilized. Their perspective may be solicited through structured questionnaire or informal interview techniques. This history should include symptoms of numbness, tingling, burning, or pain in the distribution of the median nerve occurring more than 3 times or lasting 7 days or longer in the previous 12 months (Burt et al., 2011). Having the patient fill in a hand diagram is most likely the best way to illustrate or define these symptoms.

### Physical Examination

A correct diagnosis requires specific examination of the affected body part. Many rapid assessment tools have been developed to aid the clinician in this process, including Phalen's test, Tinel's test, Flick test, reverse Phalen's maneuver, range of motion, strength, sensory, reflex, and circulation/pulse testing, the details of which are offered in more extensive texts. Carpal tunnel compression test adds to the clinical examination methods that can be used to determine the likelihood that CTS is the diagnosis or part of the diagnosis. In a prospective study on 200 hands diagnosed as having CTS a control group of 100 volunteers with no symptoms of CTS were also assessed. This study was done to evaluate the effectiveness of the compression test in the physical exam to determine if CTS was present. Essentially, the carpal tunnel compression test reproduces the disease itself because it increases the pressure within the canal by external manipulation. It can also be used on wrists with limited range of motion (Gonzalez Del Pina et al., 2003).

### Electrodiagnostic Studies

Compression of a nerve has been shown to produce slow conduction, entirely block nerve conduction, or cause axonal destruction. Electrodiagnostic studies are used as a tool to measure the time required for an impulse to travel from a proximal stimulus to a more distal site at which a response is evoked. This measure is called nerve latency.

Both medial and ulnar nerve latencies may be recorded and then compared. If median latency is significantly greater than ulnar latency, this is suggestive of CTS. If median and ulnar nerve latencies are both slow compared with normal values, low hand temperature, or peripheral neuropathy may be suggested (Bleecker and Agnew, 1987) (Figure 72.4).

Electrodiagnositic utilities have become widely instituted and are the primary means of detecting mild nerve disorders such as CTS. Early diagnosis can facilitate dramatic reductions in pain and suffering, associated costs, and lost time.

Kirschberg et al. (1994) demonstrated the effectiveness of combining clinical and electrodiagnostic diagnostic utilities to improve the reliability of findings. In a reevaluation of 112 patients who performed similar repetitive motion tasks and had reported pain, tingling, numbness, or all three in the hand, wrist, and forearm, only 35% presented positive clinical symptoms or positive electrodiagnostic findings. Only 17% overall actually had positive diagnostic results for both tests. This is also illustrated when a patient presents with consistent symptoms of numbness and/or pain but has negative electrodiagnostic findings. The hand surgeon makes the clinical decision to release the carpal tunnel and finds that the patient's symptoms are relieved following the release.

As noted in Burte et al's cross-sectional study the nerve conduction study must show electrodiagnostic criteria for median mononeuropathy. That is criteria A and B or C.

Criteria A. Slowed latency in median nerve

- Wrist to index finger sensory latency >3.7 ms or
- Mid-palm to wrist sensory latency >2.2 ms or
- Motor latency >4.4 ms

Criteria B. Normal distal ulnar nerve latency

- Wrist to little finger sensory latency ≤3.7 ms

Criteria C. Distal median nerve latency>distal ulnar latency

- Median wrist to index finger—ulnar wrist to little finger latency difference >1.0 ms or
- Median mid-palm to wrist—ulnar mid-palm to wrist latency difference >0.5 ms

### Treatment of CTS

If CTS is detected during the early stages of development, conservative treatment is recommended. This can be significantly less disruptive to the patient and less costly than surgical approaches. The patient may also be able to return to normal duties within a relatively short time and with minimal pain and suffering.

Conservative treatment of CTS combines four types of therapies: restricting motion and splinting to immobilize the affected area; applying heat or cold to facilitate the repair process; medications and injections to reduce inflammation and pain; and special exercises that promote circulation to speed recovery and increase the range of motion. A simple wrist brace will sometimes lessen symptoms of mild CTS, especially if the patient is instructed to refrain from activities that require working against the brace, which could accelerate the onset of more severe symptomatology. The brace might be most effectively worn at night during sleeping to prevent awkward wrist postures, which are thought to foster nocturnal exacerbation. Anti-inflammatory medications are used as the second line of treatment to help control swelling of soft tissue structures. An injection of cortisone into the carpal tunnel may be prescribed to decrease swelling within the carpal tunnel, thereby permitting time for recovery. Giannini et al. (1991) showed use of local steroid injection facilitated improvement in median nerve function long after the pharmacological effects of the agents ceased.

