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Occupational Risk Factors
Cumulative Trauma Disorders of the
Hand and Wrist

Final Report on Contract #200-82-2507

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CHAPTER 1

INTRODUCTION

Upper extremity cumulative trauma disorders (CTDs) may be caused, precipitated or aggravated by forceful or repetitive exertions. Occupationally related CTDs largely affect the musculoskeletal system (tendinitis, tenosynovitis, bursitis, trigger finger, epicondylitis) or the peripheral nervous system (carpal tunnel syndrome, cubital or Guyon tunnel syndrome, thoracic outlet syndrome, digital neuritis).

It has been suggested that the major occupational risk factors for these disorders include repetitiveness, force, awkward postures, vibrating and non-vibrating hand tools.

It is proposed that jobs requiring highly repetitive or highly forceful hand and wrist motions, irrespective of other factors, will be positively associated with hand wrist cumulative trauma disorders. Further, it is proposed that with jobs requiring both high repetitiveness and high force, the magnitude of association will be greater than with either factor alone.

1.1 Aims and Objectives

The overall aim of this investigation was to determine whether there were associations between cumulative trauma disorders and job attributes of force and repetitiveness, using primary sources of exposure and health status. The emphasis of this investigation was on

hand and wrist CTDs. Within this context, the specific objectives of this investigation include:

1. Development of field instruments to identify occupationally related upper extremity CTDs in active workers.
2. Estimation of the prevalence of upper extremity CTDs among workers in jobs whose force and repetitiveness requirements have been determined.
3. Estimation of the individual and multiplicative contributions of occupational and non-occupational factors which may be associated with these disorders.
4. Test the null hypothesis of no association between the prevalence of CTDs among workers with different force and repetitive work requirements.

1.2 Significance

Despite growing worker and management concern, and media attention (Lublin, 1983), there has been little documentation of actual incidence or prevalence of CTDs in the United States reported in the scientific literature.

Incidence rates, based on company medical records, OSHA 200 logs or worker's compensation records have been reported in several US studies. Armstrong et al (1982) reported 129.6 cases of upper extremity CTDs per 100 worker years in a poultry thigh skinning operation. Wherle (1976) reported 25.6 cases of carpal tunnel syndrome per 100 worker years in an automotive sewing operation. However, data used to determine health outcome in these studies were of uncertain quality.

Most epidemiologic investigations of "overuse" disorders and

occupational risk factors have taken place outside the United States. Prevalence studies, using standardized screening examinations to determine health effect, have found some types of CTDs to be present in up to 61% of some Scandinavian workers (Kourinka and Koskinen (1979).

The difficulty in estimating the incidence or prevalence of CTDs in industrial populations is not unique to the United States. Noting the 220% increase in compensation claims for "repetitive strain injuries" in New South Wales between 1970 and 1980, Browne et al (1984) believe that the estimates are merely the tip of the iceberg because of inadequacies in diagnosis, classification and reporting of these disorders in Australia. Ferguson (1984) suggests that the "epidemic" of repetitive strain injuries occurring in New South Wales is really endemic. Because active treatment has been largely ineffectual, Ferguson recommends concentrated effort on identification at the predisability stage and prevention through work organization and design. However, as a necessary precursor to this concentrated effort, he suggests a sounder knowledge of the epidemiology of these injuries is essential.

The National Swedish Board of Occupational Safety and Health recognized the adverse effects of "jobs involving the lifting of heavy loads, repetitive and monotonous movements and unsuitable work postures" on worker health and safety. The Board enacted an ordinance (AFS 1983:6) concerning Work Postures and Working Movements, effective January 1, 1984. The ordinance provides ergonomic guidelines for reducing a variety of occupational risk factors. No similar ordinance exists in the United States.

CHAPTER 2

BACKGROUND

Ramazzini (1713) noted the effects on workers of cumulative trauma from poorly designed work and described "certain violent and unnatural postures of the body, by reason of which the natural structure of the vital machine is so impaired that serious diseases gradually develop therefrom..."

Since Ramazzini's time, most of the literature on workplace causes of upper extremity cumulative trauma disorders (CTDs) still consists of case studies and clinical reports.

The first section of this review briefly describes hypothesized mechanisms of CTDs. The second section reviews some of the more commonly reported CTDs and summarizes reported risk factors. The third section focuses on field studies of upper extremity CTDs with emphasis on measures of health effects and occupational exposures. Very few studies have addressed both health effects and occupational exposures with equal rigor.

2.1 Mechanisms

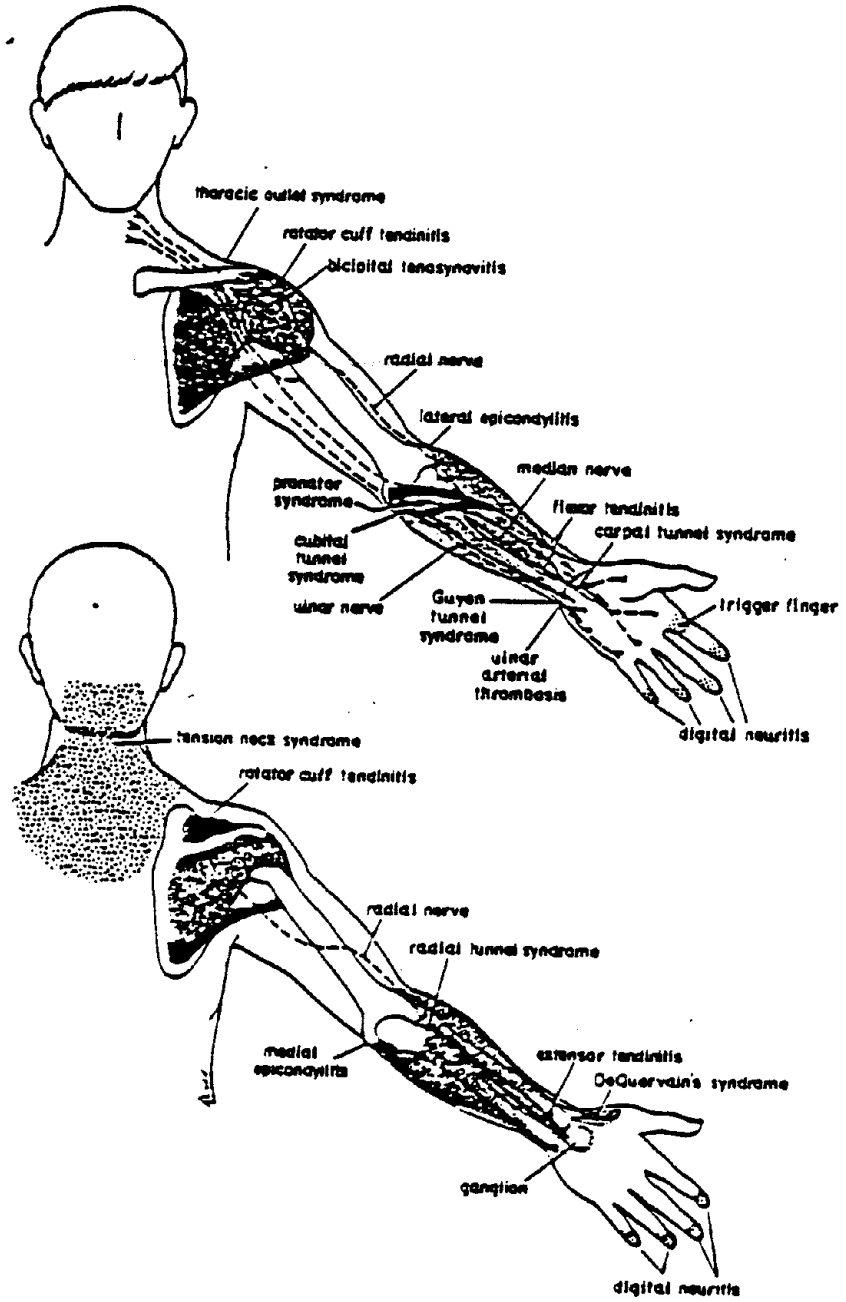
The premise of cumulative trauma is that repetitive or sustained microtrauma occurring over time compromises the integrity or functioning of the tissues. There are several ways in which forceful and repetitive motions can lead to inflammation of tendons and compression of nerves. Cumulative trauma disorders therefore largely affect the musculoskeletal system or the peripheral nervous system.

Forceful (static or repetitive) contraction of muscles causes their corresponding tendons to stretch, thereby compressing the vascular, epitendon and endotendon microstructures which in turn cause ischemia, fibrillar tearing and inflammation (Rathburn and Macnab, 1970; Herberts and Kadefors, 1976). Frictional damage to the sheaths can occur with repetitive motion (Lamphier, 1965). Also, with repetitive loading of the tendons (without adequate recovery time) progressive lengthening and "creeping" or sliding of tendon fibers through the ground substance matrix occurs, resulting in inflammation (Goldstein, 1981). Awkward postures may contribute to muscle-tendon inflammation by compression of the microstructures and by increasing the force requirements of tasks (Tichauer, 1973).

Where the nerves come into contact with less yielding structures than themselves, they can be compressed or entrapped. The carpal canal is a compact unyielding tunnel through which the flexor tendons and median nerve pass. Inflammation of these tendons and sheaths can compress the nerve. As a result, carpal tunnel syndrome is often seen with flexor tenosynovitis (Smith et al, 1977; Phalen, 1972; Gainer and Nugent, 1977). Similarly, external repetitive or sustained pressure over the nerves, such as that associated with many manual tasks, can mechanically compress them. Figure 1 shows the sites of common upper extremity cumulative trauma disorders.

FIGURE 2.1

SITES OF COMMON UPPER EXTREMITY CUMULATIVE TRAUMA DISORDERS



2.2 Review of Clinical and Case Study Literature

2.2.1 Hand and Wrist Disorders

The most commonly hand and wrist disorders reported to be associated with cumulative trauma include tendon related disorders (tendinitis, tenosynovitis, De Quervain's disease, trigger finger), carpal tunnel syndrome (CTS), Guyon tunnel syndrome, digital neuritis, ulnar arterial thrombosis (hypothenar hammer syndrome) and degenerative joint disease of the fingers. Occupational factors reported to be associated with these disorders are presented in Table 2.1.

Tendon Related Disorders include tendinitis (inflammation of the tendon tissues), tenosynovitis or tenovaginitis (separate or concomitant inflammation of the tendon and its sheath) and peritendinitis (inflammation outside the tendon sheath at the bony insertion or' musculotendinous junction). These disorders have common clinical presentations and their names often have been used interchangeably in the literature. The most common symptom is pain along or about the tendon, often accompanied by swelling or crepitus. Stenosis or thickening of the tendon sheath may occur. Two of the most common tendon related disorders are DeQuervain's disease, a stenosing tenosynovitis of the abductor pollicis longus and extensor pollicis brevis tendons, and trigger finger which is often associated with the development of a small ganglion arising in the flexor sheath (Bunnell, 1964; Mathews, 1973).

While tendon related disorders have been associated with acute trauma (Ellis, 1951; Lanfear and Clark, 1972) and rheumatoid arthritis (Urbaniak and Roth, 1982), most investigators believe the majority of cases are related to "overuse" which causes either frictional or

stretch damage. Table 2.1 includes occupational factors reported to be associated with tendon related disorders.

Carpal Tunnel Syndrome (CTS), the most common nerve entrapment, involves compression of the median nerve in the carpal tunnel. This produces symptoms of pain and paresthesia in the median nerve distribution of the hand. However, other patterns may be present (Mariancci and Von Hagen, 1965; Mathur, 1981). Occupational factors reported to be associated with carpal tunnel syndrome are summarized in Table 2.1.

CTS has been reported to be positively associated with:

-Female sex (Tanzer, 1959; Kendall, 1960; Phalen, 1972)

-Diabetes Mellitus (Mulder et al, 1961; Jung et al, 1971; McCann and Davis, 1978)

-Birth control pills (Sabour and Fadel, 1970)

-Bilateral oophorectomy (Bjorkquist, 1977; Cannon et al, 1981)

-Pregnancy (Wilkenson, 1960; Gould et al, 1978; Massey, 1978)

-Rheumatoid Arthritis, Gout (Barnes and Currey, 1967; Phalen, 1972)

-Trigger finger, Ganglion, Tennis Elbow, Raynaud's phenomenon (Phalen, 1972)

-Wrist size or shape (Gelmers, 1981; Johnson et al, 1981).

Guyon Tunnel Syndrome, less commonly reported than CTS, is an entrapment of the ulnar nerve as it passes through the Guyon tunnel. The tunnel, located more superficially than the carpal tunnel, contains the ulnar nerve and artery and some fatty tissue (no tendons). Symptoms and signs can be sensory, motor or both (Shea and McClain, 1969). An anatomically related disorder is ulnar artery thrombosis (hypothenar hammer syndrome). Repetitive use of the ulnar base of the palm as a hammer is the most commonly cited factor in both of these

disorders (Table 2.1) although anomalous muscles and acute trauma have occasionally been noted.

Degenerative Joint Disease (DJD) characterized by insidious local joint pain, stiffness, limitation and deformity (Moskowitz, 1984), has an unknown etiology. While aging has been the primary factor associated with localized osteoarthrosis of the hands (Acheson and Collart, 1975; Plato and Norris, 1979; Cummingham and Kelsey, 1984), it remains unclear whether degenerative joint disease is an inevitable disease of aging or the result of prolonged exposure to processes begun much earlier in life. Females have a higher prevalence of changes in distal interphalangeal (DIP), proximal interphalangeal (PIP) and first carpometacarpal (CMC) joints whereas males have a greater prevalence in metatarsophalangeal (MTP) and wrist joints (Kellgren and Lawrence, 1958). The role of chronic occupational trauma has been sited in a number of studies (Table 2.1). Acheson and Collart (1975) found disease to be more severe in the right hand than the left hand in right-handed people suggesting a role for chronic mechanical stress.

As can be seen in Table 2.1, similar occupational risk factors have been cited for most of these disorders. They include forceful and or repetitive hand and finger exertions, often in combination with wrist deviation and pinching grip with the fingers.

TABLE 2.1

OCCUPATIONAL FACTORS ASSOCIATED WITH HAND AND WRIST CTDS

DISORDER	OCCUPATIONAL FACTORS	REFERENCES
Carpal Tunnel Syndrome	-hands held in fixed position over prolonged period	Melville (1972)
	-repeated wrist and finger flexion	Tanzer (1959), Mather (1981) Phillips (1967), Miller (1980) Kaplan (1983), Inglis (1972)
	-light highly repetitive wrist and finger movement	Birbeck & Beer (1975) Armstrong & Chaffin (1978)
	-repeated flexion or hyper-extension of the wrist	Armstrong (1981), Wherle (1976) Rothfleisch & Sherman (1978) Bora, Osterman (1982), Sandzen (1981) Cannon et al (1981), Brain et al (1947)
	-repeated low grade trauma	Swajian (1981)
	-pressure at the base of the palm or wrist	Feldman et al (1983) Armstrong (1983, 1984) Tichauer, Gage (1977), Kendall (1960)
	-prolonged strenuous use of the hands	Marin et al (1963) Kraft, Halvorson (1983) Phalen (1972), Falck, Aarnio (1983)
	-vibration	Cannon et al (1981), Wener (1984) Rothfleisch, Sherman (1978)
	-pinching or grasping	Feldman et al (1983), Smith et al (1977)
	-wrist ulnar deviation and flexion in repetitive tasks	Tichauer (1966)
	-wrist extension with forceful pinch	Rabourn (1977) Perrott (1961)
Ulnar Nerve Entrapment (Guyon tunnel)	-use of hypothenar eminence as a hammer	Swanson et al (1983) Feldman et al (1983)
	-grasp with thumb, fingers with palmer pressure	Hunt (1911) Harris (1929), Lister (1984)
	-prolonged flexion or hyper-extension,heavy manual work	Eckman et al (1975) Dupont et al (1965
	-heavy lifting with palm	Shea, McClain (1969)
	-repetitive trauma to palm	Urbaniak, Roth (1982), Overton (1967)
Perineural fibrosis of Digital Nerves	-repeated minor trauma -grasping sharp objects in the hand	Howell, Leach (1970) Dobyns (1972), Cyriax (1978) Moidel (1981), Lister (1984) Urbaniak, Roth (1982)
Ulnar arterial thrombosis (Hypothenar hammer syndrome)	-recurrent blunt trauma	Foster, Cameron (1981) Little,Ferguson (1972)
	-vibrating tools,push,twist, pound with hands	Conn et al (1972) McCarrol (1984)
	-repeated impact of catching	Lowry et al (1976)

TABLE 2.1 CONTINUED

Tenosynovitis, Tendinitis, DeQuervain's, Peritendinitis	-repetitive motion especially in combination with ulnar deviation with fixed thumb	Eichoff (1927) Finkelstein (1930) Lamphier et al (1965)
	-overusage during angular movements	Hochberg et al (1983)
	-repeated trauma	Lipscomb (1944)
	-repetitive motions of hands and wrists	Hymovich,Lindholm (1966) Tichauer (1966), Welch (1972) Pozner (1942), Flowerdew, Bode (1942) Reed, Harcourt (1953) Wilson & Wilson (1957), Wells (1960)
	-rapid finger flexion	Bunnell (1964), Levine (1968)
	-unaccustomed repetitive work	Bunnell (1944), Conn (1931) Thompson et al (1951) Howard (1937), Ellis (1951) Wilson & Wilson (1957)
	-repetitive work with thumb and finger, grasping and radial deviation	Muckart (1964)
	-persistent strain	Zollinger (1927), Leao (1958)
	-gripping, jolting, vibration	Rhodes (1947)
	-repetitive rotary wrist	Wood, Linchcid (1973)
	-cyclic loading of tendons	Goldstein (1981)
	-extreme hand postures with maximal extension of fingers	Luopajarvi et al (1979)
	-violent pulling, wrenching	Ferguson (1971)
	-grip or twist with forearm pronation or supination	Griffith (1952)
	-pinch followed by quick pronation	Blood (1942)
Trigger finger	-excessive flexion and extension of digit against resistance	Fahey, Bollinger (1954) Lipscomb (1944)
	-overuse of index finger with pistol airtool	Tichauer (1978)
Ulnar Collateral Ligament Laxity of the Thumb (Gamekeeper's Thumb)	-thumb abduction-extension with force	Ganel et al (1980) Campbell (1955)
DJD	-pattern of usage at the joints with highest use	Hadler (1978), Radin (1971) Lawrence (1961), Anderson (1974) Partridge, Duthie (1968)

2.2.2 Elbow and Forearm Disorders

There are four common types of elbow and proximal forearm disorders reported to be associated with cumulative trauma. The most common of these is Epicondylitis, an inflammation of tendons about the elbow, either lateral (tennis elbow) or medial (golfer's elbow). Pain is experienced when the wrist and finger extensors (lateral) or flexors (medial) are in use. In an annual cross-sectional survey of the common rheumatic diseases conducted among the adult Swedish population, Allander (1974) noted a 1-3% prevalence of lateral epicondylitis among both sexes that decreased with age, unlike degenerative joint disease. This suggests that factors other than aging, including occupational stress, could be factors. Roto and Kivi (1984) recently found the prevalence of epicondylitis in meatcutters to be 8.4% compared to 1.4% among construction foremen. The prevalence among meatcutters increased with age or years on the job. Table 2.2 presents reported occupational factors associated with epicondylitis.

Radial Tunnel Syndrome is a peripheral nerve entrapment that manifests itself as a resistant tennis elbow. Morrison (1981) suggests a pathological thickening of the supinator muscle at the proximal border to be the cause.

Pronator Teres Syndrome (compression of the median nerve as it passes through the two heads of the pronator teres in the forearm) has symptoms similar to CTS that extend to the forearm. The pronator teres muscle is most active (contracting) during rapid or resisted pronation (Basmajian, 1979), and forceful pronation of the forearm with wrist flexion (Mill's test) can aggravate this syndrome (Cailliet, 1981).

Cubital Tunnel Syndrome is a compression of the ulnar nerve as it passes through the cubital tunnel behind the medial epicondyle. It is often seen in those with prolonged external pressure at the cubital tunnel. When the forearm is pronated pressure on the ulnar nerve is increased (Cailliet, 1980).