Only if the symptoms are extreme and the preceding medical treatments are ineffective should surgical means of rehabilitation be considered. Boniface et al. (1994) reported that symptomatology for 86% of CTS nerve disorder patients may be resolved without surgical intervention.

Traditional release surgery involves the making of a small incision, usually <2 inches, along the palm of the hand. This incision is continued through the palmar fascia to reveal the transverse carpal ligament, the constricting element. The transverse carpal ligament is then cut to relieve pressure from the median nerve. Only the skin incision is sutured, leaving the gap in the transverse carpal ligament open to slowly heal as scar tissue.

Improvements in surgical techniques now permit the operating physician to use endoscopic tools for this procedure. Either one or two ports may be cut, depending on the preferred variation, through which both monitoring and incision are accomplished. Although endoscopic surgeries tend to be more expensive and less successful than the traditional approach, the reported benefits include decreased surgical time, decreased postoperative attention, early return to duty, decreased pain, and increased thenar strength (Bernstein, 1994).

Several studies support aggressive postoperative rehabilitation therapy and early return to work. One cost-effective approach might be to teach self-stretching techniques to patients undergoing myofascial release surgery, which have been shown to reduce symptoms and improve electromyographic results (Sucher, 1993). In a comparative evaluation, Goodman (1992) demonstrated that 14% of a traditional treatment group, whereas only 2% of an aggressive return-to-work group failed to resume their normal duties following carpal tunnel release surgery. Furthermore, tangible costs computed were found to be 50% lower in the aggressively treated group.

If a complete and permanent recovery is expected, it is important that the worker not be returned to the same job or task that precipitated the musculoskeletal disorder unless that job or task has been appropriately modified.

### Recurrence of CTS

Recurrences of CTS following surgery are predominantly the result of inadequacies of the first procedure, such as incomplete splitting of the transverse carpal ligament or compression of the median nerve caused by excessive and improperly formed scar tissue. Additionally, up to 50% of recurrent CTS patients have medical conditions such as insulin-dependent diabetes mellitus, terminal renal insufficiency, or acromegaly that increase their susceptibility to nerve disorders (Kern et al., 1993). These reported statistics suggest that the number of operations for recurrent CTS can be dramatically reduced if the first operation is performed with greater care and attention. Patients with CTS secondary to a systemic disease are particularly at risk.

## ERGONOMIC EVALUATION OF WORKPLACE HAZARDS

Health and risk factor surveillance provides a means of systematic identification of patterns or trends of work-related musculoskeletal symptoms and disorders, and their risk factors. Through ongoing methodical collection, analysis, and interpretation of health and exposure data, surveillance systems often identify the effects of workplace hazards before individual employees would normally feel compelled to report them. When performing an ergonomic workplace evaluation, the following three steps should be followed:

*Phase I: Passive surveillance of available records.* Surveillance tools are characterized by their practicality and speed with which data collection may be conducted, rather than their accuracy. Passive surveillance relies on the analysis of information from existing databases, such as those listed in Table 102.1, and is generally accepted as a means of rapid assessment. By calculating incidence rates and comparing them with company or industry norms, it is relatively easy to identify specific areas within a facility that warrant's further investigation.

*Phase II: Active surveillance of workers.* Questionnaire and informal interviewing techniques are useful for identifying new or incipient problems as well as for assessing the effectiveness of medical interventions and ergonomic controls. Specifically designed active surveillance tools can also be used to determine employee perceptions about aggravating factors and job improvement ideas.

Once the problem areas have been identified through passive and active surveillance, the proactive administration of physical examinations may prove to be a cost-effective approach for the early detection of WRMSD among operators in that area.

*Phase III: Workplace risk factor analysis.* Worksite assessments are usually performed by experienced ergonomists or other health specialists who have received specialized training in the identification of ergonomic hazards. Workstations, posture, tools and materials, as well as organizational and environmental factors should all be considered.

Circumstances that may raise concern include awkward postures, relatively short cycle time or high task repetition, high force demands, awkward or improperly designed tools, and employee-initiated task or tool redesigns. The ergonomist will likely use a variety of techniques to record and document these circumstances for further examination.

Once an ergonomic job analysis has established the presence of potential contributors to cumulative trauma, a plan for control and prevention should be devised. The principal technique for preventing musculoskeletal disorders is to reduce exposure to associated risk factors, although the specific amount of acceptable exposure has not been determined. To this end, a combination of administrative and engineering approaches may be considered. Hand activity level (HAL) and wrist strain index (SI), parameters may also be considered.

### Engineering Controls

Engineering controls focus on the job or work environment. The aim is to redesign the job or tool to achieve control over those job factors associated with the onset of CTDs. Examples of engineering controls include the following:

1. Design jobs to reduce hand force and frequency of repetition.
2. Position the work and worker to eliminate awkward postures.

**TABLE 102.1 Tools for Work-Related Musculoskeletal Disorder and Associated Risk Factor Surveillance**

| | Method of Surveillance | |
|---|---|---|
| Surveillance Level | Passive | Active |
| Level I (low) | Company dispensary logs<br>Insurance records<br>Workers' compensation records<br>Accident reports<br>Transfer requests<br>Absentee records<br>Grievances and complaints | Checklists<br>Questionnaires |
| Level II (high) | | Interviews<br>Physical examinations |
| Workplace risk factor | | Checklists<br>Questionnaires<br>Job analysis |

*Source*: From *Traumatogens Associated with Carpal Tunnel Syndrome in Hamilton and Hardy's Industrial Toxicology 5th Edition*, Mosby, 1988.

3. Provide adjustable workstations and seating that permit postural changes.
4. Design workstations to minimize biomechanical loading.
5. Eliminate wrist deviations by angling the work toward the operator.
6. Use fixtures and jigs to support and position work pieces.
7. Provide parts bins below elbow height to avoid bent wrists.
8. Locate tools and components within easy reach.
9. Design or select hand tools using ergonomic principles to eliminate risk factors.
10. Use power tools to reduce exertion and repetition, but be sure to follow ergonomic tool selection guidelines.

### Administrative Controls

Administrative controls refer to actions taken by management or medical staff to limit the potentially harmful effects of a stressful job, which is usually achieved by modifying existing personnel functions. Appropriate administrative interventions for a given situation might include several of the following control measures:

1. Job rotation to less hand-intensive tasks.
2. Integrate work breaks to permit physiological recovery from biomechanically demanding tasks.
3. Alternate hands so that the task is not performed primarily by one hand.
4. Reduce repetitive body motion through task automation.
5. Avoid machine pacing.
6. Avoid incentive pay scales (i.e., piece work).
7. Provide and enforce the use of adequate protective equipment.
8. Control environment to prevent extreme conditions.
9. Gradually introduce new and returning employees.
10. Train workers in correct methods.
11. Educate management and supervisory personnel about the problem.
12. Employee selection; seek medical advice about job placement.

## STANDARDS AND LEGISLATION

The late 1990s was a time when American industries were grappling with significant incidence of musculoskeletal disorders and, in particular, CTS in many workplaces. Unfortunately, market forces seem to have provided insufficient incentive for top management to grasp the economic potential of workplace ergonomic investments.

During the mid-1980s, in response to the beginnings of increased CTD incidence, the NIOSH investigated appropriate strategies for the prevention and control of musculoskeletal injuries and illnesses. The following is an excerpt from their report that presently serves as the basis for the Occupational Safety and Health Administration's (OSHA's) legislative intervention endeavors.

When job demands repeatedly exceed the biomechanical capacity of the worker, the activities become trauma inducing. Hence, traumatogens are workplace sources of biomechanical strain that contribute to the onset of injuries affecting the musculoskeletal system.

In the absence of a general industry standard, OSHA continues to rely on the general safety clause 5 (a)(i) of their Health and Safety Act of 1970 to pursue legislative correction for ergonomic infringements. This approach has been successful in several well-publicized cases, including the John Morrell meatpacking facility in South Dakota (NIOSH, 1988). However, OSHA's goals lie not in seeking monetary compensation through citation, but in the prevention of occupational injuries and illnesses that can be debilitating to the employee and employer alike.

The original OSHA enactment of 1970, currently standing, is outdated as a legislative means of preventing occupational illnesses of ergonomic source. A more contemporary mandate may be required to reflect industry changes during the past two decades.