TABLE 2.2

OCCUPATIONAL FACTORS ASSOCIATED WITH ELBOW AND FOREARM DISORDERS

DISORDER	OCCUPATIONAL FACTORS	REFERENCES
Cubital Tunnel Syndrome	-repeated or prolonged elbow flexion with wrist extension	Macnicol (1979)
	-repeated trauma or leaning elbow on workbench	Feldman et al (1983)
	-habitual elbow leaners	Bora, Osterman (1982)
	-elbow flexion and repeated trauma	Feindel (1958), Reddy (1983) Craven, Green (1980)
	-flexion and pressure	Wadsworth, Williams (1973)
Pronator teres Syndrome	-repeated pronation or grasp	Hartz et al (1981)
	-tight gripping, turning of tools	Seyffarth (1951)
	-forceful pronation with finger flexion	Morris, Peters (1976) Feldman et al (1983)
	-forced pronation with elbow extension	Bora, Osterman (1982)
Radial Tunnel Syndrome	-repeated rotary movements assembly of heavy fabric	Morrison (1980)
	-repetitive wrist flexion with pronation or wrist extension with supination	Lister (1984)
	-repeated forceful movements	Roles, Maudsley (1972)
Epicondylitis (lateral most common)	-constant use of a hammer	Mills (1928)
	-repeated supination/pronation	Rasch, Brubaker (1957) Sinclair (1965), Gardner (1970) Lapidus, Guidotti (1970) Ferguson (1971) Wadsworth, Williams (1973)
	-repeated forceful wrist extension	Cyriax (1978) Roto, Kivi (1984)
	-supination of gripping hand with wrist extension, repeated activity of small muscles attached to the epicondyle	Steiner (1976)
	-unaccustomed or repetitive movements with forearm or finger extensors	Goldie (1964) Kurppa et al (1979)
	-macro/micro tears with undue stress	Cooper, Hooper (1973)
	-repeated trauma	Boyd, McLeod (1973)
	-repetitive supination with flexed elbow and 10lb. load	Perrott (1961)

With the exception of prolonged external pressure in cubital tunnel syndrome, the occupational risk factors for these four disorders are quite similar and include repetitive forearm rotation in combination with repetitive wrist deviation or finger motion.

2.2.3 Shoulder Disorders

The most common shoulder disorders reported to be associated with cumulative trauma include rotor cuff tendinitis (primarily supraspinatus) and bicipital tenosynovitis.

Shoulder function involves 3 bones, 4 joints, 12 ligaments and more than 15 muscles (Matsen and Kirby, 1982). The zones of avascularity in the supraspinatus, biceps brachii and infraspinatus tendons are subject to microruptures and degeneration (Rathburn and Macnab, 1970). As the tension on the tendons increases (as with overhead work) the venous circulation decreases and finally stops, thereby accelerating degeneration (Hagberg, 1984). Brewer (1975) suggests the progressive changes seen in the supraspinatus tendon are secondary to a summation of biomechanical forces of functional demand. The shoulder is a frequent target for degenerative joint disease and rheumatoid arthritis.

In an electromyographic study Hagberg (1981) reported rapid fatigue of the supraspinatus muscle in abduction; of the biceps brachii in flexion and of the upper trapezius in both. The fatiguing process in the muscle indicated a constant traction on the tendon. He suggests the ischemic effect on the tendon as the major etiological factor in supraspinatus tendinitis.

Reported occupational factors are summarized in Table 2.3.

TABLE 2.3

OCCUPATIONAL FACTORS ASSOCIATED WITH SHOULDER DISORDERS

DISORDER	OCCUPATIONAL FACTORS	REFERENCES
Bicipital tenosynovitis	-overhead reaching, lifting	Neviaser (1980,1983)
	-repeated minor trauma	Simon (1975)
	-pulling or lifting	Crenshaw, Kilgore (1966)
	-arm made to repeatedly work at mechanical disadvantage	DePalma, Callery (1954)
	-continuous use in abduction and rotation	Meyer (1921)
	-overuse	Boyle (1969)
Rotor Cuff tendinitis	-excessive or forcible shoulder exersion	Booth, Marvel (1975)
	-repetitive activities with rotation or elevation	Simon (1975)
	-overuse in overhead work	Matsen, Kirby (1982)
	-repetitive pulling, lifting	Neviaser (1980), Neer (1983)
	-overuse	Bush (1983), Boyle (1969)
		McLaughlin (1946)
	-sustained or repetitive flexion or abduction	Coventry (1953)
	-cumulative trauma	Meyer (1937)
	-work with hands at or above acromion height	Bjelle et al (1979, 1981)
	-prolonged tension of shoulder stabilizing muscles while performing hand intensive work	Kvarnstrom (1983)
	-loading of the arm above 60 degrees abduction or flexion	Herberts, Kadefors (1976)
		Herberts et al (1981)
	-excessive use of the hand	Mason et al (1980)
	-static muscle load	Luopajarvi et al (1979)

In summary, occupational factors associated with shoulder tendinitis primarily include repeated or sustained flexion or abduction of more than 60 degrees. Additionally, work requiring fine hand manipulation requires static loading of the shoulder to hold the entire upper extremity in place.

2.2.4 "Occupational Cervicobrachial Syndromes"

These are poorly defined disorders which have received considerable attention in the Japanese and Scandinavian literature.

The Japanese Industrial Health Association on Cervicobrachial Syndrome (1973) describes the disorder(s) as "a functional and organic disorder brought about by muscular and mental fatigue of work."

Perhaps the first report of this type of disorder and its risk factors was reported among professional writers by Ramazzini (1713) who noted "....constant writing also considerably fatigues the hand and whole arm on account of the continual and almost constant tension of the muscles and tendons" which eventually leads to "palsy of the whole arm."

Symptoms include shoulder stiffness, neck, back and forearm pain, coldness and hypesthesia (or paresthesia) of the hands, excessive physical fatique, headaches, irritation and insomnia (Maeda, 1975). Waris (1980) includes thoracic outlet syndrome, tension neck syndrome, humeral tendinitis and cervical syndrome as the primary types of "cervicobrachial syndrome." Table 2.4 presents some of the factors reported to be associated with these disorders.

Thoracic Outlet Syndrome is a general term for the compression of the neurovascular component of the upper extremity at the brachial plexus (Tyson and Kaplan,1975; Riddell, 1967). Although it is a well defined clinical entity, it is included in this section to reflect the classification of Waris (1980). Symptoms include tingling, burning and numbness along the inner arm, forearm, hand and fingers in corresponding dermatomes. There are a variety of mechanisms believed to cause this compression. Anomalous cervical ribs and aging are thought to be the primary factors by many authors. However, these symptoms are rare in the aged and those with cervical ribs (Overton, 1967). Nelson (1957) and Waris (1980) suggest posture and occupational

factors may aggravate or precipitate the symptoms but are not important in underlying etiology. Lord and Rosati (1958) noted that when the arm is abducted 180 degrees, the brachial plexus and auxiliary vessels are subject to maximum compression against the "auxiliary pulley" of the pectoris minor muscle around the coracoid process (hyperabduction syndrome).

Tension Neck Syndrome is a poorly defined condition with pain, muscle weakness and fatigability in the region of the neck and scapular area. "Objective signs" (excluding other disorders such as cervical root disorders) include muscle tenderness in the upper part of the trapezius, local muscle spasm or hardening, trigger points along the muscle insertion (Waris, 1979). Tichauer (1966) noted that when the arm is abducted 40 degrees, the upper fibers of the trapezius are stressed 8 times as much as at a 20 degree angle and 64 times as much as at a 10 degree angle. Similar types of disorders are reported by Cohen (1980), Valtonen (1968) and DeLacerda (1982).

TABLE 2.4
OCCUPATIONAL FACTORS ASSOCIATED WITH *OCCUPATIONAL CERVICOBRACHIAL SYNDROMES

DISORDER	OCCUPATIONAL FACTORS	REFERENCES
Tension Neck (primary tension myalgia) Scapulacostal Syndrome	-acute strain	Komoike (1979)
	-repetitive high speed finger wrist and arm motion	Ferguson (197 Kourinka (1979)
	-static arm, elbow elevation of 60-90 degrees	Valtonen (1968)
	-prolonged neck, shoulder bending	Cohen (1980)
	-chronic occupational muscle strain	Simons (1975)
	-repetitive or sustained arm abduction more than 75 degrees	DeLacerda (1982)
Thoracic Outlet (hyperabduction, anterior scalene costoclavicular syndromes)	-carrying heavy objects	Silver (1980) Naffziger, Grant 1938) Lascelles et al (1977) Brickner (1927) McCleery et al (1951) Lord, Rosati (1958) Nichols (1967) Falconer, Weddell (1943) Miller (1984)
	-overhead work (repeated or sustained)	Urschel et al (1968) Wright (1945), Bateman (1968) Lascelles et al (1977) Beyer, Wright (1951) Kremer, Ahlquist (1975) Lord, Rosati (1958)
	-rapid finger motions	McCleery et al (1951) Riddell (1967), Brickner (1927)
	-throwing or rowing	Strukel, Garrick (1978)
	-vibration	Riddell (1967) Roos, Owens (1966)
	-hammering	Kremer, Ahlquist (1975)
Cervicobrachial Disorder	-high speed repetitive use of hands and fingers	Maeda (1974) Komoike (1975)
	-static or dynamic burden on arms (elevated)	

2.3 Epidemiologic Studies

Epidemiology has been used to evaluate relationships between health effects and occupational exposures or risk factors. Prospective cohort studies, in general, provide the most convincing evidence of causal relationships. Cross-sectional or prevalence studies are useful in generating hypotheses about risk factors. Case-control studies are often used as an initial step in determining whether there is an association between a suspected cause and effect (MacMahon and

Pugh, 1970).

Prospective studies of upper extremity CTDs have not been reported in the literature. Prevalence and case-control designs have been employed in studies of cumulative trauma disorders in industrial groups to generate hypotheses in this relatively new area of epidemiologic investigation.

The emphasis of this review is to address the following points:

1. What health endpoints have been associated with cumulative trauma and how can they be ascertained in studies of industrial populations?
2. How common are these disorders in industry?
3. What exposure measures are important to ascertain?
4. How have potentially important confounders and effect modifiers been addressed in these studies?

Four basic approaches have been used to identify health effects and occupational exposures in the cross-sectional and case control studies reviewed. Type I studies have concentrated on relatively rigorous definitions of health effects (primarily degenerative joint changes) and less precise measures of exposure. Type II studies have utilized variations of postural discomfort or symptoms as a measure of health effect and more precise measures of exposure. Type III studies have used existing plant records to measure health effect and a variety of techniques to measure exposure. Type IV studies have used clinical criteria to evaluate primarily soft tissue health effects and more precise measures of exposure including detailed analysis of specific jobs.

2.3.1 Examples of Type I Studies

A number of industrial populations were surveyed by the British Industrial Survey Unit of the Arthritis and Rheumatism Council in the

1950s-1960s, including dock workers, civil servants, miners, foundry workers and cotton operatives (Lawrence and Aitken-Swan, 1952; Partridge and Duthie, 1968; Anderson and Duthie, 1963; Lawrence, 1961; Partridge et al 1968; Duthie and Anderson, 1962). Health effects were determined by clinical examination including x-rays of hands, feet, cervical, dorsal and lumbar spine. Disorders of interest were primarily degenerative joint disease of the spine and limbs, and rheumatoid arthritis. Soft tissue disorders were of secondary interest. Peripheral neuropathies were not investigated.

Positives were those who met pre-determined criteria. "Rheumatic complaint" was defined as persistent or recurring musculoskeletal pain without immediate traumatic cause. Those with pain at the time of interview or during the previous year were "positives" and those who had symptoms only prior to one year were "intermediates". Those with Heberden's nodes but without generalized changes were described as localized osteoarthrosis (LOA). Chronic tenosynovitis was defined as a history of continuous or intermittent pain on movement of a tendon within its sheath or on pressure over the sheath for at least 6 weeks. Chronic tenosynovitis and bursitis were grouped as "other specified rheumatic conditions" (Anderson, 1972).

Combined results for 2,684 males from the various studies indicated a marked increase in LOA from 2.49% at 25-34 years of age, to 12.26% at 55+ years. A much less dramatic increase was observed for "other rheumatic diseases,": 3.53% at 25-34 years to 4.03% at 55+ years. This suggests that age may not be an important factor in tendon related disorders. However, among civil servants (Partridge and Duthie, 1968), an increase in "other rheumatic conditions was observed

with increasing age: 2.2% at 35-44 years to 11.1% at 55+ years. Among dockyard workers, the prevalence decreased slightly from 25-34 years (3.8%) to 55+ years (1.5%). Civil servants also tended to have more neck and shoulder girdle pain than dockyard workers (13.8% versus 8.3%) with no apparent age trend. Partridge and Duthie suggested working posture among civil servants as a possible explanation of the difference. Generalized osteoarthrosis increased with age in all populations.

The majority of these studies were conducted among males. Lawrence (1961) reported results for both male and female cotton operatives 45+ years of age and their controls for osteoarthrosis. Heberden's nodes were present in 38% of male and 35% of female cotton operatives compared to 12% and 22% among respective controls. DIP, PIP and first CMC joint involvement was more frequent in male cotton operatives than their controls. Female cotton operatives had similar patterns of joint involvement but did not differ significantly from controls. One of the difficulties noted in this study was that of finding appropriate control populations. One-third of the males in the general community were coal miners, an occupational group among whom elevated prevalences of osteoarthrosis had been reported. Occupations of female controls were not discussed.

Exposure was measured by the Industrial Survey Unit using the BAHLPS system (back, arms, hands, legs, posture, site) which graded the effort exerted by the body part and the environmental temperature (Anderson, 1972, 1974). Increased effort was associated with some rheumatic diseases including chronic tenosynovitis and bursitis. The major limitation of these studies was that occupation rather than

specific work tasks was used to classify exposure.

Lockshin et al (1979) conducted detailed clinical evaluations for the prevalence of rheumatoid, gouty and degenerative arthritis among miners and non-miners. No significant differences were observed. The imprecision of the exposure classifications may have masked any positive occupational associations.

Brown and Lingg (1961) investigated the prevalence of rheumatic complaints among New York Consolidated Edison employees reporting musculoskeletal complaints to the company medical bureau. Cases were classified by the criteria of the American Rheumatism Association. There was no significant gender difference in the incidence of rheumatic complaints (15% males and 16% females). However, incidence of rheumatic complaints increased with age for both sexes (11% males and 10% females less than 40 years, 17% males and 19% females more than 40 years).

Imprecise exposure categories, similar to those of the British studies, were used. No relationship between rheumatic complaints and increased work stress among males was observed. However, females in the light indoor category had a significantly elevated prevalence of subdeltoid bursitis and bicipital tendinitis (3.7%). Upon closer examination, it was noted that females in this category were engaged in typing, keypunching and filing tasks. The prevalence of these disorders was similar among males and females performing these tasks. This finding suggests the need for more precise exposure measurements to detect differences, particularly a refinement of "light" work.

Hadler et al (1978) conducted a study of hand and wrist degenerative joint disease among active Virginia female worsted mill

workers with at least 20 years on one of three jobs (spinners, burlers, winders). Measures of health effects included a questionnaire (not described) and clinical examination (range of motion and joint measurements) and x-rays of the hands and wrists.

Measurement of exposure is not completely described. Task description was performed by a ergonomist who observed the jobs. Significant increased impairment of both wrists was noted among winders (143-144 degrees flexion-extension versus 151-154 degrees) whereas increased second and third digit joint radiographic changes were noted on the right hand among burlers and spinners. Analysis of the jobs indicated that winders used bilateral wrist motions with power grips and little fine finger movement whereas the other jobs required primarily right first to third digit movement. These patterns of DJD correlated well with the different patterns of hand usage among these workers. This study demonstrates the need for detailed task analysis to identify specific occupational risk factors that may be associated with specific disorders.

While these Type I studies were concerned primarily with degenerative joint disease, many of the investigators note the importance of more precisely defining exposure to estimate the influence of occupational factors on various disorders. However, precise diagnostic categories, particularly for non-articular "rheumatic diseases," may not be as important as the location of the disorder. Neck and shoulder girdle pain among civil servants (Partridge and Duthie, 1968) and shoulder disorders among clerical workers (Brown and Lingg, 1961) indicate that a closer look at "light work" is in order.

2.3.2 Examples of Type II Studies

A number of studies have used variations of Corlett and Bishop's Postural Discomfort technique (1976) to assess the effect of various sustained or repetitive tasks. The assumption is that pain or discomfort is a precursor to disease and disability. In addition to an overall discomfort rating, the technique included body diagrams on which workers are asked to indicate painful areas using a 7 point scale for each area. The localized postural discomfort technique has been well correlated with functional anatomical and electromyographic studies of muscle load (Kourinka, 1983; Lee and Wu, 1984; Hagg and Suurkula, 1984). The technique has been used for pre and post evaluation of job modifications among spot welders (Corlett and Bishop, 1976), office workers (Webb et al, 1984) and shoe assemblers (Drury and Wick, 1984). A variation of this approach was reported by Wells et al (1983) who used telephone interviews to assess musculoskeletal complaints of letter carriers and two reference populations.

In an intervention study in the shoe industry, Drury and Wick (1984) used the Corlett and Bishop technique to evaluate pre and post job modification results. Jobs were videotaped and later analyzed for task and posture. Force was determined by estimating compressive forces on spinal disks calculated by body angle and by weighing objects. Postural analysis of the upper extremity was similar to that described by Armstrong et al (1982). Repetitiveness was estimated as the number of times a motion occurred. Results were presented as the frequency of "pathological combinations" for the upper extremity such as each task element where wrist deviation with a pinch occurred. Both job analysis and postural discomfort ratings were performed before and after

modification. Postural stresses and discomfort scores were reduced considerably after modification. Local body discomfort ratings were used to make further job modifications where necessary.

Karlqvist (1984) expanded the postural discomfort technique in a study of 118 Swedish female fish canning bench operators. Evidence of acute trauma of the hands and forearms (carving scars, etc.) were recorded by an industrial nurse. All hands were copied in real size on paper. Workers marked injuries as well as areas of subjective complaints including pain, ache, numbness or tingling.

Exposure measurements included analyzing videotapes of the jobs for knife holding positions, movement patterns and types of grasps. Results were not stratified by age or years on the job. The most complaints were in the knife holding hand: the wrists were the most likely to have pain, swelling and stiffness; neurological symptoms were most prevalent in the knife holding hand especially the thumb and index finger. For example, 67% of the workers identified problems with the right index finger versus 11% with the left index finger. Job factors associated with these symptoms included: ulnar deviation with the thumb pushing down on the knife, high workload of the finger flexors, wrist flexion and muscle strain in the arms and shoulders. New knives were developed and pilot tested to facilitate less stressful working postures. Preliminary followup reports by workers indicated decreased fatigue and an unwillingness to return the new knives.

These studies demonstrate the usefulness of questionnaires to identify jobs requiring ergonomic intervention. However, it remains unclear whether discomfort leads to CTDs.

2.3.3 Examples of Type III studies

Common industrial sources of health effect information include OSHA 200 logs, worker's compensation and insurance claims, and plant medical records. There are inherent biases in each of these which limit their usefulness in studies of upper extremity cumulative trauma disorders. Entries into OSHA logs, by law, must include disorders "believed to be associated with repetitive trauma" if they involve restriction of work or motion, transfer to another job or more than first aid treatment. But there is no definition or general agreement as to what constitutes repetitive motion disorders or first aid, and therefore inconsistent reporting may exist. The worker's compensation system is an adversarial process which may result in distortions in reporting and acknowledgement of claims which bears little relationship to objective medical evidence. Plant medical records vary in quality and may reflect selective reporting of workers to the plant medical departments for a variety of reasons. Worker utilization of outside medical resources for health care may lead to underestimates of prevalence based on plant medical records. In case control studies, this may result in classifying some with CTDs as controls.

Company data often available for exposure classification include department or job classification. Misclassification of exposure (job of onset versus current job) or imprecise measures of exposure (departmental rates versus rates for jobs in different departments with the same work attributes) are potential problems. The limitations of these data sources are demonstrated in a case control study of carpal tunnel syndrome among aircraft engine manufacturing employees (Cannon et al, 1981). Cases were ascertained from workers compensation records and medical department memory whereas controls were chosen from the

rest of the plant population without any screening measures to insure that they were without carpal tunnel syndrome. Imprecise exposure measures weaken the findings of increased risk of carpal tunnel syndrome with bilateral oophorectomy, use of vibrating tools and repetitive motion tasks.

Despite the inadequacies of using these types of secondary data, they have sometimes been used to identify clusters of CTDs for ergonomic evaluation. Examples of studies using plant health records to target specific jobs for ergonomic investigations include those of Hymovich and Lindholm (1966), Ferguson (1971), Wherle (1976), Rabourn, 1977; Armstrong and Chaffin (1979), Armstrong et al (1982). When plant records are used to look for associations between specific disorders and more generalized exposure measures, the adequacy of plant health records becomes more critical because there is already considerable misclassification.

Kvarnstrom (1983) used plant medical records to identify cases and controls in a study of shoulder disorders in a Swedish electronics plant. Cases were defined as those who: 1) had shoulder problems limiting their ability to work, 2) were off work more than four weeks, 3) had pain or excessive fatigue aggravated by their work , and 4) had shoulder tenderness on clinical examination. Controls were randomly selected from company factory workers matched for age and sex. Interviews were conducted to gather information regarding onset, amount worked, physical and psychosocial workload and environment, social and ethnic conditions, and past work history. Shoulder muscle strength was measured with strain guages at least one year after reporting symptoms by cases.