In light of the Morrell case, a guideline was set forth for the meatpacking industry (OSHA, 1990), which proved to be the most effective testing ground (see the case study). OSHA has since pursued a general industry enactment of their workplace ergonomics protection standard (EPS), the first draft of which was released in March 1995 (OSHA, 1995). Neither the profession of ergonomics nor manufacturing industries supported the first draft of the EPS because of potential financial ramifications. Efforts to refine the standard into a suitable format continue.

The OSHA again published an ergonomics program standard on 11/14/2000 that went into effect on 01/16/01. Congress overturned the rule in 2001. A major factor in defeating this standard was again the economic impact on industry. In addition, it was felt that there was a multiple factorial etiology for CTS that is the worker's outside of work activities also significantly contributed to the CTS and the industry will not have to pay for the cost of care.

Progress has been made in research and assessment tools for the effect of exertion on upper extremity muscles and structures. The American Conference of Governmental Industrial Hygienists (ACGIH) threshold limit value (TLV) for hand activity is a method for evaluation of job risk factors due to musculoskeletal disorders of the hand and wrist. The TLV for HAL is aimed for monotask jobs with 4 or more hours of repetitive handwork (www.ttl.fi/workloadexposuremethods June2009).

The level of hand activity is identified by using a scale of 0–10, where zero is virtually no activity to a level of 10 (highest imaginable hand activity) The normalized peak flow (NPF) is the relative level of effort on a scale of 0–10 that a person of average strength would exert in the same posture required by the task (v1.52/17/02 2002 Thomas E Bernard and ACGIH).

### Hand Activity Level (HAL) TLV Scoring Sheet

***HAL/TLV Scoring Graft*** Tiffany Cash described in her Thesis and Dissertations "Using the Strain Index and TLV for HAL to Predict Incidence of Aggregate Distal Upper Extremity Disorders in a Prospective Cohort" 2012 that if the job falls above the TLV line on the graph, it is said to be hazardous to most workers. If the plotted line falls below the Al (action level) line it is said to be safe for most workers.

The wrist SI includes six putative risk factors (force, repetition, percent, duration of exertion, postural, speed of work, and shift duration and was derived from epidemiology of (Moore and Garg, 1995). Garg et al. (2012) studied a cohort of 536 workers monthly for a period of 6 years to determine if the TLV for HAL and the SI were useful metrics for estimating exposure to biomechanical stressors. "Both the TLV for HAL and the SI were found to predict risk of CTS when adjusted for relevant covariates."

Workplace and industrial risk factors for CTS was a cross-sectional study published in 2011. This study concluded that the quantitative and rating space job exposure measures were each associated with CTS and that obesity increased the association between frequency and exertion and CTS (Burt et al., 2011).

The value of these entities is that they allow not only the ability to design research tools to investigate the relationship of these factors, but also the ability to assess the safety of workplace tasks. Thus, jobs can be modified to prevent the development of CTS. These research and measurement methods allow industry to design systems that are less likely to contribute to the development of CTS. The concept of action level in TLV certainly placed traumatogens in the realm of industrial toxicology.

## CASE STUDY

In 1990 OSHA published its Ergonomics Guidelines for the Meatpacking Industry (OSHA, 1990). This directive was developed in cooperation with the meat industry and the American Meat Institute (AMI) trade association in an attempt to combat the extraordinarily high and ever increasing incidence of CTDs among industry employees.

It is speculated that the meat industry has the highest rates of CTS because of the high percentage of the workforce that performs hand-intensive tasks. Further, the meat industry faced severe engineering constraints on equipment development as a result of the random shapes of their products and strict sanitation requirements. Although the financial benefits of an ergonomic risk management program are understood among health and safety specialists, it was believed that direct legislation would provide the necessary impetus to initiate proactive intervention programs and keep them going. Thus, OSHA and AMI developed the first industry-specific ergonomic guidelines in an attempt to control CTD incidence.

The meatpacking ergonomics guidelines encourage management commitment as evidenced by a written company program, employee involvement, and regular program review and evaluation. The guidelines, while being flexible enough to be adapted to the needs and resources of each employer, provided policy on the following four program elements: (1) worksite analysis, (2) hazard prevention and control, (3) medical management, and (4) training.

The results of 4 years' postguideline experience are encouraging. Although still 30 times greater than the general industry norm, CTD incidence in the meat industry has demonstrated a promising trend since 1991, during which time rates have declined by almost 16%. These data support the notion that employer ergonomics programs in the meat industry are working and that OSHA's Ergonomics Guidelines for the Meatpacking Industry are having a positive impact.