Company engineers graded jobs of onset (or job during the same time for the controls) for degrees of monotony and repetitiveness. This included flexibility of the job, degree of job enrichment and other non-described items.

Cases had significantly more repetitive and monotonous work and less strength than controls. In a case control study, it is difficult to determine whether decreased muscle strength in cases was a cause or an effect of the shoulder disorder. Female sex and immigrant status were associated with disease and exposure. The frequency of shoulder disorders was higher in 25-47 year old females than older women, perhaps a survivor effect. There were no differences in well-being or psychological content of work, previous work history, or height. The author concluded that a static tension in the shoulder stabilizing muscles over excessively long periods while performing repetitive hand work was found to be a main cause of the syndrome.

The utilization of plant records in this study may be less problematic than in most US investigations because health care in Sweden is integrated into one system. While the findings are strengthened by analyzing job attributes rather than broad occupational classifications, a more detailed description of the exposure measurements would have strengthened the conclusions.

2.3.4 Examples of Type IV Studies

Herberts and Kadefors (1976, 1981) compared the prevalence of shoulder disorders among male shipyard welders and male office clerks. Questionnaire interviews were used. Workers with shoulder pain, stiffness and/or weakness that interfered with work, and an equal number responding negatively, were invited to participate in clinical

examinations. Clinical examinations were not performed until a year after questionnaires and included: inspection, palpation, gross muscle strength using a dynomometer and active, passive and resisted motion testing. Previous ergonomic evaluation, using electromyography, of overhead welding jobs had been performed by the investigators (Herberts and Kadefors, 1976). No evaluation of clerk jobs was reported.

While this study suggests overhead welders are at a significantly greater risk of having shoulder tendinitis, it suffers from the following weaknesses: 1) not all welders and clerks received clinical evaluations; 2) differential criteria for entry into the study were used (welders with more than 5 years work, clerks more than 39 years of age); 3) no ergonomic evaluation of clerk jobs appears to have been performed; 4) 34% of welders were lost to followup clinical examinations; 5) the one year time lag between questionnaire and clinical examination may have diminished the associations. In general, the limitations would tend to minimize positive associations.

Bjelle et al (1979) studied 20 male industrial workers with prolonged shoulder pain of more than 3 months and their controls during a one year period. Cases came from 3 machine shops, 2 pulp mills and a saw mill and were seen initially by the same physician. Controls were selected from manual workers in the same plants as the cases and matched on age and sex. Physical examination of the cases included grip strength, routine blood and urine tests. Patients were then referred to the rheumatology outpatient clinic for extensive evaluation.

Health care personnel, knowledgeable of the workplaces, interviewed subjects to determine physical workload and working height

of the hands. Three cases had related systemic diseases and were excluded. Twelve of the remaining 17 cases had bicipital or supraspinatus tendinitis. Mean grip strength of cases was significantly lower than controls. There was no difference in previous or current physical workload levels. Work at or above acromion height was significantly higher for cases than controls.

The conclusion that heavy work at or above acromion height is a risk factor for prolonged shoulder problems is weakened by 1) informational bias due to possible differential treatment of subjects (no indication that controls received the same examination) and 2) potential observer bias when subjects were classified into exposure groups by those knowledgeable of their health status.

Bjelle et al (1981) conducted another case control study of acute shoulder/neck disorders in a Swedish truck cabin manufacturing company where major jobs included assembly, press and welding operations. Cases were 20 consecutive workers attending the industrial health center for the first time with acute shoulder/neck pain. Each patient received a detailed clinical examination, laboratory tests and x-rays. On the same day anthropometric measures and isometric muscle strength was assessed in various shoulder/elbow postures with strain guage instruments. Athropometric measurements and strength testing were determined for controls as well.

Seven of the 20 cases were classified as "diseased cases" (congenital malformations, arthritis, post-infection syndromes). Two controls for each of the remaining 13 cases were matched on age, sex and place of work (factory halls). There was no indication that controls had a clinical examination which might have ruled out any

unreported shoulder/neck disorders.

Non-diseased cases had primarily right sided supraspinatus tendinitis. Muscle tenderness was found in all but one. Anthropometric data were not significantly different between cases and controls. Isometric strength was stronger among controls in some of the tests performed.

Exposure data was based on biomechanical analysis and electromyography (EMG). The duration and frequency of shoulder abduction or flexion of more than 60 degrees was measured by a laboratory assistant blinded to health status. All non-diseased cases had work tasks demanding their hands at or above acromion height and had significantly longer duration and higher frequency of right and left abduction and flexion compared to controls. EMG analysis showed a significant decrease in mean power frequency in the suparaspinatus muscle over one-hour recordings in 4/5 of assemblers evaluated indicating fatiguing muscle processes. The authors suggest cumulative ischemic trauma, as evidenced by EMG and muscle enzyme data (transitory increases in aldolase, creatine kinase or both), as the important etiological factor related to exposure.

The major potential weakness in this otherwise convincing study is that controls may not have had the same screening examinations as cases to determine if they were in fact controls.

Falck and Aarnio (1983) evaluated carpal tunnel syndrome (CTS)in 17 of 19 eligible butchers working in two Finnish slaughter houses. All subjects were right handed and had no systemic disease or relevant injuries. Symptom questionnaires, clinical examinations (Phalen's test, Tinel's sign, cuff test, body mass index), and bilateral ulnar

and median sensory nerve conduction velocities (NCV) were measured using a standard protocol. Nine (53%) had subjective symptoms and positive NCV findings on the nondominant left side. Those that had bilateral CTS were more severely affected on the left, except one case. Clinical tests correlated poorly with symptoms and NCVs. This suggests that interview data alone may be sufficient to detect carpal tunnel syndrome. Positive findings were not associated with age or body mass index. The butchers felt that the load on the left hand was much greater than on the right hand. When jobs were analyzed, it was found that the right hand holds the cutting knife while the left hand holds and turns the carcass and tears the hide off.

Waris et al (1979) developed a screening tool for use in epidemiologic studies of occupational upper extremity disorders. Specific diagnostic criteria based on interview and non-invasive clinical examination were determined. The exam consisted of inspection; palpation; passive, active and resisted range of motion tests and hand grip strength in several positions. All test results (except hand grip) were recorded as negative or positive. Each record was later analyzed and compared to the predetermined criteria to ascertain the presence of a disorder. Interviews, conducted after the examinations, pertained to history of previous diseases, outside activities, and subjective symptoms. This screening tool was used in several Finnish industrial studies.

Kuorinka and Koskinen (1979) used the screening tool in a prevalence study of workers in a scissor making factory. Temporary workers and those with recent trauma were excluded. Data from both screening and work evaluations were available for 93 workers (90 female

and 3 male). The overall prevalence of tension neck syndrome was 61% and of wrist muscle-tendon disorders was 18%. No age association was observed for either of these disorders. No distinction was made between sexes because the vast majority of subjects were females.

There was a 10 month delay between job evaluation and screening evaluation of workers. Two types of work related data were collected. First, relatively complete production data for the previous year was available for 76 workers. Second, videotaping and observation of workers were used to estimate repetitiveness and wrist posture. The amount of time per cycle in which wrist deviation of more than 20 degrees occurred was multiplied by the the number of cycles per hour times the number of hours worked in the previous year. This was used as an index of wrist load. Task variables included cycle time (short and long), inspection or manipulation type of task, and wrist deviation index. These were summarized by specific jobs. There were no significant differences observed in task variables for those with and without these disorders. The number of symptoms increased as estimated parts per year increased. Hand posture was not included in the wrist load index. There is no indication of whether changes in work methods took place in the 10 month interval between job and health evaluations.

Luopajarvi et al (1979) used the same screening tool to compare the prevalence of upper extremity disorders in female assembly line packers to that of female shop assistants (excluding cashiers). Every workplace was ergonomically analyzed by a team of foreman, worker, labor safety officer and occupational physiotherapist (measures not specified). Jobs were videotaped and evaluated by a physician and work study engineer.

Significantly more shop assistants were classified as non-diseased than packers (63% versus 30%). Packers had significantly higher prevalences of shoulder disorders (12.5% versus 3.8%) and hand/wrist disorders (56% versus 14%). Packers had significantly more extensor than flexor tenosynovitis. Common job factors identified among packers, but not among shop assistants were: 1) repetitive finger and hand motions at high speeds; 2) static muscle loading; 3) extreme hand postures; 4) lifting 5,000 Kg average per day in some tasks; 5) use of non-fitting gloves. Exposure measurement methodology is not well described in this report.

Viikari-Juntura (1983) utilized the screening tool described by Waris (1979) in a prevalence study of slaughterhouse workers. An additional clinical examination was also employed. Of the 113 workers (52 cutters, 38 butchers, 23 byproduct workers), 82 were males. Mean age was 30.1 for males and 36.1 for females. Mean length of employment was 5.5 years.

At the end of the screening examination and interview, the subject used a diagram to shade in the areas of pain experienced in the previous 24 hours. The screening diagnosis was used if it did not conflict with the drawing. The clinical examination involved non-invasive neurological testing as well as many of the same tests used in the screening examination. Diagnostic criteria for the clinical examination was not as restrictive as for the screening examination and identified 20 more cases.

More females (58.1%) reported neck and shoulder symptoms in the previous 12 months than males (45.7%). However, the prevalence of hand and forearm symptoms in the preceding 12 months was similar (61.3% and

59.3%, respectively). Fifteen men (13.3%) reported physician diagnosed tenosynovitis or peritendinitis in the preceeding 12 months, 12 of the men were under 30 years of age and all were butchers or cutters.

Prevalences of clinically diagnosed tension neck (6.2%) and tenosynovitis (4.4%) were much lower than in the populations reported by Kourinka and Koskinen (1979) and Luopajarvi (1979). The author suggests that high selection/ survival factors among workers; and a recent labor management dispute (2 weeks before the study) which had just reduced the workload by 25%, as possible explanations. Additionally, while noting that the clinical examination could not be used as a test of the validity of the screening examination because both used many of the same procedures, the author believes that "softer" criteria should be used in epidemiologic screening so that disorders can be detected at an earlier stage.

2.4 Summary

The incidence and prevalence of upper extremity CTDs in US industrial populations have not been well documented. Many of the clinical and case study reports suggest that factors such as forceful or repetitive work, awkward postures and vibration may lead to a variety of occupational cumulative trauma disorders. However, in uncontrolled clinical studies which include only patients who seek medical attention, the result may reflect Berkson's fallacy (Fleiss, 1981). This selection bias may result in unfounded risk factor hypotheses.

A number of potential confounders or effect modifiers were identified in the clinical literature and to a lesser extent in the epidemiologic literature. These include:

1. Sex. Several studies have indicated that females are at a higher risk than males for carpal tunnel syndrome as well as rheumatological conditions (Linos, 1980; Hochberg, 1981; Armstrong and Chaffin, 1979; Phalen, 1972; Kendall, 1960; Tanzer, 1959).
2. Age. A number of articular disorders have been associated with advancing age (Hochberg, 1981; Linos, 1980; Allander, 1974; Lawrence, 1961; Anderson, 1974; Partridge and Duthie, 1968).
3. Prior Injuries. A previously fractured finger or wrist may prevent full range of motion. A whiplash may precipitate symptoms of thoracic outlet syndrome (Roos and Owens, 1966).
4. Chronic Diseases. A number of disorders may present assymptoms of CTDs. For example, rheumatoid arthritis, systemic lupus erythematosus, Reiter's syndrome, ankylosing spondylitis, Crohn's disease and gonorrhea may present with pain and swelling of the joints and in some cases consequent peripheral neuropathies (Phalen, 1972; Lister, 1984). Diabetes mellitus, chronic alcoholism or a ruptured disk may be manifested in peripheral neuropathies (Cyriax, 1978). Gall bladder disease, angina pectoris and myocardial infarction may be manifested in referred shoulder and arm pain (Cailliet, 1981).
5. Reproductive history. Pregnancy, use of oral contraceptives and bilateral oophorectomy have been reported to be associated with carpal tunnel syndrome among females (Sabour and Fadel, 1970; Wilkenson, 1960; Kendall, 1960; Bjorkvist, 1977; Cannon, 1981).
6. Sports and Hobbies. Non-work activity may lead to or exacerbate CTDs. For example, lateral epicondylitis may be related to regular tennis playing (Conrad and Hooper, 1983).
7. Prior Job. CTDs may have occurred prior to the current job.

Prevalence studies of rheumatic complaints (Type I) conducted among industrial populations indicate that degenerative joint changes increase with age (Anderson, 1972); that females tend to have more changes in digital joints than males (Partridge and Duthie, 1968); and that specific patterns of joint degeneration may be associated with specific patterns of usage (Hadler, 1978). No clear age or sex pattern was noted with soft tissue disorders. However, when specific jobs were isolated from broad occupational categories, associations with soft tissue disorders were observed (Brown and Lingg, 1961). However, for the most part, these studies have focused on joint changes and broad exposure definitions rather than specific job attributes.

Type II studies, concentrating primarily on ergonomic assessment and intervention, have presumed that pain or discomfort was a result of the specific job rather than external factors. Rarely have potential confounders or effect modifiers been addressed in these studies.

Type III studies, utilizing existing plant records, have generally neglected to evaluate the quality of medical data upon which their findings rest.

To date, Type IV studies present the most potential to assess associations between defined health effects and defined job attributes. The majority of Type IV studies used either direct observational or videotape analysis of specific jobs for estimates of exposure. Electromyography was used to estimate forceful exertions about the shoulder in some of these studies but was not used to estimate forceful exertions about the wrist. Armstrong, et al (1982) have successfully used electromyography to estimate forces about the wrist in Type III studies. The prevalence of hand/wrist disorders varied from 4.4% among

slaughterhouse workers (Viikari-Juntura, 1983) to 56% among assembly line packers (Luopajarvi et al, 1979).

With the exception of Viikari-Juntura (1983), the Type IV studies have been conducted largely among study populations of one gender or the other. Viikari-Juntura found no significant gender differences in the prevalence of these disorders. No apparent age trend has been identified with the soft tissue disorders whereas a clear increase in prevalence is seen with increasing age in degenerative joint disorders. Recreational activities did not appear to be an important factor in any of the studies that investigated these factors. Differences in prevalence of hand/wrist CTDs reported by Luopajarvi (1979) and Kourinka and Koskinen (1979) may be a result of differences in types of jobs studied, job analysis methods, individual characteristics or other unknown "plant" factors. This "plant effect" is not addressed by either of these studies. Viikari-Juntura (1983) suggests plausible "plant effect" factors which may explain the low prevalence of disorders observed among slaughterhouse workers, including a "survivor effect" and recent changes in production.

There have been no Type IV studies reported among US industrial populations. An important step in continuing this work is a carefully controlled study in which subjects are chosen solely on the basis of the types of tasks they perform and without knowledge of health status. Standardized ascertainment of symptoms, potential confounders and clinical findings (performed blinded to subject tasks) and concomitant standardized ergonomic assessment of those tasks, will provide insight into the relationship between these disorders and potential risk factors in US industrial workers.

CHAPTER 3

MATERIALS AND METHODS

The objective of this investigation was to estimate the prevalence of upper extremity cumulative trauma disorders (CTDs) among active workers, who worked at least one year on jobs that required one of four specific hand/wrist force and repetitiveness attributes:

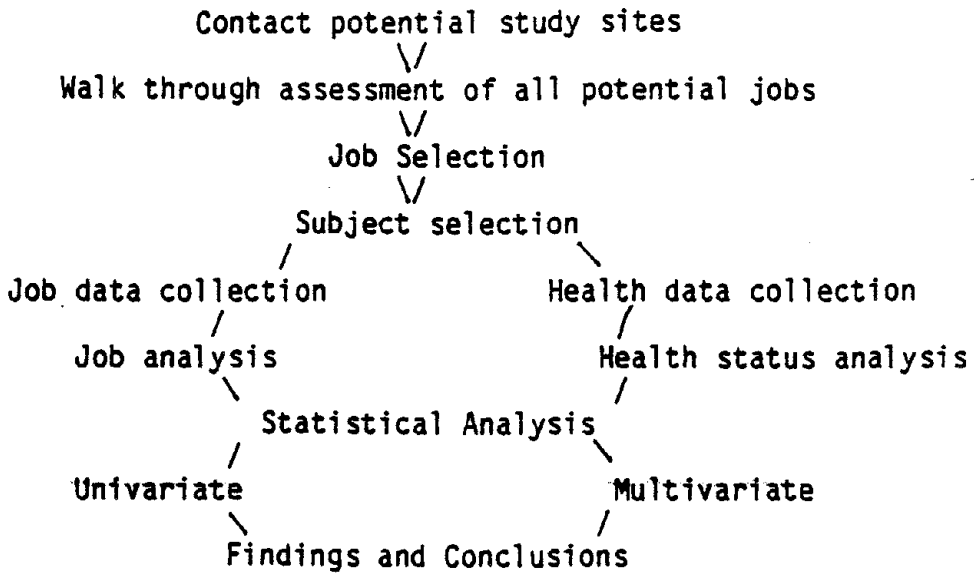
1. low force-low repetitiveness (LOF.LOR)
2. high force-low repetitiveness (HIF.LOR)
3. low force-high repetitiveness (LOF.HIR)
4. high force-high repetitiveness (HIF.HIR).

The low force-low repetitiveness (LOF.LOR) category served as an internal comparison population for the other three categories (exposed). Odds ratios were used to estimate risk of CTDs in the exposed categories compared to the unexposed category (LOF.LOR). The null hypothesis was that of no association between CTDs and exposure. The final study population included 574 active workers from six different industrial plants.

A simplified flow chart of the study is presented in Figure 3.1

FIGURE 3.1

FLOW CHART OF THE STUDY DESIGN



3.1 Site Selection

Approximately 20 plants were contacted for possible participation in the study. Six plants were selected based on these criteria:

1. At least one job for each exposure category with approximately 20 workers performing each job
2. Stable employment and production patterns over the previous two years
3. Plant willingness to release employees for health evaluation
4. No active labor-management disputes in progress.

Seven plants did not have enough workers performing the same job in each of the four exposure categories. Two plants were concerned that the study might result in increased workers compensation claims. Three plants had extensive administrative delays and two plants were in the process of changing product lines.

Of the seven plants that participated in the study, three had previous relations with the University of Michigan Center for Ergonomics. Contact with the other three plants was made through a State Health Department, an International Union, or plant Industrial Engineering's request to participate. Table 3.1 presents the type and size of the 7 participating plants and jobs studied.

TABLE 3.1

STUDY JOBS SELECTED BY PLANT

Plant 1. Electronics Assembly, Southern USA, 6000 employees

LOF.LOR: 664Board- insert wires into circuit boards *
Solder Touchup- solder and repair circuit boards
HIF.LOR: Mold Housing- unload parts from injection molding
Automatic Press- load and unload presses
LOF.HIR: Eyeletting- feed small parts into punching machine
Drill & Tap- feed plastic parts into thread machine
HIF.HIR: Buffing- use stationary buffing wheel to polish product
Mold Handles- load and unload presses, knock out excess parts *

Plant 2. Major Appliance Manufacture, Midwest USA, 1600 employees

LOF.LOR: Inspector- use guages to check parts specification
HIF.LOR: Auto Screw Machine- load and unload steel rods
LOF.HIR: Punch Press- load metal blanks into punch press *
HIF.HIR: Hanger- transfer parts to and from moving racks (89:lids,* 48:motor parts)

Plant 3. Investment Casting, Midwest USA, 2,200 employees

LOF.LOR: Wax Assembly- assemble clusters of wax impressions
Gauging- guage parts to check specifications
HIF.LOR: Wax injection- remove formed wax parts from dies
Ceramic Press- load and unload ceramic inserts
LOF.HIR: Mounted Point- fine grind small ceramic parts
Belt Sander- use small wheel to sand metal part
HIF.HIR: Burr Bench- use small hand grinder to remove burrs *
Cutoff- use stationary cutting wheel to disassemble castings

TABLE 3.1
(continued)

STUDY JOBS SELECTED BY PLANT

Plant 4. Apparel Sewing, Southeast USA, 650 employees

LOF.LOR: Supervisor- supervise sewing and material handling
HIF.LOR: Material Handler- load/unload warehouse material
LOF.HIR: Hem Legs- use power sewing machine to hem pantlegs *
HIF.HIR: Belt Loops- use machine to attach loops to waist band *

Plant 5. Ductile Iron Foundry, Southeast USA, 1500 employees

LOF.LOR: Control Panel Operator- control materials flow
HIF.LOR: Hutchinson Machine Operator- shell making for castings
LOF.HIR: Core Cleaner- file excess off cores
HIF.HIR: Stationary grinder- grind sprue off casting
Hand Grinder- use small hand grinders to remove sprue from casting

Plant 6. Bearing Manufacture, Midwest USA, 370 employees

LOF.LOR: Staff- office and supervisory personnel excluding typists
HIF.LOR: Auto Screw Machine- load steel rods into machine
LOF.HIR: Plunge Grind Operator- load/unload small shafts in automatic grinding machine *
HIF.HIR: Water Pump Assembly- place and space balls into bearing rings and assemble

Plant 7. Bearing Manufacture, Midwest USA, 500 employees

LOF.LOR: Plater: monitor and maintain plating tanks
HIF.LOR: Plater helper - place bearings in racks and move to plating machine
LOF.HIR: Manual Machine Operator: insert individual bearings into machine and operate*
HIF.HIR: Automatic Machine Operators: transfer group of bearings into conveyor for machining*

* changed exposure categories with detailed job analysis (Table 4.5)

3.2 Job Selection

At least one job for each category was selected per plant. At each plant, management was asked to provide a list of all employees, their social security number, birthdate, seniority

date, sex, department and occupational code. Those occupational codes which had approximately 20 or more workers were abstracted from the employee roster. Exclusion from potential job selection included newly introduced jobs (within the previous two years). A preliminary analysis of them was performed to assess job force and repetitiveness attributes for final job selection. The preliminary job analysis was performed by project investigators blinded to worker health problems.

Repetitiveness was measured in terms of the percentage time spent doing the same task and the time to complete the task, called the cycle time. In cases where the same set of motions or work elements was repeated, the amount of time spent performing the fundamental cycles was used.

Cycle times were measured, in some cases, by observing the jobs as they were performed by experienced workers. This was usually done from video tapes to minimize disturbances in the plants. Area supervisors were asked to recommend experienced operators for study. In other cases, work standards and production records were used to estimate cycle times for the preliminary analysis. Jobs were classified initially as low repetitive if the cycle time was more than 30 seconds or if less than 50% of the cycle time involved performing the same kind of fundamental cycle. Jobs were classified as high repetitive if their cycle time was less than 30 seconds or if more than 50% of the cycle time involved performing the same kind of fundamental cycle.

Forcefulness was estimated from the weight of tools and parts or from the effort that the workers appeard to exert. In some cases, surface electromyography as described by Armstrong et al. (1979) and Armstrong et al. (1982) was used. Jobs were classified initially as low force if their peak force requirements were less pounds or less. Jobs were classified as high force if there peak force estimate was ten pounds or greater.

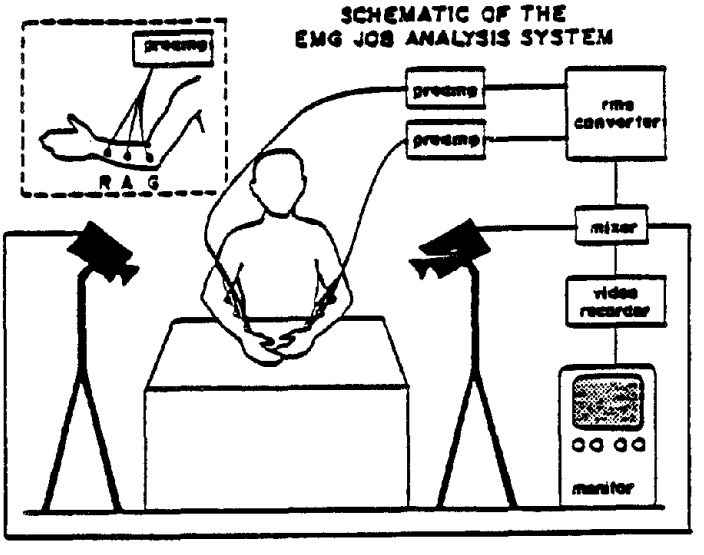
All jobs meeting one of the four category criteria were then listed within each category. Job selection was determined by choosing the most extreme within the category to maximize between category differences. For example, if two jobs met the criteria for low force-high repetitiveness, the job that was the most repetitive was selected. After the preliminary job analysis and final job selection was completed a second, more thorough, analysis was performed to further quantify the job forcefulness, repetitiveness and postural attributes.

3.3 Job Analysis

A second job analysis was performed to verify the initial exposure classification of jobs based on the preliminary job analysis and to determine the job postural attributes. At least 3 workers in each selected job were videotaped performing the job for at least 3 cycles. Signal generators displaying time, date, frame number and bilateral electromyographic (EMG rms) recordings were incorporated into the system's video mixer (Figure 3.2). The surface electromyogram was calibrated so that force could be estimated for all of the observed hand postures as described by Armstrong et al, (1979); and Armstrong et al., (1982).

The EMG system in this investigation (Figure 3.2) used three surface electrodes per arm (active placed on the belly of the flexor muscle; reference placed approximately two inches distal to the active; and a ground placed on or slightly above the medial epicondyle) attached to a pre-amplifier system placed on the arm (to boost the electrical signal generated by muscle activity). The pre-amplifier is connected through a flexible cable to a low pass filtering amplifier and Analog Devices integrated circuit board (true rms to dc converter). The root mean square value (integrated averaging of the signal over time) of the boosted EMG signal is digitalized and displayed through the video system as a bar graph.

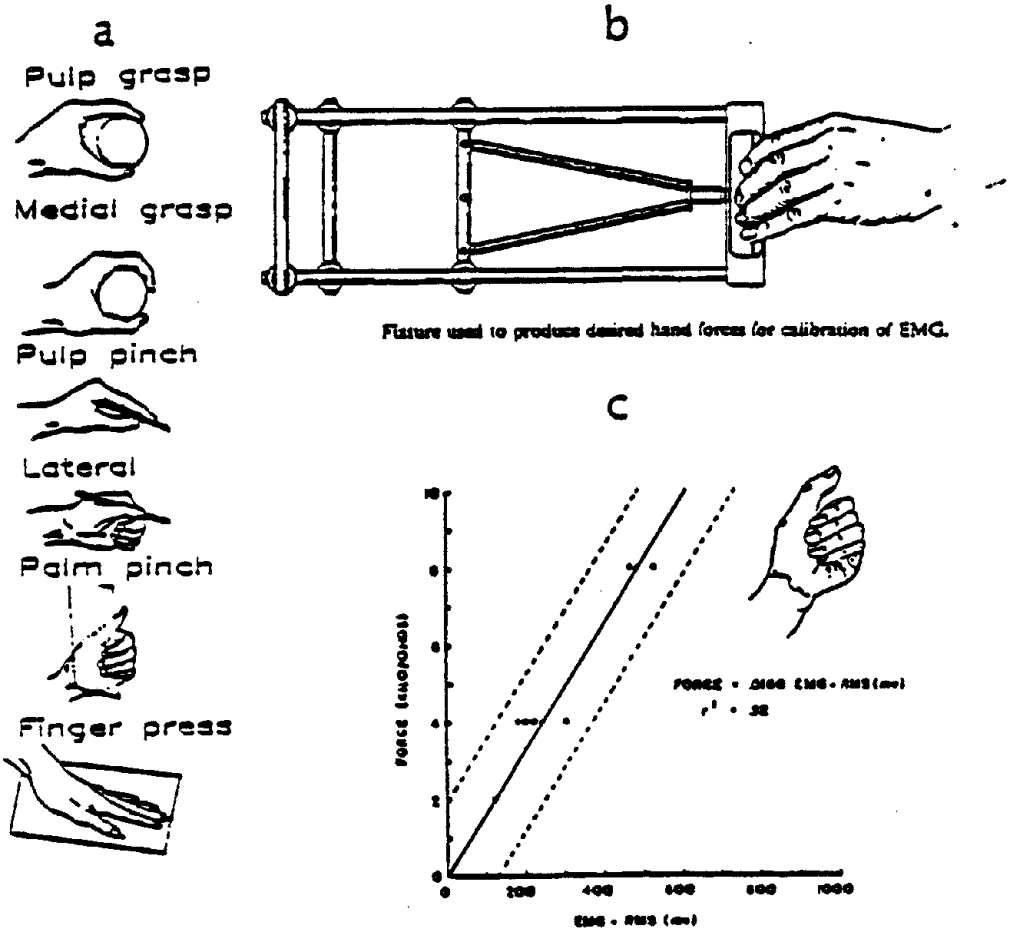
FIGURE 3.2



Calibration of EMGs to known forces was performed before and after the subject is filmed. The most frequent working hand postures or grips (6 different possible pinching or grasping postures are identified, Figure 3.3a) are used with a spring fixture with known force levels (Armstrong, 1979; Figure 3.3b) to calibrate the EMG recordings. An example of a typical calibration plot is illustrated in Figure 3.3c (Armstrong, 1979).

FIGURE 3.3 EMG CALIBRATION

a) hand posture b) known force c) calibration curve



(Adapted from Armstrong et al., 1979, 1982)

3.3.1 Repetitiveness

A stopwatch was used to estimate mean time for three cycles. A traditional industrial engineering work methods procedure was used to analyze the work content (Barnes, 1972). Each task was described as series of steps or elements as by Barnes (1972). Sequences of elements that repeated were defined as fundamental cycles. The percent of cycle time spent performing the fundamental cycles was estimated. Example of this procedure is shown in Table 3.2 for the Drill and Tap job at Plant 1 and and in Table 3.3 for the Belt Sand job at Plant 3. The Drill and Tap job involves only one task and has a cycle time of 1.67 seconds; therefore it meets the high repetitive criteria. The Belt sand job also involves only one cycle, but its cycle time is 41.5 seconds. It can be seen from the work analysis in Table 3.3, that 59% of the cycle consists of a repeating set of similar elements. The fundamental cycle time is calculated as 1.8 seconds. Thus the Belt Sanding job also meets the high repetitive criteria.

Several of the LOF.LOR jobs required multiple diverse tasks and had no defined cycles. These included plant 2 inspectors and plant 4 supervisors, plant 5 control panel operators and plant 6 staff. With these jobs, work sampling techniques were used to characterize these jobs (percent of time performing different tasks).

TABLE 3.2

ONE CYCLE OF DRILL AND TAPE (SUBJECT 1012)

	LEFT					RIGHT				
FRAME	ELEM	WRIST DEV	WRIST ANGLE	HAND POSIT	FRC KG	ELEM	WRIST DEV	WRIST ANG	HAND POSIT	FRC KG
70353	MOVE	NEU	NEU	P PNC	0.0	REACH	NEU	45F	IDLE	0.0
70373	RLSE	NEU	45F	IDLE	0.0	GRASP	ULN	NEU	P PNC	1.2
30393	HOLD	NEU	NEU	P PNC	2.8	POSIT	ULN	NEU	P PNC	1.8
70413	MOVE	NEU	NEU	P PNC	5.5	POSIT	ULN	NEU	P PNC	0.6
70433	HOLD	ULN	NEU	P PNC	2.8	MOVE	ULN	NEU	P PNC	1.2
70453	HOLD	NEU	NEU	P PNC	2.8	REL	NEU	NEU	IDLE	0.0

Average cycle time: 1.67 sec.

		LEFT	RIGHT
WRIST DEV	NEU	84%	33%
	ULN	16%	67%
WRIST ANG	NEU	84%	84%
	45F	16%	16%
HAND POSIT	IDLE	16%	33%
	P PNC	84%	67%
FORCE	AVG.	2.2	0.8
	ST.DV.	1.9	0.7
	ADJ.	3.9	1.3

TABLE 3.3

ONE CYCLE OF BELT SAND (SUBJECT 4022)

		LEFT				RIGHT				
CYC	FRAME	ELEM	WRIST DEV	WRIST ANG	HAND POSIT	FRC KG	ELEM	WRIST DEV	WRIST ANG	HAND POSIT	FRC KG
	212100	IDLE	NEU	NEU	IDLE	0.0	REACH	NEU	NEU	IDLE	0.0
	212120	IDLE	NEU	NEU	IDLE	0.0	GRASP	NEU	NEU	PGRSP	0.3
1	212140	IDLE	NEU	NEU	IDLE	0.0	MOVE	NEU	NEU	PGRSP	0.3
1	212202	GRSP	NEU	NEU	LPNC	1.3	POSIT	NEU	NEU	PGRSP	0.5
2	212220	MOVE	NEU	NEU	LPNC	1.3	MOVE	ULN	NEU	PGRSP	1.3
2	212240	POSIT	ULN	E45	LPNC	0.5	POSIT	ULN	NEU	PGRSP	0.4
3	212300	POSIT	ULN	E45	LPNC	0.8	MOVE	ULN	NEU	PGRSP	0.2
3	212320	POSIT	ULN	E45	LPNC	0.8	POSIT	ULN	NEU	PGRSP	0.2
4	212340	POSIT	ULN	E45	LPNC	1.0	MOVE	ULN	NEU	PGRSP	0.3
4	212400	POSIT	ULN	E45	LPNC	1.3	POSIT	ULN	NEU	PGRSP	0.3
5	212420	POSIT	ULN	E45	LPNC	1.5	MOVE	ULN	NEU	PGRSP	0.3
5	212440	POSIT	ULN	E45	LPNC	0.8	POSIT	ULN	NEU	PGRSP	0.3
6	212500	POSIT	ULN	E45	LPNC	1.0	MOVE	ULN	NEU	PGRSP	0.3
6	212520	POSIT	ULN	E45	LPNC	1.0	POSIT	ULN	NEU	PGRSP	0.3
7	212542	POSIT	ULN	E45	LPNC	1.0	MOVE	NEU	NEU	PGRSP	0.2
7	212600	POSIT	ULN	E45	LPNC	1.5	POSIT	NEU	NEU	PGRSP	0.2
8	212620	HOLD	ULN	E45	LPNC	1.0	HOLD	NEU	NEU	PGRSP	0.3
8	212640	MOVE	NEU	NEU	LPNC	1.8	MOVE	NEU	NEU	PGRSP	0.3
	212700	INSP	NEU	NEU	LPNC	0.8	INSP	NEU	EXT	PGRSP	0.0
9	212720	MOVE	NEU	E45	LPNC	1.0	MOVE	ULN	NEU	PGRSP	0.3
9	212740	HOLD	NEU	E45	LPNC	0.5	POSIT	ULN	NEU	PGRSP	0.2
	212801	MOVE	NEU	E45	LPNC	0.5	MOVE	ULN	NEU	PGRSP	0.3
10	212821	HOLD	NEU	E45	LPNC	0.8	HOLD	ULN	NEU	PGRSP	0.1
10	212841	MOVE	NEU	E45	LPNC	1.0	MOVE	ULN	NEU	PGRSP	0.2
	212901	HOLD	NEU	E45	LPNC	0.5	HOLD	ULN	NEU	PGRSP	0.1
	212921	INSP	NEU	E45	LPNC	0.8	INSP	NEU	EXT	PGRSP	0.1
	212941	MOVE	NEU	E45	LPNC	1.0	MOVE	NEU	EXT	PGRSP	0.3
11	213001	MOVE	NEU	E45	LPNC	1.0	MOVE	ULN	NEU	PGRSP	0.3
11	213023	HOLD	NEU	E45	LPNC	1.0	HOLD	ULN	NEU	PGRSP	0.3
12	213041	MOVE	NEU	E45	LPNC	1.3	MOVE	ULN	NEU	PGRSP	0.3
12	213101	POSIT	NEU	E45	LPNC	1.5	POSIT	ULN	NEU	PGRSP	0.3
	213121	POSIT	NEU	E45	LPNC	1.3	POSIT	ULN	NEU	PGRSP	0.1
	213141	HOLD	NEU	E45	LPNC	1.5	HOLD	I;M	MEI	PGRSP	0.3
13	213201	POSIT	NEU	E45	LPNC	0.8	POSIT	ULN	NEU	PGRSP	1.3
13	213221	MOVE	NEU	E45	LPNC	1.0	MOVE	NEU	EXT	PGRSP	0.3
	213241	INSP	NEU	E45	LPNC	1.0	INSP	NEU	EXT	PGRSP	0.0
	213301	MOVE	NEU	NEU	LPNC	1.8	MOVE	ULN	E45	PGRSP	1.2
	213321	MOVE	NEU	NEU	LPNC	1.7	RELS	NEU	NEU	IDLE	0.0
	213341	RELS	NEU	NEU	IDLE	0.0	GRASP	NEU	NEU	PGRSP	1.2
	213401	GRASP	NEU	NEU	LPNC	0.8	MOVE	ULN	NEU	PGRSP	1.0

TABLE 3.3 (CONTINUED)

ONE CYCLE OF BELT SAND (SUBJECT 4022)

		LEFT				RIGHT				
CYC	FRAME	ELEM	WRIST DEV	WRIST ANG	HAND POSIT	FRC KG	ELEM	WRIST DEV	WRIST ANG	HAND POSIT	FRC KG
14	213421	POSIT	NEU	E45	LPNC	0.8	MOVE	ULN	NEU	PGRSP	0.3
14	213441	POSIT	NEU	NEU	LPNC	0.8	POSIT	ULN	NEU	PGRSP	0.1
	213501	HOLD	NEU	NEU	LPNC	0.5	HOLD	ULN	NEU	PGRSP	0.3
15	213521	POSIT	NEU	NEU	LPNC	0.5	MOVE	ULN	NEU	PGRSP	0.1
15	213541	POSIT	NEU	NEU	LPNC	0.8	POSIT	ULN	NEU	PGRSP	0.5
16	213601	HOLD	NEU	NEU	LPNC	1.0	HOLD	ULN	NEU	PGRSP	0.3
16	213621	MOVE	NEU	NEU	LPNC	1.3	MOVE	ULN	NEU	PGRSP	0.5
	213641	POSIT	NEU	NEU	LPNC	2.6	RELS	NEU	NEU	IDLE	0.0
	213703	RELS	NEU	NEU	IDLE	0.0	GRASP	NEU	F45	MGRSP	0.3
	213721	IDLE	NEU	NEU	IDLE	0.0	MOVE	NEU	F45	MGRSP	0.9
	213741	IDLE	NEU	NEU	IDLE	0.0	MOVE	NEU	NEU	MGRSP	0.9
	213803	IDLE	NEU	NEU	IDLE	0.0	RELS	NEU	NEU	IDLE	0.0
	213821	IDLE	NEU	NEU	IDLE	0.0	REACH	NEU	NEU	IDLE	0.0

Average cycle time: 28.7 seconds
Fundamental cycles: 16
1.8 seconds

		LEFT	RIGHT
WRIST DEV	NEU	77%	40%
	ULN	23%	60%
WRIST ANG	F45	0%	4%
	NEU	45%	81%
	E45	55%	2%
	EXT	0%	9%
HAND POSIT	IDLE	17%	9%
	LPNCH	83%	0%
	PGRSP	0%	85%
	MGRSP	0%	6%
FORCE	AVG.	0.8	0.3
	ST.DV.	0.5	0.3
	ADJ.	1.2	0.7

3.3.2 Force.

EMG recordings (number of bars on the video) and hand posture were abstracted approximately every 20 to 30 frames of the video tape (one-third to one-half second). Mean force and standard deviation for the right and left hand were estimated (using calibration curves for each hand posture for each subject, Figure 3.3c) and averaged over the subjects performing the same job. Electromyography was impractical with 5 LOF.LOR jobs (Plant 2 inspectors, plant 4 supervisors, plant 6 staff, plant 7 platers and tool crib attendants) because their jobs required traversing the plants. A default value of 1 Kg$\pm$0.5 was used. Example of the estimated force for one cycle of two jobs, Drill and Tap at Plant 1 and Belt Sand at Plant 3 are shown in Tables 3.2 and 3.3. Hand force ranged from 0 to 5.5 Kg for the left hand and 0 to 1.8 Kg for the right hand in Drill and Tap (see Table 3.2). Force ranged from 0 to 2.6 Kg for the left hand and 0 to 1.3 for the right hand in Belt sand (see Table 3.3).

Several methods were considered to characterize the EMG estimated force requirements of different jobs. In addition to mean force over the cycle, a weighting measure was developed to take into account extreme variability in force within the cycle. The weighted measure is referred to as "adjusted force."

Adjusted Force=(Variance/Mean Force)+ Mean Force

Another weighted measure of force considered was mean force plus 2 standard deviations. The three values for the right and left hand are presented in Chapter 4. The adjusted force was used to classify jobs into low and high force categories. An adjusted

force (either right or left hand) of more than 6 Kg was defined as high force and less than 6 Kg was defined as low force. The Drill and Tap job shown in Table 3.2 had an adjusted force of 3.9 Kg versus a mean and standard deviation of 2.2±1.9 Kg for the left hand and 1.3 Kg versus 0.8±0.7 Kg for the right. The Belt Sand job shown in Table 3.3 had an adjusted force of 1.2 Kg versus a mean and standard deviation of 0.8±0.5 Kg for the left hand and 0.7 Kg versus 0.3±0.3 Kg for the right.

3.3.3 Posture

Wrist postures was characterized in terms of flexion and extension (movement towards and away from the palm) and ulnar and radial deviation (towards and away from the little finger). Because it was not possible to precisely estimate joint angles to the nearest degree, the range of joint motion were divided into a series of ranges or zones as described by Priel 1974; Corlett et al., 1979; Armstrong et al., 1982.