## CONCLUSIONS

Carpal tunnel syndrome, a compression neuropathy affecting the median nerve, may develop whenever task demands habitually exceed a worker's capacity to respond to those demands. Personal or medical factors might predispose certain individuals to the development of CTS such that, in the absence of sufficient physiological recovery, relatively inconsiderable occupational demands may impose mechanical stresses on the musculoskeletal system.

Hand activity level and wrist SI through ongoing passive and active surveillance of health and exposure data, the effects of workplace hazards may be identified before employees would normally feel compelled to report them. The solution is to balance task demands with worker capacity through the appropriate implementation of engineering and administrative controls.

## REFERENCES


Araki, S., et al. (1986) Psychological performance in relation to central and peripheral nerve conduction in workers exposed to lead, zinc and copper. *Am. J. Ind. Med.* 9:535–542.

Bernstein, R.A. (1994) Endoscopic carpal tunnel release. *Conn. Med.* 58:387–394.

Bleecker, M.L. and Agnew, J. (1987) New techniques for the diagnosis of carpal tunnel syndrome. *Scand. J. Work Environ. Health* 13:385–388.

Boniface, S.J., Morris, I., and Macleod, A. (1994) How does neurophysiological assessment influence the management and outcome of patients with carpal tunnel syndrome? *Br. J. Rheumatol.* 33:1169–1170.

Brogmus, G.E. and Marko, R. (1990) Cumulative trauma disorders of the upper extremities: the magnitude of the problem in U.S. industry, *Proceedings of the IEA Conference on Human Factors in Design for Manufacturability and Process Planning, Honolulu*.

Brogmus, G.E., Webster, B., and Sorock, G. (1994) Recent trends in cumulative trauma disorders of the upper extremities in the United States: an evaluation of possible reasons. *J. Occup. Environ. Med.* 38(4):401–411.

Bureau of Labor Statistics (2008) *Summary of Occupational Illnesses and Injuries*, Washington, DC: US Department of Labor, Tables 20, 21 and 23.

Burt, S., Crombie, K., Jin, Y., et al. (2011) Work place and individual risk factors for carpal tunnel syndrome. *Occup. Environ. Med.* 68:928–933, originally published online 05/25/2011.

Chabon, S.J. (1985) *Carpal tunnel syndrome: a medical and occupational disease, PA Outlook September: 4–16*.

Chammas, M., et al. (1995) Dupuytren's disease, carpal tunnel syndrome, trigger digit and diabetes mellitus. *J. Hand Surg. Am.* 20:109–114.

Garg, A., Kapellusch, J., Hegmann, K., Wertsch, J., Merryweather, A., Deckow-Shaefer, G., Malloi, E.J., and the WISTAH Hand Study Research Team (2012) The Strain Index (SI) and Threshold Limit Value TLV for Hand Activity Level (HAL: risk of Carpal Tunnel Syndrome (CTS) and a prospective cohert. *Ergonomics* 55(4):396–414.

Giannini, F., et al. (1991) Electrophysiologic evaluation of local steroid injection in carpal tunnel syndrome. *Arch. Phys. Med. Rehabil.* 72:738–742.

Gonzalez Del Pina, J., Delgato-Martinez, A.D., Gonzalez, I., Gonzalez, and Lovic, A. (1997) Value of the carpal compression test in the diagnosis of carpal tunnel syndrome. *J. Hand Surg. Br.* 22B(1):38–41.

Goodman, R.C. (1992) An aggressive return-to-work program in surgical treatment of carpal tunnel syndrome: a comparison of costs. *Plast. Reconstr. Surg.* 89:715–717.

Green, R.A. and Briggs, C.A. (1989) Effect of overuse injury and the importance of training on the use of adjustable workstations by keyboard operators. *J. Occup. Med.* 31:557–562.

Kern, B.C., et al. (1993) The recurrent carpal tunnel syndrome. *Zentralbl. Neurochir.* 54:80–83.

Kiesler, S. and Finholt, T. (1988) The mystery of RSI. *Am. Psychol.* 43:1004–1015.

Kirschberg, G.J., et al. (1994) Carpal tunnel syndrome: classic clinical symptoms and electrodiagnostic studies in poultry workers with hand, wrist, and forearm pain. *South. Med. J.* 87:328–331.