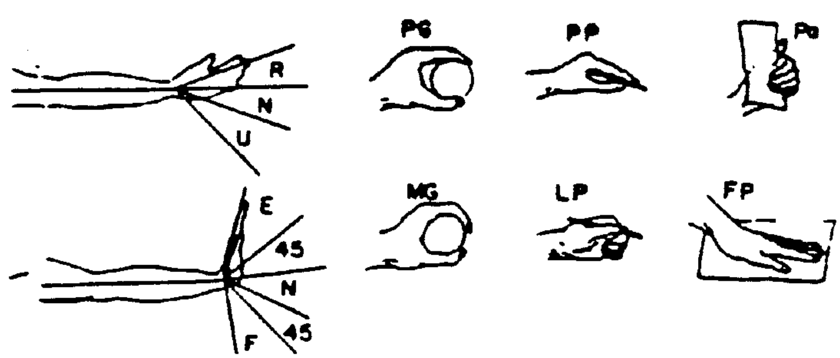
A form for recording upper extremity postures that has been used extensively in studies of cumulative trauma disorders by Armstrong et al., (1982) is shown in Figure 3.4. It includes two axes of wrist rotation. Each of the axes is divided into ranges according to the overall range of motion. The 57 degrees of possible radial-ulnar deviation (Youm et al., 1978) was divided into three zones and labeled U, N or R for Ulnar deviation, Neutral or Radial deviation. The 131 degrees of possible flexion-extension (Bradley and Sunderland, 1953) was divided into five zones and labeled E, 45E, N, 45F, F for more than 45 degrees

FIGURE 3.4
FORM FOR RECORDING UPPER EXTREMITY POSTURES

ANALYST ________
DATE ________

JOB: ________
HAND: *RIGHT/LEFT*

STEP	WORK ELEMENT	WRIST: Dev (RADIAL, NEUTRAL, ULNAR)	WRIST: Angle (EXTEND, 45° EX, NEUTRAL, 45° FLX, FLEX)	HAND: Position (PGRASP, MGRASP, PPINCH, LPINCH, PaPINCH, FPRESS)	OTHER	HAND: Fingers (0, 1, 2, 3, 4, 5)	FORCE
		R N U	E 45 N 45 F	PG MG PP LP Pa FP		0 1 2 3 4 5	
		R N U	E 45 N 45 F	PG MG PP LP Pa FP		0 1 2 3 4 5	
		R N U	E 45 N 45 F	PG MG PP LP Pa FP		0 1 2 3 4 5	
		R N U	E 45 N 45 F	PG MG PP LP Pa FP		0 1 2 3 4 5	
		R N U	E 45 N 45 F	PG MG PP LP Pa FP		0 1 2 3 4 5	
		R N U	E 45 N 45 F	PG MG PP LP Pa FP		0 1 2 3 4 5	
		R N U	E 45 N 45 F	PG MG PP LP Pa FP		0 1 2 3 4 5	
		R N U	E 45 N 45 F	PG MG PP LP Pa FP		0 1 2 3 4 5	
		R N U	E 45 N 45 F	PG MG FP LP Pa FP		0 1 2 3 4 5	
		R N U	E 45 N 45 F	PG MG PP LP Pa FP		0 1 2 3 4 5	
		R N U	E 45 N 45 F	PG MG PP LP Pa FP		0 1 2 3 4 5	
		R N U	E 45 N 45 F	PG MG PP LP Pa FP		0 1 2 3 4 5	
		R N U	E 45 N 45 F	PG MG PP LP Pa FP		0 1 2 3 4 5	
		R N U	E 45 N 45 F	PG MG PP LP Pa FP		0 1 2 3 4 5	
		R N U	E 45 N 45 F	PG MG PP LP Pa FP		0 1 2 3 4 5	
		R N U	E 45 N 45 F	PG MG PP LP Pa FP		0 1 2 3 4 5	
STEP	WORK ELEMENT	Dev	Angle	Position		Fingers	FORCE
		WRIST		HAND			



Extension, 15 to 45 degrees Extension, 15 degrees Extension to 15 degrees Flexion, 15 degrees Flexion to 45 degrees Flexion and more than 45 degrees Flexion. In this system the analyst used a stop action video tape player to observe the work posture approximately three times per second. The postures then were recorded by circling the appropriate cell on the table. Additional resolution was added as needed by circling two adjacent cells. The results of the postural analysis for one subject performing one cycle of the Drill and Tap job at Plant One is shown in Table 3.2 and the Belt Sand job at Plant Three is shown in Figure 3.3. In Drill and Tap the left wrist was flexed 15 to 45 degrees and ulnarly deviated 16% of the time and neutral the rest of the time. The right wrist was ulnarly deviated 67% and flexed 15 to 45 degrees 16% of the time and neutral the rest of the time. In Belt Sand, the left wrist was neutral and extended 15 to 45 degrees 45% and 55% of the time; it was neutral and ulnarly deviated 77% and 23% of the time. The left wrist was neutral and extended 15 to 45 degrees 45% and 55% of the time. The right wrist was flexed 15 to 45 degrees, neutral, extended 15 to 45 degrees and extended more than 45 degrees 4%, 81%, 2% and 9% of the time.

A joint by joint posture analysis of the hand involved unnecessary detail. Therefore, a system loosly based on the highly simplified systems of Jacobson and Sperling (1976) and used by Armstrong et al., (1982) was employed. An encoding form for this system is shown in Figure 3.4. First the hand position was indicated as a medial grasp, palmar grasp, pulp pinch, lateral pinch, palm pinch, or a press by circling the header in the appropriate cell.

Second, the area of contact, with the palm, first, second, third, fourth or fifth digit, was indicated by circling the 0, 1, 2, 3, 4, or 5 in the appropriate cell. The analysis of hand posture was performed at the same time as that of the wrist and the EMG. The results of the postural analysis for one subject performing one cycle of the Drill and Tap job at Plant One is shown in Table 3.2 and the Belt Sand job at Plant Three is shown in Table 3.3. In Drill and Tap, both the right and left hands were in pulp pinch postures 84% of the time and idle 16% of the time. In Belt Sand, the left wrist was idle and in lateral pinch 17% and 83% of the time. The right wrist was in idle, palmar grasp and medial grasp 9%, 85% and 6% of the time.

3.4 Subject Selection

All current workers performing the chosen jobs were identified. Excluded from potential selection were those workers who had been on the specific job for less than one year immediately prior to the date of examination. A random sample of 12-20 workers per job were chosen for health evaluation. Within each job, where possible, worker selection was stratified by sex and age. The last digit of the social security number was used with a random numbers table (Remington and Schork, 1970), to choose subjects within each strata. Prior selection of workers (whether by employer or employee) into jobs, particularly with respect to gender, mitigated against equal distributions of males and females in many jobs.

3.5 Evaluation of Health Status

Standardized structured interviews and physical examination were used to evaluate the presence of CTDs among subjects (Appendices 1-5). All health evaluations were conducted in private rooms in the plants during working hours by University of Michigan personnel.

3.5.1 Interview.

A "Primary Interview," administered by research team interviewers to all subjects, (blinded to exposure status) elicited demographic, prior health and work history information. Potential confounders or effect modifier data obtained by Primary Interview included sex, age, prior injuries to the upper extremity, chronic diseases, reproductive status for females, recreational activities and prior job activities. The remaining questions addressed upper extremity pain or discomfort experienced in the previous two years. If the subject had experienced recurring difficulty in one or more parts of the upper extremity, the appropriate secondary interview instrument was used (Appendix 1).

The secondary interviews were designed to obtain more detail about the subject's complaints including location, duration, onset, aggravating factors and treatment (Appendices 2-4).

3.5.2 Physical Examination (PE).

All subjects received a standardized non-invasive physical examination (Appendix 5) from a research team examiner blinded to medical history and occupational exposures. The physical examination consisted of the following:

A. Inspection of the upper extremity for abnormal bony contours, contractures, deformities, scars, Heberden's nodes, bony swelling which might interfere with range of motion. Swelling, depending on the location and presence of redness, suggest tendinitis, infection, rheumatoid arthritis. Blanching of one or both hands or fingers may suggest a vascular disorder, including Raynaud's phenomenon, thoracic outlet syndrome, hand-shoulder syndrome. Palpation was reserved for the end of the examination to reduce the likelihood of precipitating generalized pain (Cyriax, 1978).

B. Range of Motion (ROM). Active and passive ranges of motion as well as resisted tests were performed about each joint of the upper extremity. Pain (scale of 1 =minimal to 8=worst pain ever experienced), limitation, strength (1 to 7) and symptoms of numbness or tingling were recorded. Passive ranges of motion were not performed if active ROM was normal. However, passive ROM was always tested at the wrist.

The general concepts of evaluating ranges of motion were derived from the work of Cyriax (1978). Active range of motion indicates willingness and ability to perform the action and that range of motion is possible. Passive range of motion indicates the state of the inert tissue or joint. A painful arc, felt at mid range, implies impingement of soft tissue between bony surfaces. Resisted movements provide information on the state of every muscle-tendon group about the joint. Pain on resisted motions, with no limitation on passive ROM, indicates a muscle or tendon lesion. Significant weakness, in the absence of pain, suggests rupture of the tendon or a central nervous system disorder. Weakness and pain on resisted motions indicate a gross lesion. Positive signs must always be balanced by corroborative negative signs. For example, in lateral epicondylitis, there is no pain or limitation on full passive ROM; there is pain on resisted extension of the wrist (with fingers flexed) and pain on resisted radial deviation of the wrist. There is no pain on resisted ulnar deviation. Pain may be present at the epicondyle on palpation.

C. Specific Tests. Phalen's test (Phalen, 1966, 1972; Smith, 1977, Sandzen, 1981) and Tinel's test (Kendall, 1960; Phalen, 1972; Cailliet, 1981) are used to evaluate the presence of carpal tunnel syndrome.

Finkelstein's test is used to assess the presence of De Quervain's disease (Finkelstein, 1930; Muckart, 1964; Lamphier, 1965; Hymovich, 1966).

D. Pulses. Brachial and radial pulses are palpated to determine if there is any evidence of occlusion which might account for a subject's symptoms.

E. Reflexes. Triceps, biceps, brachioradialis and finger flexor reflexes are checked with a reflex hammer for evidence of neurological disorders.

F. Dermatomes. Pinprick sensation is evaluated for the ulnar, medial and radial nerves for evidence of sensory loss (Cailliet, 1981; Brown, 1977).

G. Hand Grip Strength. A dynamometer is used to evaluate grip strength. The dynamometer is adjusted for the subject's hand to facilitate a power grip. The largest of two tries is recorded for each hand. The dominant hand is expected to have the strongest hand grip (Ellis, 1951; Waris, 1979; Ferguson, 1971).

H. Two-Point Discrimination. The tips of the palmar surfaces of the index and little fingers are tested to evaluate sensory loss of median and/or ulnar nerves in the hands. This may be present in Raynaud's phenomenon, carpal tunnel syndrome, and thoracic outlet syndrome as well as cervical root disorders (Brown, 1977, Sandzen, 1981; Carlson, 1979; Corlett, 1981).

I. Additional Tests. If abnormalities are detected on the physical examination, additional tests are performed to more closely localize the disorder. For example, with evidence of radicular signs, all dermatomes of the upper extremity are checked for pinprick sensation.

A protocol was developed to minimize differences between interviewers and between examiners (Appendix 6).

3.5.3 Endpoints

The interviews and physical examination were developed to identify specific endpoints (Table 3.5). These were grouped in broad categories about the major joints.

Diagnostic criteria for specific disorders are presented in Appendix 7. General criteria were used to define a positive CTD case on Interview and Physical Exam (Table 3.6).

TABLE 3.5

ENDPOINTS

A. All Hand, Wrist, Finger Disorders
   -Ulnar nerve compression (Guyon' tunnel)
   -Carpal tunnel syndrome
   -Trigger finger
   -Tendinitis, tenosynovitis, De Quervain's Disease
   -Non-specific pattern of pain, numbness or tingling
   -Degenerative Joint Disease (LOA)
B. Hand/Wrist Disorders Excluding LOA
C. Tendon Related Hand/Wrist Disorders
   -Tendinitis, tenosynovitis, De Quervain's Disease
D. Carpal Tunnel Syndrome
E. All Elbow, Forearm Disorders
   -Lateral and medial epicondylitis
   -Olecranon bursitis
   -Radial nerve compression (radial tunnel syndrome)
   -Median nerve compression (pronator teres syndrome)
   -Ulnar nerve entrapment (cubital tunnel syndrome)
F. Shoulder Disorders
   -Bicipital tendinitis
   -Rotor cuff tendinitis
   -"Frozen shoulder"
   -Degenerative joint disease
G. Neck, Scapular Area
   -Tension neck syndrome
   -Scapulocostal syndrome

TABLE 3.6

GENERAL CRITERIA FOR CTDS

INTERVIEW
1. Meets one of the endpoint criteria
2. Symptoms lasting more than 1 week and/or occurring 20+ times in previous year
3. No evidence of acute traumatic onset
4. No related systemic diseases
5. Onset since on current job

PHYSICAL EXAMINATION
1. Characteristic signs of endpoints
2. Rule out other conditions with referred symptoms

Those subjects meeting the Interview criteria but with no physical findings were classified as Positive Interview. Those who reported

symptoms occurring in the previous year, but not present at the time of evaluation, would not be expected to have physical findings.

Those subjects who met the Interview criteria and had characteristic physical findings were classified as Positive PE and Interview. Those subjects with positive physical findings but were asymptomatic on Interview were classified as negative CTD.

3.6 Methods of Statistical Analysis of Associations

In order to test the hypotheses of no association between exposure categories and cumulative trauma disorders two basic approaches were used: contingency analysis and multiple logistic regression.

The first step in the analysis was to determine if any of the potential confounders were associated with exposure. Analysis of variance was used with the continuous variables of age and years on the study job (Neter and Wasserman, 1974). Categorical variables were tested for independence with contingency analysis (Chi square or Fisher Exact test when an expected cell was less than 5). Those factors for which there was not a two fold difference between exposure groups (or for sex, within exposure groups) were dropped from consideration as potential confounders. Similarly, several factors were initially considered to be effect modifiers of disease such as reproductive status of females and carpal tunnel syndrome, recreational activities, number of hours worked at the time of evaluation. Odds ratios were calculated to estimate the associations and Fisher Exact probabilities (two-tailed) or uncorrected Chi square (Mantel-Haenszel) tests were used to test independence with categorical variables. Student t tests were used to test the hypothesis of no difference in time worked between those with and without recurring problems.

Throughout the analyses, gender was considered a potentially important confounder or effect modifier. In order to test the hypotheses of no association between sex and various CTDs, job-adjusted odds ratios (Mantel-Haenszel) for females compared to males were calculated, restricted to jobs with both male and female subjects, (Fleiss,1981; Kleinbaum et al, 1982).

Plant-adjusted odds ratios (Mantel-Haenszel) were used to estimate associations between exposure and CTDs, while controlling for a potential "plant effect." Plant combined or crude odds ratios were also presented for comparison to the plant-adjusted odds ratios. Analyses were stratified by sex. Sex-combined analyses were also performed when no significant associations between sex and CTDs were identified within exposure categories in the job-adjusted odds ratios.

Odds ratios, rather than prevalence ratios, were chosen as the measure of association because computer software was more readily available. The odds ratios may overestimate the magnitude of association when there is a high prevalence of disease. The odds ratio is more reflective of the prevalence ratio when the prevalence of disease is low. Overestimates were expected when all CTDs were analyzed. However, as the analysis proceeded to more specific CTDs with lower prevalence, the odds ratios would be more reflective of prevalence or risk ratios. Therefore, the term "risk" will be used to describe the magnitude of associations observed with specific CTD's and "odds" will be used to describe the magnitude of associations observed with all CTD's.

In the stratified analyses for hand wrist CTDs, tests for trend (Fleiss, 1981, Schlesselman, 1982) were used to test the hypothesis of no difference in prevalence of CTDs by age group.

Unconditional multiple logistic regression techniques (Kleinbaum, 1982) were used to estimate associations between various hand wrist CTDs on PE and Interview while controlling for age, years on the study job, sex and plant.

Continuous variables included age, years on the job, percent wrist flexion, percent pinch, fundmental cycles per hour, mean force and adjusted force. Dummy variables (0,1) were constructed for sex (1), plant (5), and exposure category (3). Each variable (or set of dummy variables was entered into the model separately and together in both forward and backward stepwise fashion. The predicted associations between exposure and CTDs were compared to the observed associations estimated in the stratified analysis for consistency. In general 3 models were presented (Chapter 5). All models contained plant variables. Model I contained age, sex, years on the study job. Model II contained the same variables as Model I plus final exposure classification variables. Model III contained the same variables as Model I plus initial exposure classification variables. Interaction terms between these variables were also entered into the models.

The following model was constructed:

$$P(D/X) = \frac{1}{1 + \exp -(Bo + BiXi)}$$

where:
P(D/X) is the probability of disease (CTD) given-

X2	=HIF.LOR (initial classification)	(0,1)	Model III
X3	=LOF.HIR (initial classification)	(0,1)	"
X4	=HIF.HIR (initial classification)	(0,1)	"
X5	=Repetitive (initial classification)	(0,1)	
X6	=Force (initial classification)	(0,1)	
X14	=Sex (male,female)	(0,1)	
X15	=Age		
X16	=Years on specific job		
X18	=Plant 2	(0,1)	
X19	=Plant 3	(0,1)	
X12	=Plant 4	(0,1)	
X20	=Plant 5	(0,1)	
X21	=Plant 6	(0,1)	
X300	=% wrist flexion		
X301	= fundamental cycles/hour		
X302	=% pinch		
X303	=% ulnar deviation		
X304	=% flexion with ulnar		
X305	= flexion with pinch		
X306	= hyperextension with pinch		
X307	= awkward		
X308	= awkward with pinch		
X1000	=Age* Years on specific job		
X1002-04	=Age*Exposure group		
X1005	=Age*Sex		
X1006	=Age*Years on Job*Sex		
X1007	=Sex*Years on Job		
X1008-10	=Sex*Exposure group		
X1011-25	=Plant*Exposure group		
X1026-28	=Years on Job*Exposure group		
X1032	=Sex*pinch		
X2046=	HIF.LOR (Final classification)	(0,1)	Model II
X2047=	LOF.HIR (Final classification)	(0,1)	"
X2048=	HIF.HIR (Final classification)	(0,1)	"
X2050=	Adjusted force		
X2060=	Mean force		
X2051=	Force (Final classification)	(0,1)	
X2052=	Repetitve (Final classification)	(0,1)	

Estimates of associations between Exposure and CTDs were performed for both initial exposure category classification and final exposure category classification for comparison.

Results of the job analyses are presented in Chapter 4.

CHAPTER 4

JOB ANALYSIS RESULTS

Jobs chosen on the basis of the preliminary analysis were analyzed further to reduce misclassification among exposure groups and to assess their postural attributes. Job analysis results are based on review of videotapes of at least 3 workers performing each selected job to provide job summary estimates of hand wrist force, repetitiveness and postural characteristics for the jobs.

4.1 Repetitiveness

High repetitiveness is defined as cycle time of less than 30 seconds or more than 50% of cycle time spent performing the same fundamental cycle. Summary estimates for repetitiveness are presented in Table 4.1. Using the original criteria for classifying repetitiveness into "high and low" categories, 4 jobs changed categories: Mold handles at Plant 1, Plunge grind at Plant 6 and Automatic machine operator at Plant 7 were determined to be low repetitive jobs. 664 Board at Plant 1 was determined to be a high repetitive job.

The Mold handle job was comprised of 3 basic tasks: 1) removing plastic handles from an injection molding machine and positioning them on a work bench, 2) knocking out metal inserts from the handles by hitting the handles against the work bench, 3) placing metal inserts into the molding machine for the next cycle. In many respects, this job would intuitively be considered a high repetitive job,

particularly in comparison to some of the other "low repetitive" jobs such as AC Press in the same plant. However, the mean cycle time was more than 30 seconds and the percent of the cycle time spent knocking out inserts was less than 50%.

The Plunge grind job at Plant 6 was comprised of 3 basic tasks: 1) load a handful of shafts into a grinding machine (6-8 per handful), 2) remove one or two shafts for inspection and guaging, 3) pick up a handful of finished parts and place them in a storage bin. Occasionally, machine maintenance would be performed. It was initially assumed that because 1900-2300 parts were produced per shift that this was a high repetitive job. The mean cycle time was 54.6 seconds and guaging parts accounted for less than 37% of the cycle time.

The automatic machine operator job consisted of 2 tasks: 1) getting several stacks of bearings from a bin and positioning them on a conveyor belt which fed into the machine, and 2) removing stacks of finished bearings from a lower conveyor belt and positioning them in a storage bin. Depending on the specific machine, cycle time ranged from 15-57 seconds. The mean cycle time was 38.0 ± 14.4 seconds. Loading and unloading stacks of bearings accounted for 44% of the cycle time. This job was therefore designated low repetitive.

TABLE 4.1

SUMMARY ESTIMATES OF REPETITIVENESS BY JOB

PLANT (Job)	CYCLE TIME Seconds	MAJOR FUNDAMENTAL CYCLE Name (#)	Time	% of Cycle Time
PLANT 1				
Eyelet	4.4			
Drill & Tap	2.0			
Mold housing	44.9	File *12	14.8	33%
AC Press	3600.0	Unload *7	54.5	2%
Mold Handle	57.8	Knockout *10	15.4	27%
Buffing	22.0	Buff 8-14	19.2	87%
Touchup	102.7	Solder *12	44.3	43%
664 Board	203.8	Wire 12-60	97.6	50%
PLANT 2				
Punch Press	13.0			
Hang89	14.0			
Hang48	36.8	Load *10	25.9	70%
Screw Machine	1800.0	Load *6	165.7	9%
Inspector**	5400.0	Guage *123	2075.4	38%
PLANT 3				
Belt Sand	41.5	Sand *14	24.3	59%
Mounted Point	138.3	Sand *102	117.2	85%
Burr Bench	146.7	Grind * 340	118.2	81%
Cutoff	102.0	Cut *12	79.6	78%
Guage	54.5	Guage *2	21.4	39%
Wax Assembly	846.4	Brush *86	292.1	35%
Core Press	159.4	Spray *5	30.4	19%
Wax Injection	73.3	Inspect *2	16.0	22%
PLANT 4				
Hemlegs	11.5	Sew *2	9.2	80%
Belt Loops	22.6	Sew *10	18.1	80%
Material Handle**	384.0	Unload *4	121.8	33%
Supervisor**	2127.6	Pushcart *20	177.6	8%
PLANT 5				
Hand Grind	12.0	Grind *6	10.6	88%
Stat Grind (med size)	7.0	Grind *4	5.9	84%
Stat Grind (lg size)	76.7	Grind *18	55.0	72%
Core Clean	20.5	File *35-50	18.2	89%
Hutch Machine	130.0	Insert *5	25.9	20%
Panel Operator**	854.3	Insert *2	60.5	7%
PLANT 6				
Plunge Grind	54.6	Guage *2	20.1	37%
Pump Assembly	22.9	Insert *12	13.2	58%
Screw Machine	1800.0	Load *6	87.4	5%
Staff**	28800.0	Housekeeping		35%
PLANT 7				
Plater **	1800.0	None		
Tool Crib Attn **	72.0	None		
Plater Helper	100.9	load bearing*21	22.6	22%
Automatic Op	38.0	load/unload*4	16.6	44%
Manual Op	5.3	none		

** Estimated by job sampling techniques

The 664 Board job consisted of 3 basic tasks involved in assembly of electronic circuit boards: 1) inserting 12-20 wires depending on the board, 2) soldering the wires, 3) crimping or clipping the wires with needle-nosed pliers/clippers. There was considerable variation between the jobs of the 4 workers analyzed on videotape due to the different boards that were assembled. Cycle time ranged between 75.7 seconds and 332 seconds (the latter occurring when 3 boards were assembled together).

Although there were a number of fundamental cycles occurring in each task, inserting wires required the most time (varying between 46.1% and 54.2% of the cycle time). This job was on the border between "high" and "low" repetitiveness. The most conservative approach, with respect to estimating associations between CTDs and exposure, was to classify this job as "high repetitive" because the average percent fundamental cycle time was 50%.

No other jobs changed repetitiveness categories between the initial and final classification.

4.2 Force

Summary force estimates (mean, adjusted and mean+2 standard deviations) for the left and right hand are presented in Table 4.2. Initial classification relied on weighing parts or estimating the amount of force required to perform certain tasks (push palm buttons, pull cloth, squeeze the trigger of a spray gun). However, the initial classification resulted in modest overlap between low and high force jobs (Figures 4.1, 4.2, 4.3). Cutoffs for "low" and "high" force were selected which both minimized misclassification of the initial walk through classification and resulted in more homogeneous groups. These

cutoffs were 3.5 Kg for mean force and 6 Kg for adjusted force and mean force + 2 standard deviations (St Dev).

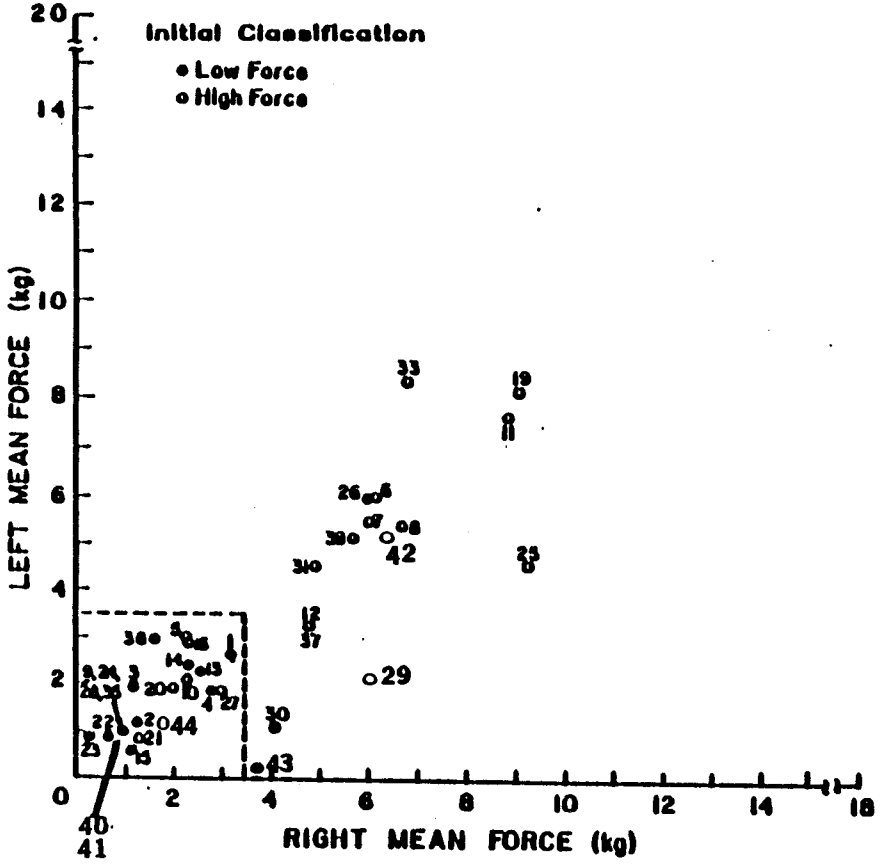
TABLE 4.2
THREE MEASURES OF ESTIMATED HAND/WRIST FORCES

JOB		JOB EXPO LEFT HAND Mean	St Dev	Adjust	Mean + 2 St Dev	RIGHT HAND Mean	St Dev	Adjust	Mean + 2 St Dev
PLANT 1									
Mold housing	5 HI	3.0	3.4	6.9	9.9	2.3	2.9	5.8	8.0
AC Press	6 HI	6.0	6.8	13.7	19.6	6.1	7.5	15.4	21.2
664 Board	1 LO	2.7	2.4	4.9	7.5	3.2	2.9	5.8	9.0
Touchup	2 LO	1.2	1.5	3.2	4.2	1.3	1.9	4.0	5.1
Eyelet	4 LO	1.9	1.3	2.8	4.5	2.8	2.2	4.6	7.3
Drill & Tap	3 LO	2.0	1.8	3.5	5.5	1.2	0.9	1.9	3.0
Mold Handles	8 HI	5.4	5.7	11.4	16.8	6.8	6.6	13.2	20.1
Buffing	7 HI	5.5	4.3	8.9	14.2	6.0	4.2	9.0	14.4
PLANT 2									
Punch Press	13 LO	2.3	3.6	8.0	9.5	2.6	3.1	6.4	8.8
Hang 89	10 HI	2.1	2.3	4.7	6.8	2.3	2.7	5.5	7.7
Hang 48	11 HI	7.7	9.8	20.1	27.2	8.9	10.6	21.5	30.1
Screw Machin	12 HI	3.3	5.1	11.1	13.4	4.8	4.6	9.2	14.0
Inspector*	9 LO	1.0	0.5	1.3	2.0	1.0	0.5	1.3	2.0
PLANT 3									
Gauge	14 LO	2.7	2.0	4.2	6.7	2.4	1.9	3.9	6.2
Wax Assembly	15 LO	0.6	0.6	1.1	1.7	1.2	1.3	2.6	3.7
Mount point	22 LO	0.9	0.5	1.1	1.8	0.7	0.4	0.9	1.5
Belt Sand	23 LO	2.1	1.9	3.7	5.8	2.0	1.2	2.8	4.5
Wax Inject	20 HI	1.8	3.1	7.2	8.1	2.4	4.1	9.5	10.6
Core Press	21 HI	1.2	2.0	4.5	5.2	2.4	3.5	7.4	9.4
Cutoff	19 HI	9.6	12.0	24.5	33.6	7.2	5.9	12.0	19.0
Burr Bench	16 HI	1.6	1.4	2.9	4.4	3.6	2.4	5.1	8.3
PLANT 4									
Beltloops	27 HI	1.9	1.4	2.9	4.6	3.0	2.7	5.4	8.4
Hemlegs	26 LO	6.0	4.9	10.0	15.8	6.2	4.2	9.1	14.7
Matl Handler	25 HI	4.6	9.6	24.9	23.8	9.3	10.4	20.9	30.1
Supervisor*	24 LO	1.0	0.5	1.3	2.0	1.0	0.5	1.3	2.0
PLANT 5									
Stat grind	31 HI	5.2	5.1	10.1	15.3	6.5	6.9	13.8	20.3
Hand Grind	33 HI	6.1	4.6	9.6	15.3	13.6	12.2	24.6	38.0
Core Clean	30 LO	2.8	1.9	4.1	6.6	2.7	1.5	3.5	5.7
Hutchinson	29 HI	2.3	6.5	20.8	15.4	6.1	19.8	70.4	45.7
Panel Op	28 LO	1.0	0.5	1.3	2.0	1.6	2.0	4.1	5.6
PLANT 6									
Plunge Grind	38 LO	0.7	1.8	5.3	4.3	1.7	0.7	1.9	3.0
Pump Assembl	39 HI	5.3	2.6	6.6	10.5	5.7	4.8	9.7	15.3
Screw Machin	37 HI	3.3	5.1	11.1	13.4	4.8	4.6	9.2	14.0
Staff*	35 LO	1.0	0.5	1.3	2.0	1.0	0.5	1.3	2.0
PLANT 7									
Manual op	43 LO	0.5	1.3	3.8	3.1	3.7	4.8	9.9	13.3
Auto op	44 HI	1.2	3.5	11.4	8.2	1.7	4.9	15.5	11.5
Plater help	42 HI	5.0	9.8	24.0	24.6	6.4	10.4	23.4	27.2
Plater*	40 LO	1.0	0.5	1.3	2.0	1.0	0.5	1.3	2.0
Tool Crib*	41 LO	1.0	0.5	1.3	2.0	1.0	0.5	1.3	2.0

ADJUST =(VARIANCE/MEAN) + MEAN
* DEFAULT VALUES (NO EMGS)

Table 4.3 presents the potential changes in force classification using these cutoff points. Each of the jobs identified with the adjusted force measure was also identified with at least one of the other measures. As a result, those jobs identified for change in classification by adjusted force were used in the final classification of jobs into exposure categories.

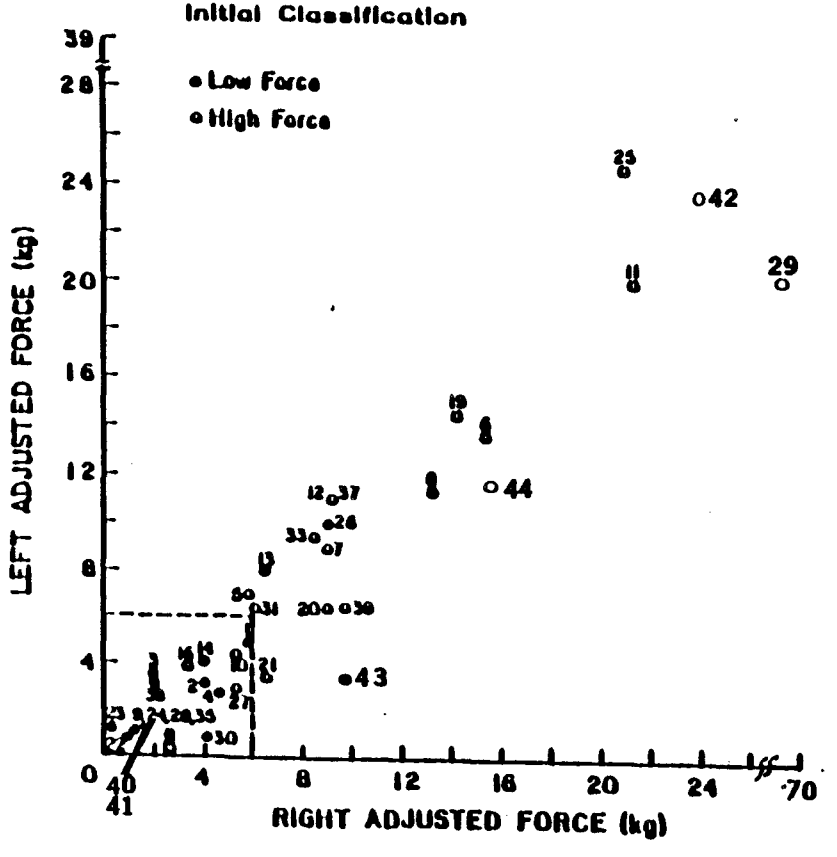
FIGURE 4.1
ESTIMATES OF FORCE BY JOB:MEAN FORCE



JOB CODE

1. 664 Board	15. Wax Assembly	31. Stat Grind
2. Touchup	16. Burr Bench	33. Hand Grind
3. Drill & Tap	19. Cutoff	35. Staff
4. Eyelet	20. Wax Inject	37. Auto Screw
5. Mold Housing	21. Core Press	38. Plunge Grind
6. AC Press	22. Mounted Point	39. Pump Assem
7. Buffing	23. Belt Sand	40. Plater
8. Mold Handle	24. Supervisor	41. Tool Crib
9. Inspector	25. Matl Handler	42. Plater help
10. Hang 89	26. Hemlegs	43. Manual Op
11. Hang 48	27. Beltloops	44. Automatic Op
12. Screw Machine	28. Panel op	
13. Punch Press	29. Hutch Machine	
14. Gauge	30. Core Clean	

FIGURE 4.2
ESTIMATES OF FORCE BY JOB:
ADJUSTED FORCE



JOB CODE

1. 664 Board
2. Touchup
3. Drill & Tap
4. Eyelet
5. Mold Housing
6. AC Press
7. Buffing
8. Mold Handle
9. Inspector
10. Hang 89
11. Hang 48
12. Screw Machine
13. Punch Press
14. Gauge
15. Wax Assembly
16. Burr Bench
19. Cutoff
20. Wax Inject
21. Core Press
22. Mounted Point
23. Belt Sand
24. Supervisor
25. Matl Handler
26. Hemlegs
27. Beltloops
28. Panel op
29. Hutch Machine
30. Core Clean
31. Stat Grind
33. Hand Grind
35. Staff
37. Auto Screw
38. Plunge Grind
39. Pump Assem
40. Plater
41. Tool Crib
42. Plater help
43. Manual Op
44. Automatic Op

FIGURE 4.3
ESTIMATES OF FORCE BY JOB:
MEAN PLUS 2 STANDARD DEVIATIONS

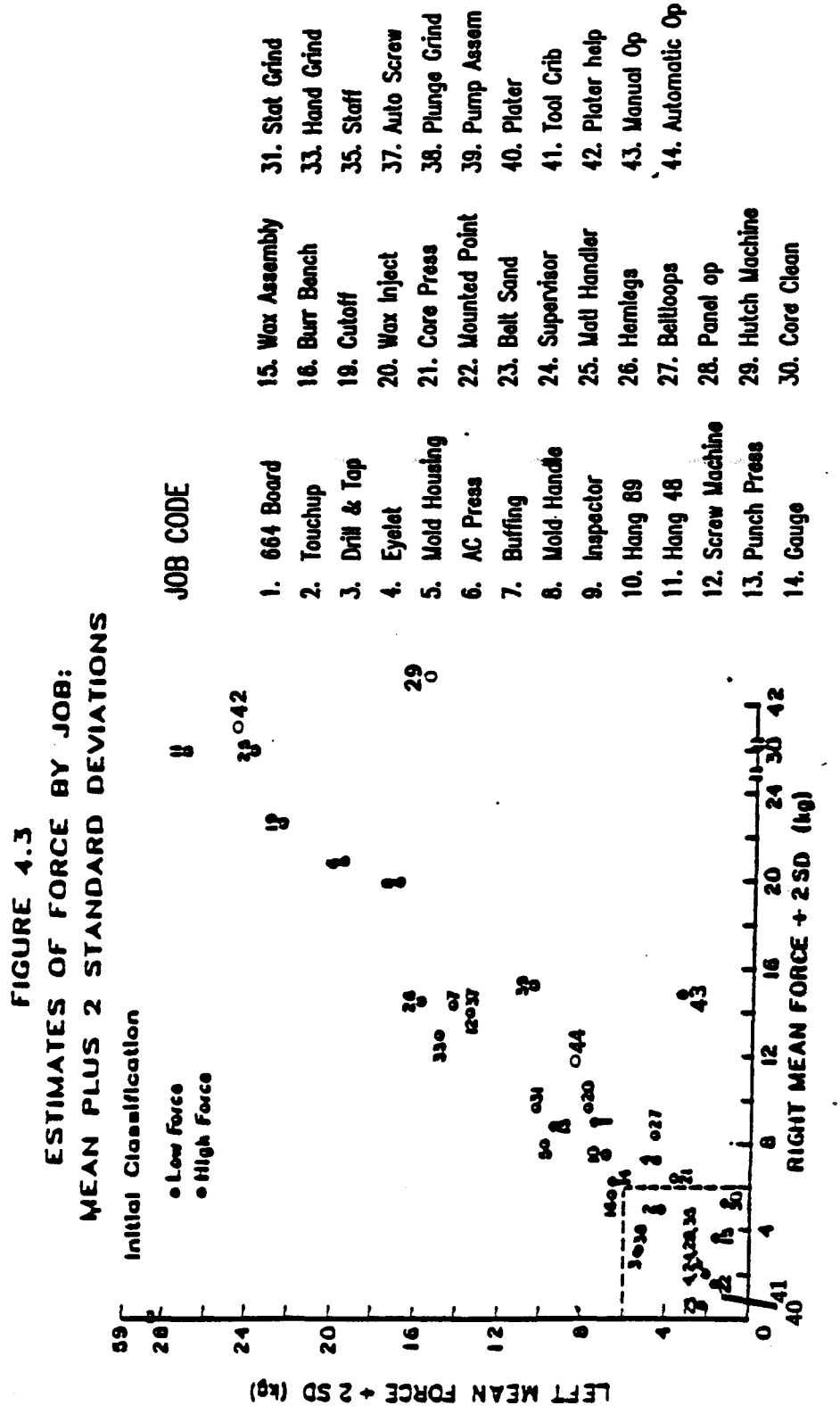


TABLE 4.3

COMPARISON OF FORCE CATEGORY CHANGES
IDENTIFIED BY 3 FORCE MEASURES

A. Initial Category Low Force: Change to High Force

MEAN FORCE	ADJUSTED FORCE	MEAN + 2 ST DEV
Hemlegs (26)	Hemlegs (26)	Hemlegs (26)
Core Clean (30)	Punch Press (13)	Punch Press (13)
Manual Op (43)	Manual Op (43)	Eyelet (4)
		664 Board (1)
		Guage (14)
		Manual Op (43)

B. Initial Category High Force: Change to Low Force

MEAN FORCE	ADJUSTED FORCE	MEAN + 2 ST DEV
Hang 89 (10)	Hang 89 (10)	
Burr Bench (16)	Burr Bench (16)	
Belt Loops (27)	Belt Loops (27)	
Mold Housing (5)		
Wax Injection (20)		
Core Press (21)		

(number refers to job number in Figures 4.1, 4.2 and 4.3)

The Hang 89 (Job 10) job at Plant 2 was originally combined with the Hang 48 (Job 11) job. However, the force requirements for these two jobs were quite different (Table 4.3) and the jobs were separated in the final exposure classification.

At Plant 4, Hemlegs (Job 26) and Belt Loops (Job 27) changed force categories. Neither job required lifting heavy weights. However, it was difficult to estimate how much force was required on these sewing jobs in the plant walk throughs.

There was considerable variation within the Punch Press job (Job 13) at Plant 2 and the Burr Bench job (Job 16) at Plant 3. In the Punch Press job, mean right force varied between subjects from 1.4-5.0 Kg with peak forces between 5.3-24.0 Kg. Left mean force varied between 2.1-3.6 Kg with peak forces of 6.8-35.6 Kg. Right mean force

for the Burr Bench job varied between 0.8-4.4 Kg with peak forces of 8.3-26.5 Kg. Left mean force varied between 1.39-3.5 Kg with peak forces of 5.7-12.8 Kg.