Moore, J.S. and Garg, A. (1995) The strain index: A proposed method to analyze jobs for risk of distal upper extremity disorders. *Am. Ind. Hyg. Assoc. J.* 56:443–458 (page 447).

Morgenstern, H., et al. (1991) A cross-sectional study of hand/wrist symptoms in female grocery checkers. *Am. J. Ind. Med.* 20:209–218.

Murata, K., et al. (1994) Changes in autonomic function as determined by ECG R-R interval variability in sandal, shoe and leather workers exposed to n-hexane, xylene and toluene. *Neurotoxicology* 15:867–875.

Musculoskeletal Disorders and Workplace Factors, A Critical Review of Epidemiological Evidence for Work Related Musculoskeletal Disorders of the Neck, Upper Extremity and Low Back, 2nd Printing, US Department of Health and Human Services, Public Health Service, CDC, NIOSH.

Murata, K., Araki, S., and Aono, K. (1990) Central and peripheral nervous system effects of hand-arm vibrating tool operation: a study of brainstem auditory-evoked potential and peripheral nerve conduction velocity. *Int. Arch. Occup. Environ. Health* 62:183–187.

Murata, K., Araki, S., and Maeda, K. (1991) Autonomic and peripheral nervous system dysfunction in workers exposed to hand-arm vibration: a study of R-R interval variability. *Int. Arch. Occup. Environ. Health* 63:205–211.

Murata, K., et al. (1994) Changes in autonomic function as determined by ECG R-R interval variability in sandal, shoe and leather workers exposed to n-hexane, xylene and toluene. *Neurotoxicology* 15:867–875.

Nathan, P.A., et al. (1994) Slowing of sensory conduction of the median nerve and carpal tunnel syndrome in Japanese and American industrial workers. *J. Hand. Surg. Br.* 19B:30–34.

National Institute for Occupational Safety and Health (NIOSH) (1988) *Health Hazard Evaluation Report: John Morell*, HETA 88-180-1958, Sioux Falls, SD: National Institute for Occupational Safety and Health.

O'Riordan, J.I., et al. (1995) Peripheral nerve dysfunction in adult patients with cystic fibrosis. *Ir. J. Med. Sci.* 164:207–208.

Occupational Safety and Health Administration (OSHA) (1990) *Ergonomics Guidelines for the Meatpacking Industry*, Washington, DC: Occupational Safety and Health Administration.

Occupational Safety and Health Administration (OSHA) (1995) *Ergonomics Protection Standard (Draft)*, Washington, DC: Occupational Safety and Health Administration.

Osorio, A.M., et al. (1994) Carpal tunnel syndrome among grocery store workers. *Am. J. Ind. Med.* 25:229–245.

Palmer, D.H., and Hanrahan, L.P. (1995) Social and economic costs of carpal tunnel surgery. *Instr. Course Lect.* 44:167–172.

Pascual, E., et al. (1991) Higher incidence of carpal tunnel syndrome in oophorectomized women. *Br. J. Rheumatol.* 30:60–62.

Putz-Anderson, V. editor. (1988) *Cumulative Trauma Disorders: A Manual for Musculoskeletal Diseases of the Upper Limbs*, London: Taylor & Francis.

Radecki, P. (1994) The familial occurrence of carpal tunnel syndrome. *Muscle Nerve* 17:325–330.

Robbins, H. (1963) Anatomical study of the median nerve in the carpal tunnel and the etiologies of the carpal tunnel syndrome. *J. Bone Joint Surg. Am.* 45A:953–966.

Silverstein, B.A., Fine, L.J., and Armstrong, T.J. (1986) Hand wrist cumulative trauma disorders in industry. *Br. J. Ind. Med.* 43:779–784.

Sucher, B.M. (1993) Myofascial release of carpal tunnel syndrome. *J. Am. Osteopath. Assoc.* 93:92–94.

Tanaka, S., et al. (1995) Prevalence and work-relatedness of self-reported carpal tunnel syndrome among U.S. workers: analysis of the occupational health supplement data of 1988 national health interview survey. *Am. J. Ind. Med.* 27:451–470.

Van Wely, P. (1970) Design and disease. *Appl. Ergon.* 1:262–269.

Werner, R.A., et al. (1994) The relationship between body mass index and the diagnosis of carpal tunnel syndrome. *Muscle Nerve* 17:632–636.