Among manual machine operators at Plant 7, mean right force ranged between 2-5.8Kg with peak forces of 6-21Kg whereas the left mean forces were 0.4-1.3Kg with peaks of 3.4-7.3Kg.

Student t tests were used to determine if there was a statistically significant difference in the overall means between low and high force jobs based on adjusted force classification (whichever hand had the highest adjusted force was used). The mean adjusted force for "high force" jobs was 14.5 ± 6.2 Kg and was 3.2 ± 1.6 Kg for low force jobs ($p < 0.0001$).

.However, there were also significant differences within the force categories when stratified by repetitiveness. The mean adjusted force for LOF.LOR was 2.3 ± 1.3 Kg and was 4.2 ± 1.4 Kg for LOF.HIR. The mean adjusted force for HIF.LOR jobs was 14.4 ± 5.7 Kg and was 14.6 ± 6.8 Kg for HIF.HIR. The difference within the low force category was due to the default value given to 4 LOF.LOR jobs where EMG estimates of force were not available. When these were excluded, the mean adjusted force for LOF.LOR was 3.5 ± 0.8.

Table 4.4 summarizes the changes in exposure category between initial and final classification of selected jobs.

Table 4.4

EXPOSURE CATEGORY CHANGES FROM INITIAL TO FINAL PLACEMENT

PLANT	JOB	INITIAL	FINAL
1	664 Board	LOF.LOR	LOF.HIR
1	Mold Handle	HIF.HIR	HIF.LOR
2	Punchpress	LOF.HIR	HIF.HIR
2	Hanger 89*	HIF.HIR	LOF.HIR
3	Burr Bench	HIF.HIR	LOF.HIR
4	Hemlegs	LOF.HIR	HIF.HIR
4	Beltloop	HIF.HIR	LOF.HIR
6	Plunge Grind	LOF.HIR	LOF.LOR
7	Automatic Op	HIF.HIR	HIF.LOR
7	Manual Op	LOF.HIR	HIF.HIR

* originally combined with Hanger 48

4.3 Posture

Hand and wrist postures (abstracted from videotapes, Chapter 3) were averaged over 3 cycles for each worker in a job and then averaged over 3 workers per job. Postures cited in the literature as contributing to hand wrist CTDs include flexion, hyperextension and ulnar deviation of the wrist and pinching. Percent of cycle time spent in these postures as well as wrist flexion with a pinch are presented in Table 4.5. Pinch includes pulp,lateral and palm pinch combined. It must be noted that there was often considerable variation in posture between operators performing similar jobs.

TABLE 4.5
PERCENT OF CYCLE TIME IN POSTURES (MEAN)

JOB	JOB #	PINCH	FLEXION	ULNAR DEV	HYPER-EXTEND	FLEXION + PINCH
PLANT 1						
664 Board	1	82.0	15.3	52.5	3.2	4.7
Solder	2	74.6	9.8	24.6	8.2	6.7
Drill &Tap	3	54.1	38.3	31.8	0.0	17.6
Eyelet	4	42.4	17.4	68.5	0.0	2.4
Mold Housing	5	48.1	25.1	51.1	8.0	12.4
AC Press	6	13.5	25.6	21.1	4.0	1.6
Buffing	7	17.3	14.1	50.7	10.3	1.4
Mold Handles	8	2.3	5.5	19.6	6.5	0.0
PLANT 2						
Inspector*	9	20.0	22.8	25.0	0.0	0.0
Hang 89	10	73.0	17.1	75.0	0.0	11.8
Hang 48	11	9.6	14.5	22.0	0.9	5.2
Screw	12	15.4	55.2	11.9	0.9	0.3
Punch Press	13	30.2	28.6	26.8	7.3	2.6
PLANT 3						
Gauge	14	36.8	17.8	33.1	0.7	8.4
Wax Assem	15	98.0	40.8	55.1	0.6	0.8
Burr Bench	16	60.1	11.8	24.7	10.0	2.3
Cutoff	19	12.2	19.1	42.1	4.8	1.1
Wax Inject	20	27.1	8.9	17.9	2.1	2.5
Core Press	21	36.3	7.2	17.8	0.5	1.6
Mount Point	22	97.5	0.2	59.3	0.2	0.6
Belt Sand	23	61.4	5.7	31.0	2.3	3.4
PLANT 4						
Supervisor*	24	20.0	22.8	25.0	0.0	0.0
Matl Handle	25	6.7	23.9	49.2	4.9	5.0
Hemlegs	26	77.0	26.9	33.4	2.2	16.7
Beltloops	27	74.5	19.1	22.2	0.0	17.6
PLANT 5						
Panel op	28	20.0	22.8	25.1	0.0	0.0
Hutchinson	29	13.6	2.4	7.4	3.4	0.4
Core Clean	30	38.5	9.5	26.1	3.0	1.0
Stat Grind	31	0.5	20.0	30.0	0.0	0.0
Hand Grind	33	0.0	1.9	55.6	1.0	0.0
PLANT 6						
Staff*	35	20.0	22.8	24.9	0.0	0.0
Screw mach	37	15.4	55.2	11.9	0.9	0.3
Plunge Grind	38	10.0	0.0	25.1	10.8	0.0
Pump Assem	39	75.8	19.5	44.3	1.0	12.5
PLANT 7						
Plater*	40	20.0	22.9	25.2	0.0	0.0
Tool Crib*	41	20.0	22.7	25.1	0.0	0.0
Plater Help	42	10.8	4.9	15.0	0.5	0.0
Manual Op	43	64.9	5.2	7.2	2.1	5.2
Auto Op	44	2.0	1.0	7.6	0.9	0.0

* Default Values

CHAPTER 5

RESULTS

ASSOCIATIONS BETWEEN JOB ATTRIBUTES AND HEALTH STATUS

This chapter presents the results of the epidemiologic analysis of upper extremity disorders among 652 active workers in four exposure categories of hand force and repetitiveness. Methods of analyses included contingency analysis and logistic regression analysis to test the hypotheses of no associations between various cumulative trauma disorders (CTDs) and exposure categories.

Results are presented for the final classification of jobs into exposure categories. Results based on initial exposure classification are also presented in prevalence figures and logistic regression analyses for comparison.

5.1 Response

A total of 727 workers were originally selected from employee rosters to participate in the study (Table 5.1). Approximately 2% refused to participate. The highest refusal rate was in Plant 3 (4.6%). Another 3.3% were on medical leave of absence at the time of evaluation. Plant 6 had the highest percent of known medical leaves of absence (10.2%). Thirty-five or 4.8% were not actually working on a study job, on layoff or had less than one year on the study job. Six were excluded after health evaluation because of active Rheumatoid arthritis at the time of evaluation. Of those originally selected, 89.7% (652) were included in the study. It was not known how many workers in each study job had left the job or the plant due to CTDs.

TABLE 5.1

SUBJECT SELECTION BY PLANT

	PLANT						
	1	2	3	4	5	6	7
SELECTED	96	92	173	81	111	88	86
REFUSED	0	3	8	1	0	1	0
MEDICAL LOA	0	1	7	4	0	9	0
EXCLUDED	1	0	3	1	1	0	0
OTHER *	0	4	3	2	8	10	8
INCLUDED	95	84	152	73	102	68	78
PERCENT TOTAL	99%	91%	88%	90%	92%	77%	91%

* includes layoff, didn't meet study criteria

5.2 Study Group Characteristics

Of the 652 subjects in the final study group, the mean age was 39.4 $\pm$ 10.4 years (Table 5.3). There were 358 males and 294 females (Table 5.2) with similar mean ages. Mean years on the study jobs for the entire study group was 7.7$\pm$6.1 years (8.0$\pm$6.6 for males and 7.4$\pm$5.3 years for females) (Table 5.4). The distributions were essentially the same by initial exposure classification.

Sex. Neither males or females were evenly distributed between exposure categories or jobs. There were 21 out of 39 specific jobs in which there were both males and females. Males tended to predominate in the HIF.LOR category (38.8% of males and 19.0% of females). Females tended to predominate in the LOF.HIR category (34.8% of females and 14.0% of males).

Age. Analysis of variance indicated no significant difference in overall mean age between exposure categories, sexes or sex*exposure categories. However, mean age for all males and for all females (exposure groups combined) differed significantly between plants ($p < 0.0001$).

TABLE 5.2

SEX DISTRIBUTION BY EXPOSURE GROUP AND PLANT

PLANT	EXPOSURE GROUPS							
	LOF.LOR		HIF.LOR		LOF.HIR		HIF.HIR	
	Male	Female	Male	Female	Male	Female	Male	Female
PLANT 1								
Initial	1	22	11	13	6	18	11	13
Final	1	11	17	19	6	29	5	7
PLANT 2								
Initial	21		22		4	18	18	1
Final	21		22		11	1	11	18
Plant 3								
Initial	12	27	6	32		40	25	10
Final	12	27	6	32	12	50	13	
Plant 4								
Initial	2	16	13	1		21		20
Final	2	16	13	1		20		21
Plant 5								
Initial	18		21		14		39	10
Final	18		21		14		39	10
Plant 6								
Initial	10	5	22		11	2		18
Final	21	7						18
Plant 7								
Initial	18	3	14	3	15		24	1
Final	18	3	38	4			15	
TOTAL								
Initial	82	73	109	49	50	99	117	76
Percent	22.9	24.8	30.4	16.7	14.0	34.5	32.7	25.9
Final	93	64	139	56	43	100	83	74
Percent	26.0	21.8	38.8	19.0	12.0	34.0	23.2	25.2

(Final and Initial exposure classification)

TABLE 5.3

MEAN AGE BY EXPOSURE GROUP AND PLANT
FINAL EXPOSURE CLASSIFICATION

PLANT	EXPOSURE GROUP							
	LOF.LOR		HIF.LOR		LOF.HIR		HIF.HIR	
	Male	Female	Male	Female	Male	Female	Male	Female
Plant 1								
Mean age	29.0	29.0	36.5	38.1	28.8	34.9	31.0	35.1
St Dev		5.3	4.9	4.2	3.4	7.9	8.3	9.6
Plant 2								
Mean age	50.2	—	46.6	—	48.5	34.0	35.5	40.8
St Dev	8.7		7.4		7.2		10.9	9.7
Plant 3								
Mean age	35.1	44.4	38.0	37.9	34.3	45.8	34.2	—
St Dev	7.2	11.6	9.6	9.1	7.0	11.3	9.4	
Plant 4								
Mean age	34.0	41.4	32.8	20.0	—	35.5	—	35.9
St Dev	5.7	6.8	9.8			10.3		9.7
Plant 5								
Mean age	33.9	—	46.2	—	46.9	—	37.6	34.9
St Dev	6.3		6.7		6.0		7.7	7.4
Plant 6								
Mean age	36.4	35.6	35.6	—	—	—	—	43.2
St Dev	9.0	6.9	11.4					9.5
Plant 7								
Mean age	46.0	36.7	38.1	33.0	—	—	43.2	--
St Dev	11.1	22.0	11.5	15.0			13.6	
Total								
Mean age	40.6	39.7	39.6	37.3	41.3	40.4	37.4	38.6
St Dev	10.8	11.2	10.4	8.3	9.8	11.4	10.0	9.7

TABLE 5.4

MEAN YEARS ON THE STUDY JOB BY EXPOSURE GROUP AND PLANT
FINAL EXPOSURE CLASSIFICATION

PLANT	EXPOSURE GROUP							
	LOF.LOR		HIF.LOR		LOF.HIR		HIF.HIR	
	Male	Female	Male	Female	Male	Female	Male	Female
Plant 1								
Years	3.0	3.9	8.1	5.2	6.1	4.9	4.9	5.9
St Dev		1.8	3.2	2.3	2.5	2.7	1.7	2.5
Plant 2								
Years	7.3	—	9.2	--	10.8	3.0	6.1	7.1
St Dev	5.2		7.6		9.1		5.9	5.8
Plant 3								
Years	8.5	9.5	10.5	6.3	9.3	10.2	9.0	—
St Dev	6.4	6.9	5.3	4.3	4.9	6.3	7.1	
Plant 4								
Years	5.0	3.7	5.4	2.5	—	7.4	--	8.0
St Dev	2.8	4.4	3.6			4.2		5.4
Plant 5								
Years	6.1	—	15.4	—	6.6	—	9.6	6.2
St Dev	3.1		6.8		7.2		6.3	2.6
Plant 6								
Years	5.5	4.6	7.5	—	--	—	--	8.9
St Dev	4.2	3.6	5.6					6.9
Plant 7								
Years	5.5	4.3	4.9	3.9	—	--	11.6	—
St Dev	4.4	4.9	6.4	3.6			13.2	
TOTAL								
Years	6.4	7.8	8.2	5.7	8.3	8.0	9.1	7.5
St Dev	4.6	5.8	6.8	3.6	6.8	5.6	7.1	5.4

Years Worked on the Study Jobs. There was some correlation between age and mean years worked on the study jobs (r2=0.22 for males and 0.27 for females, p <0.0001). Analysis of variance indicated no significant differences in mean years on the study jobs between sexes or between exposure groups. However, there were significant differences between sex*exposure groups (p <0.05). There were also significant differences between males and between females (exposure groups combined) in different plants (p <0.001).

In summary, age, sex and seniority differed across plant*exposure strata and were therefore treated as potential confounders.

Relevant Health History. There were no significant differences in the reporting of potentially related diseases for males or females by exposure category (Table 5.5). Eighty-two (12.6%) subjects reported physician diagnosed "arthritis," (14.3% of females and 11.24% of males), although the type and location was most often not specified by the subjects. Females tended to report more "arthritis" than males.

TABLE 5.5
SELF-REPORTING OF RELEVANT DISEASES
(% Positive, Final Exposure Class)

	Final Exposure Classification							
	LOF.LOR		HIF.LOR		LOF.HIR		HIF.HIR	
	M 93	F 64	M 139	F 56	M 43	F 100	M 83	F 74
CTS	1.1	6.3	2.2	3.6	4.7	4.0	6.0	6.8
Diabetes	1.1	1.6	2.2	0.0	9.3	4.0	3.6	1.4
Gout	3.2	3.1	2.9	0.0	4.7	1.0	3.6	2.7
Gall bladder	1.1	12.5	1.4	12.5	0.0	4.0	0.0	8.1
Angina	4.3	1.6	2.2	1.8	4.6	2.0	1.2	0.0
Disk	6.5	4.7	2.9	0.0	4.6	6.0	2.4	4.1
Other*	9.7	4.7	7.9	7.1	11.6	6.0	6.0	5.4
None	76.3	67.2	78.4	76.8	72.1	78.0	75.9	79.7
"Arthritis"**	5.4	18.8	16.5	8.9	7.0	13.0	10.8	16.2

* Includes: rash, psoriasis, bowel disease, gonorrhea, Reiter syndrome (1), ankylosing spondylitis (1).
** asked separately from other diseases listed

Peripheral neuropathies can be associated with chronic alcoholism. Although males reported more alcohol consumption than females, there were no significant differences between exposure categories (Table 5.6).

TABLE 5.6

REPORTED WEEKLY ALCOHOL CONSUMPTION

	Final Exposure Classification							
	LOF.LOR		HIF.LOR		LOF.HIR		HIF.HIR	
	Male	Female	Male	Female	Male	Female	Male	Female
N	93	64	139	56	43	100	83	74
				NONE				
Percent	36.6	76.6	46.0	57.1	58.1	82.0	41.0	62.2
(n)	34	49	64	32	25	82	31	46
				1-7 DRINKS PER WEEK				
Percent	34.4	17.2	33.8	26.8	23.3	15.0	37.3	33.8
(n)	32	11	47	15	10	15	31	25
				8-14 DRINKS PER WEEK				
Percent	12.9	4.7	11.5	12.5	11.6	3.0	13.3	4.1
(n)	12	3	16	7	5	3	11	3
				MORE THAN 14 DRINKS PER WEEK				
Percent	16.1	1.5	8.6	3.6	7.0	0.0	8.4	0.0
(n)	15	1	12	2	3	0	7	0

Reproductive History: Females. Reproductive history including pregnancy, birth control pill use (BCP), hysterectomy and bilateral oophorectomy, was obtained from all female subjects because of reported association with carpal tunnel syndrome (CTS). No significant association between symptoms of CTS on Interview and any of these factors was observed (Table 5.7).

TABLE 5.7

REPRODUCTIVE HISTORY AND SYMPTOMS OF CARPAL TUNNEL SYNDROME

	Bilat Oophorectomy		Hysterectomy		Current BCP	
	YES	NO	YES	NO	YES	NO
CTS	1	13	2	12	1	13
NO CTS	27	254	58	223	33	247
Odds Ratio		0.72		0.64		0.58
Fisher Exact P (two-tailed)		0.61		0.43		0.50

Recreational Activities. Subjects were asked about regular outside plant activities including sports and hobbies such as playing a musical instrument, knitting, sewing, gardening or other (Table 5.8). Within each exposure category, males tended to report more recreational activities than females. There were no significant differences in recreational activity among either the male exposure categories or among the females. There was no difference in distributions between initial and final exposure classifications

TABLE 5.8

PERCENT PARTICIPATING IN REGULAR RECREATIONAL ACTIVITIES

	LOF.LOR	HIF.LOR	LOF.HIR	HIF.HIR
Males (n yes)	49	43	18	33
% *	65.3	42.6	41.9	48.5
Females (n yes)	28	17	39	21
	45.9	32.7	39.4	28.4

5.3 Recurring Upper Extremity Pain and Discomfort

Subjects were asked about recurring or persistent (more than once or lasting more than one week) upper extremity pain or discomfort in the previous two years (Figures 5.1-5.3). Within each exposure

FIGURE 5.1
RECURRING NECK/SHOULDER PROBLEMS
(Last 2 years)

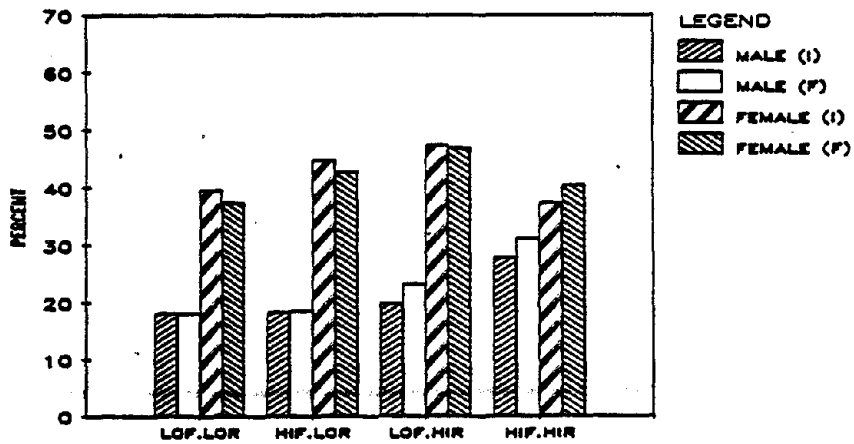


FIGURE 5.2
RECURRING ELBOW/FOREARM PROBLEMS
(Last 2 years)

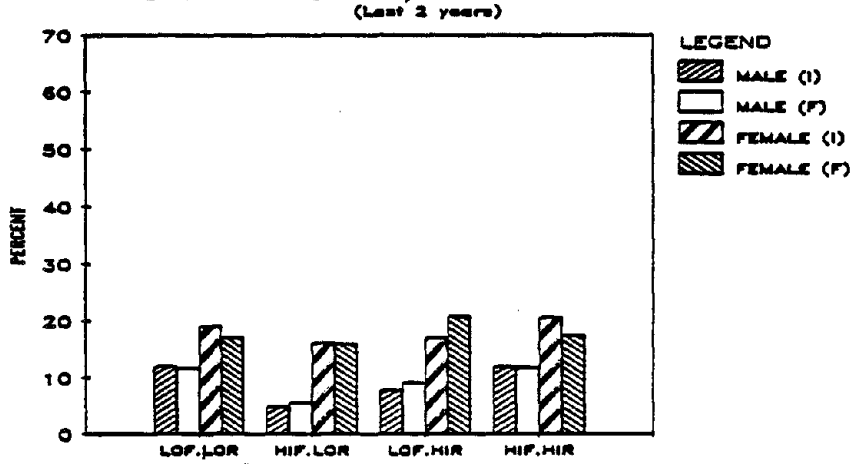
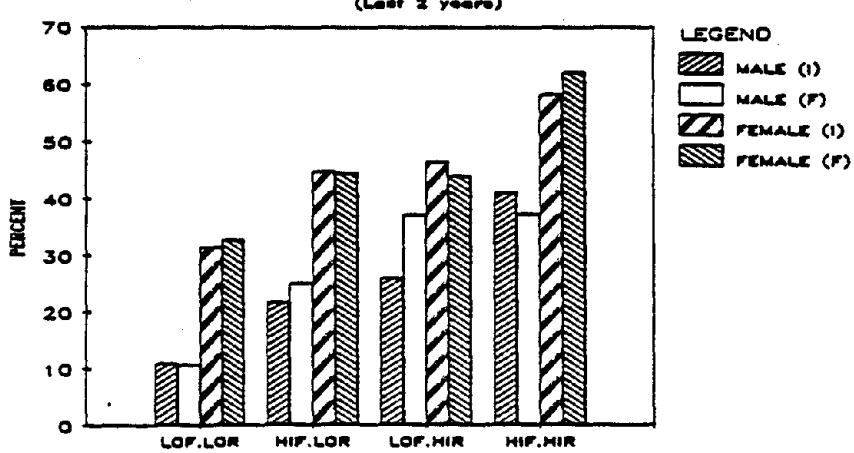


FIGURE 5.3
RECURRING HAND/WRIST PROBLEMS
(Last 2 years)



(I) INITIAL, (F) FINAL EXPOSURE CLASSIFICATION

category, females tended to report approximately twice as many recurring problems as males. There were no significant differences between categories for reported neck/shoulder or elbow/forearm problems. However, there were significant differences between categories for reported hand/wrist problems (Figure 5.3, Table 5.9).

TABLE 5.9

REPORTED RECURRING HAND WRIST PROBLEMS: LAST 2 YEARS
PLANT COMBINED ODDS RATIOS

	FINAL EXPOSURE CLASSIFICATION			
	LOF.LOR	HIF.LOR	LOF.HIR	HIF.HIR
MALES				
Yes (n)	10	35	16	31
No (n)	83	104	27	52
Odds Ratio	1.0	2.8*	4.9***	5.0****
FEMALES				
Yes (n)	21	25	44	46
No (n)	43	31	56	28
Odds Ratio	1.0	1.7	1.6	3.4**

*p <0.05 **p <0.01 ***p <0.001 ****p <0.0001

"Recurring" does not discount those whose symptoms began prior to work on the study job or those related to non-CTD problems (acute injury onset, cervical root disorders, etc.).

With respect to the reporting of recurring problems, number of hours worked at the time of interview was examined. There were no significant differences in the hours worked between those reporting problems and those not reporting problems (the mean was approximately 3 hours for both groups). Additionally, there were no significant differences in the reporting of recurring problems by interviewer when stratified by exposure group.

5.4 Any Upper Extremity Cumulative Trauma Disorders

There were 205 (31.4%) subjects who met the general criteria

(Table 3.3) of having any upper extremity CTD on Interview. Females had approximately twice the prevalence of CTDs on Interview (44.6%) as males (20.7%). CTDs on PE and Interview were identified among 60 males (11.2%) and 80 females (27.2%) (Figure 5.4). The difference in prevalence between males and females (exposure groups combined) was statistically significant ($p < 0.0001$).

Males and females within categories were not always performing the same job. Job adjusted odds ratios for females compared to males working on the same jobs indicates that females in HIF.LOR and LOF.HIR jobs had significantly higher odds of having any CTD on Interview than males. No significant differences were detected on PE and Interview (Table 5.10).

TABLE 5.10

ANY CTDS: FEMALE TO MALE COMPARISON
WITHIN EXPOSURE CATEGORIES
JOB ADJUSTED ODDS RATIOS

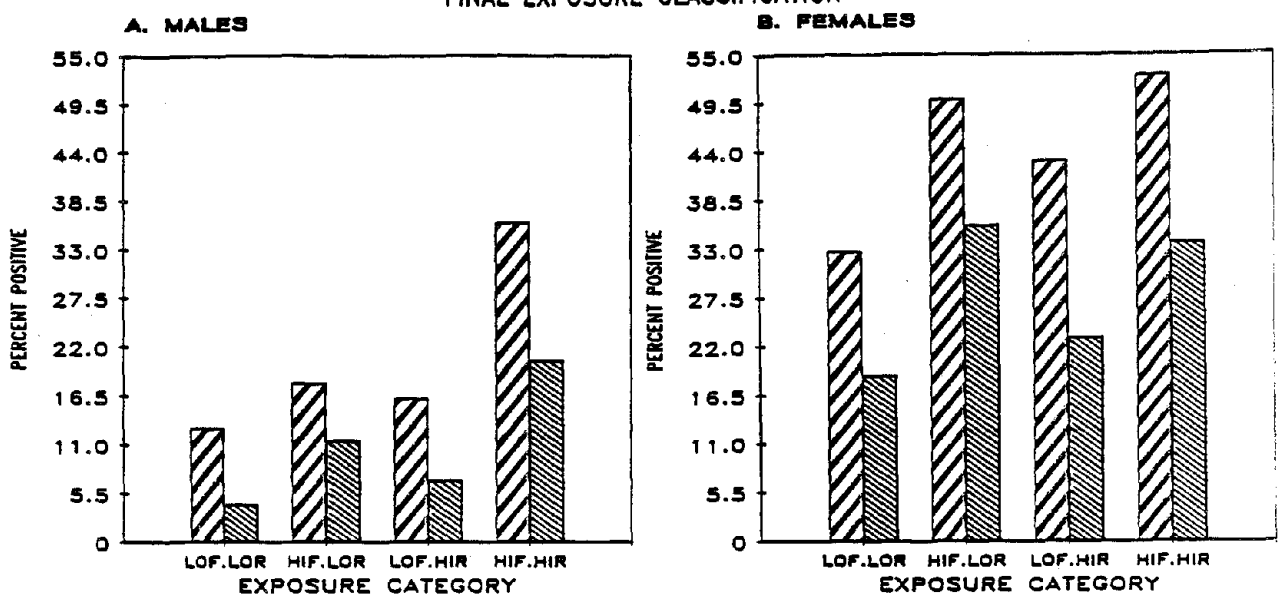
	LOF.LOR	HIF.LOR	LOF.HIR	HIF.HIR	TOTAL
JOBS	(7)	(8)	(3)	(3)	(21)
INTERVIEW	1.0	3.3*	6.0*	2.4	2.5***
#	(6)	(8)	(3)	(3)	(20)
PE & INTERVIEW	0.7	2.0	2.9	2.3	1.8
#	(4)	(8)	(2)	(3)	(17)

Chi square (M-H) *p <0.05 **p <0.01 ***p <0.001
(Total of 188 males and 151 females in 21 Jobs)
Number of jobs in which there were any cases

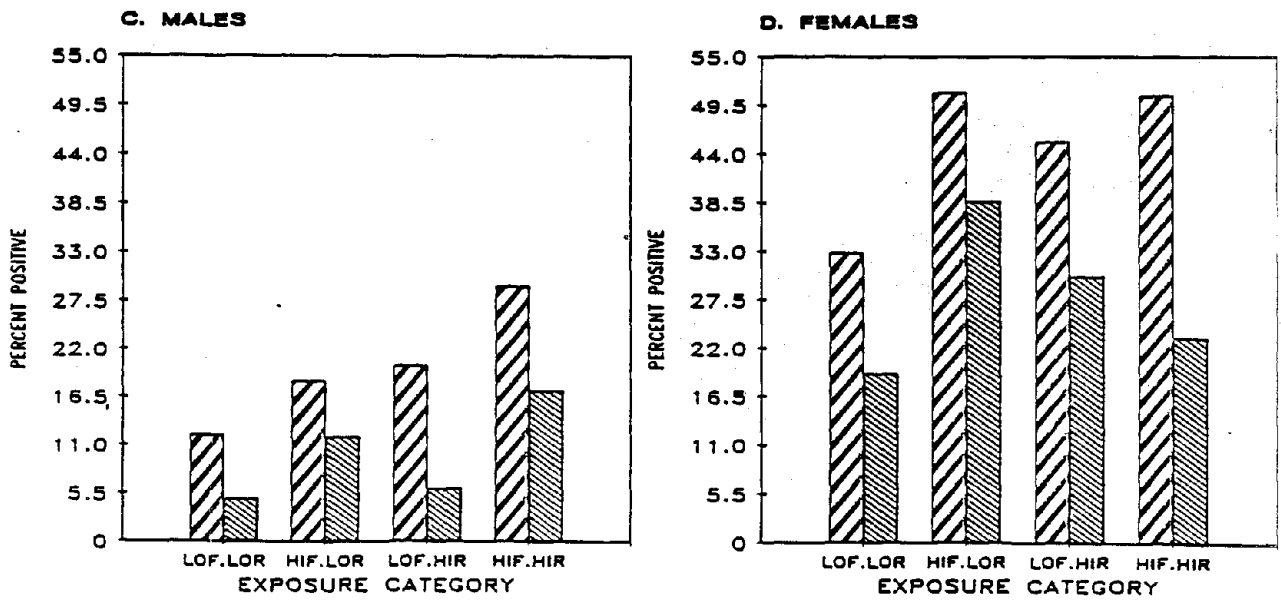
FIGURE 5.4

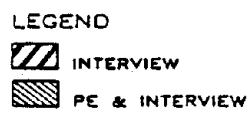
PREVALENCE OF ANY CTDS

FINAL EXPOSURE CLASSIFICATION



INITIAL EXPOSURE CLASSIFICATION





Plant adjusted odds ratios were elevated for all male groups compared to the LOF.LOR group (Table 5.11). The odds ratios HIF.LOR males (OR=2.7) and for HIF.HIR males (OR=3.6) on PE and Interview were statistically significant. Significant differences between females were not detected.

TABLE 5.11

ANY CTDS BY FINAL EXPOSURE CLASSIFICATION: ODDS RATIOS (OR)

		EXPOSURE			
INTERVIEW		LOF.LOR	HIF.LOR	LOF.HIR	HIF.HIR
MALES					
Yes	(n)	12	25	7	30
No	(n)	81	113	36	53
Crude OR		1.0	1.5	1.3	3.8****
Plant Adjusted OR		1.0	2.0	1.3	3.5**
FEMALES					
Yes	(n)	21	28	43	39
No	(n)	43	28	57	35
Crude OR		1.0	2.1	1.4	2.1*
Plant Adjusted OR		1.0	1.5	1.2	2.4
PE & INTERVIEW					
		LOF.LOR	HIF.LOR	LOF.HIR	HIF.HIR
MALES					
Yes	(n)	4	16	3	17
No	(n)	89	123	40	66
Crude OR		1.0	2.9	2,7	5.7**
Plant Adjusted OR		1.0	2.7*	3.6	3.6*
FEMALES					
Yes	(n)	12	20	23	25
No	(n)	52	36	77	49
Crude OR		1.0	3.6*	1.2	2.1
Plant Adjusted OR		1.0	1.9	1.0	2.5

*p <0.05 **p <0.01 ***p <0.001 ****p <0.0001

There were 64 individuals (9.8%) who had more than one CTD on Interview and 29 individuals (4.4%) with more than one CTD on PE and Interview, (Table 5.12). Compared to the LOF.LOR category, workers in the other three categories tended to have more multiple CTDs on both

Interview and on PE and Interview. The differences were significant for both high repetitive categories.

TABLE 5.12

PREVALENCE OF MULTIPLE CTDS BY FINAL EXPOSURE CLASSIFICATION

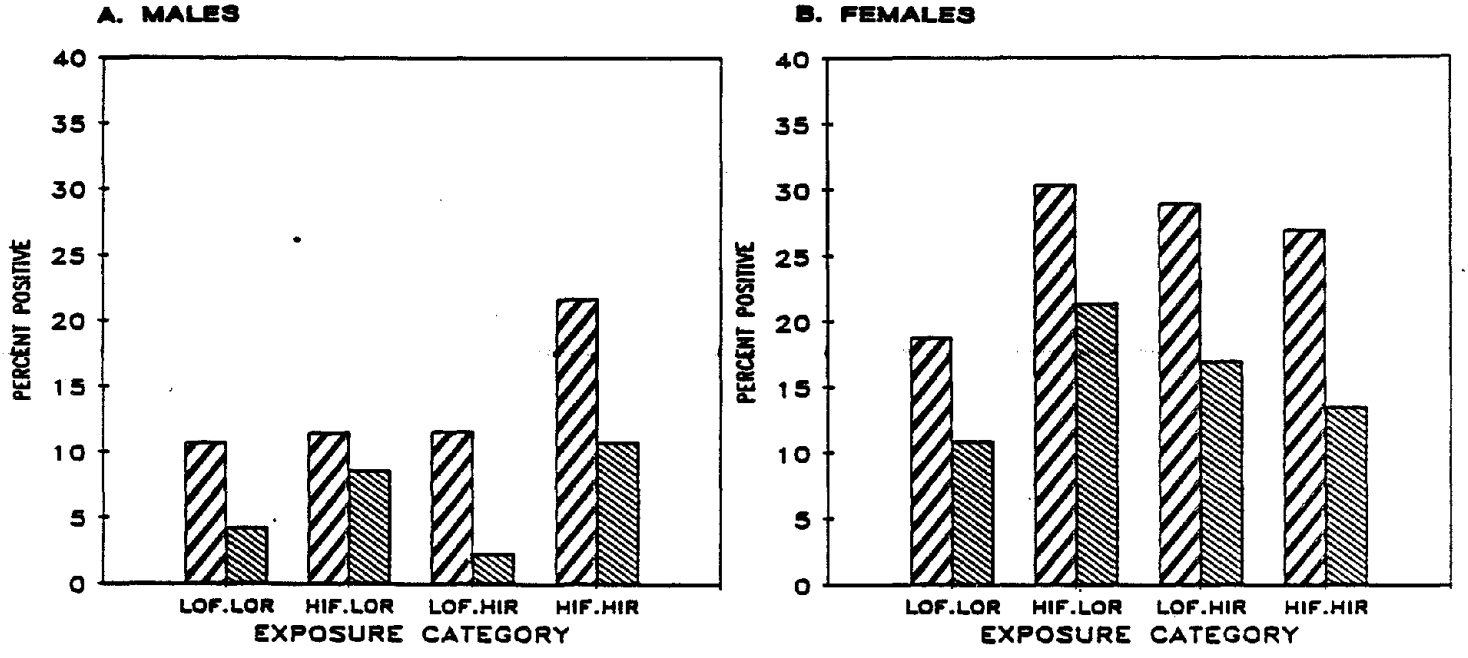
	EXPOSURE			
	LOF.LOR	HIF.LOR	LOF.HIR	HIF.HIR
INTERVIEW	4.5%	8.7%	13.3%*	13.4%*
(n yes)	7	17	19	21
PE & INTERVIEW	1.3%	4.1%	7.0%*	5.7%*
(n yes)	2	8	10	9

*p <0.05 **p <0.01

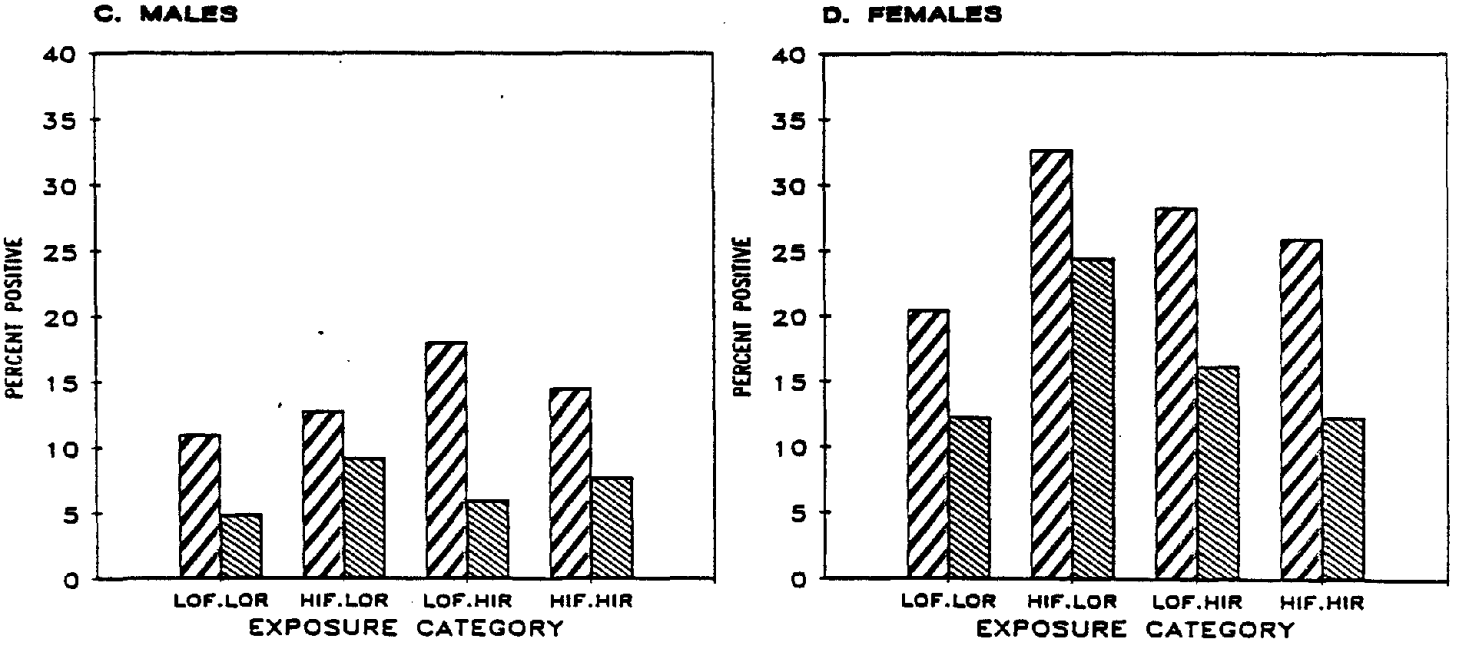
When hand wrist CTDs were excluded from "Any Upper Extremity CTDs," there were no statistically significant differences between exposure categories for either males or females (Figure 5.5, Table 5.13).

FIGURE 5.5
PREVALENCE OF ANY CTDS EXCLUDING HAND WRIST CTDS

FINAL EXPOSURE CLASSIFICATION



INITIAL EXPOSURE CLASSIFICATION



LEGEND

INTERVIEW

PE & INTERVIEW

TABLE 5.13

PREVALENCE OF ANY UPPER EXTREMITY CTDs EXCLUDING HAND WRIST
Final Exposure Category

INTERVIEW		EXPOSURE LOF.LOR	HIF.LOR	LOF.HIR	HIF.HIR
MALES					
Yes	(n)	1.0	16	5	18
No	(n)	83	123	38	65
Crude OR		1.0	1.1	1.1	2.3
Plant Adjusted OR		1.0	1.6	0.8	2.0
FEMALES					
Yes	(n)	12	17	29	20
No	(n)	52	39	71	54
Crude OR		1.0	1.9	1.8	1.6
Plant Adjusted OR		1.0	1.5	1.3	2.4

PE & INTERVIEW		LOF.LOR	HIF.LOR	LOF.HIR	HIF.HIR
MALES					
Yes	(n)	4	12	1	9
No	(n)	89	127	42	74
Crude OR		1.0	2.1	0.6	2.7
Plant Adjusted OR		1.0	2.1	1.1	1.7
FEMALES					
Yes	(n)	7	12	17	10
No	(n)	57	44	83	64
Crude OR		1.0	2.2	1.7	1.3
Plant Adjusted OR		1.6	1.8	1.3	0.8
SEX COMBINED					
Crude OR		1.0	3.0	4.5*	9.8****
Plant Adjusted OR		1.0	2.4	2.7	16.6****

*p <0.05 **p <0.01 ***p <0.001 ****p <0.0001

5.4.2 Hand Wrist Disorders

Analyses were performed for Any Hand Wrist CTDs (Chapter 3, Evaluation of Health Status). A subset of Any Hand Wrist CTDs was also analyzed (Hand Wrist CTDs Excluding Localized Osteoarthrosis). In this subset (5.4.2A), those subjects with only symptoms of localized osteoarthrosis of the finger joints were considered as negative for CTDs. Two additional subsets of hand wrist CTDs were also analyzed: Hand Wrist Tendinitis (Section 5.4.2A.1) and Carpal Tunnel Syndrome (Section 5.4.2A.2). These two specific hand wrist CTDs were included in Any Hand Wrist CTDs and Hand Wrist CTDs (excluding LOA).

There were 128 subjects (19.6%) who met the criteria for any hand/wrist CTDs on Interview (11.7% of males and 29.3% of females, p <0.0001). On PE and Interview, there were 66 subjects (10.1%) with hand wrist CTDs (4.7% of males and 16.7% of females, p <0.0001) (Figure 5.8).

TABLE 5.14

ANY HAND WRIST CTDS: FEMALE TO MALE COMPARISON
JOB ADJUSTED ODDS RATIOS

JOBS	LOF.LOR (7)	HIF.LOR (8)	LOF.HIR (3)	HIF.HIR (3)	TOTAL (21)
INTERVIEW	1.2	3.9*	5.2*	2.6	2.8***
#	(5)	(7)	(2)	(3)	(14)
PE & INTERVIEW	5.8	2.6	4.7	1.8	2.2*
#	(2)	(6)	(1)	(3)	(12)

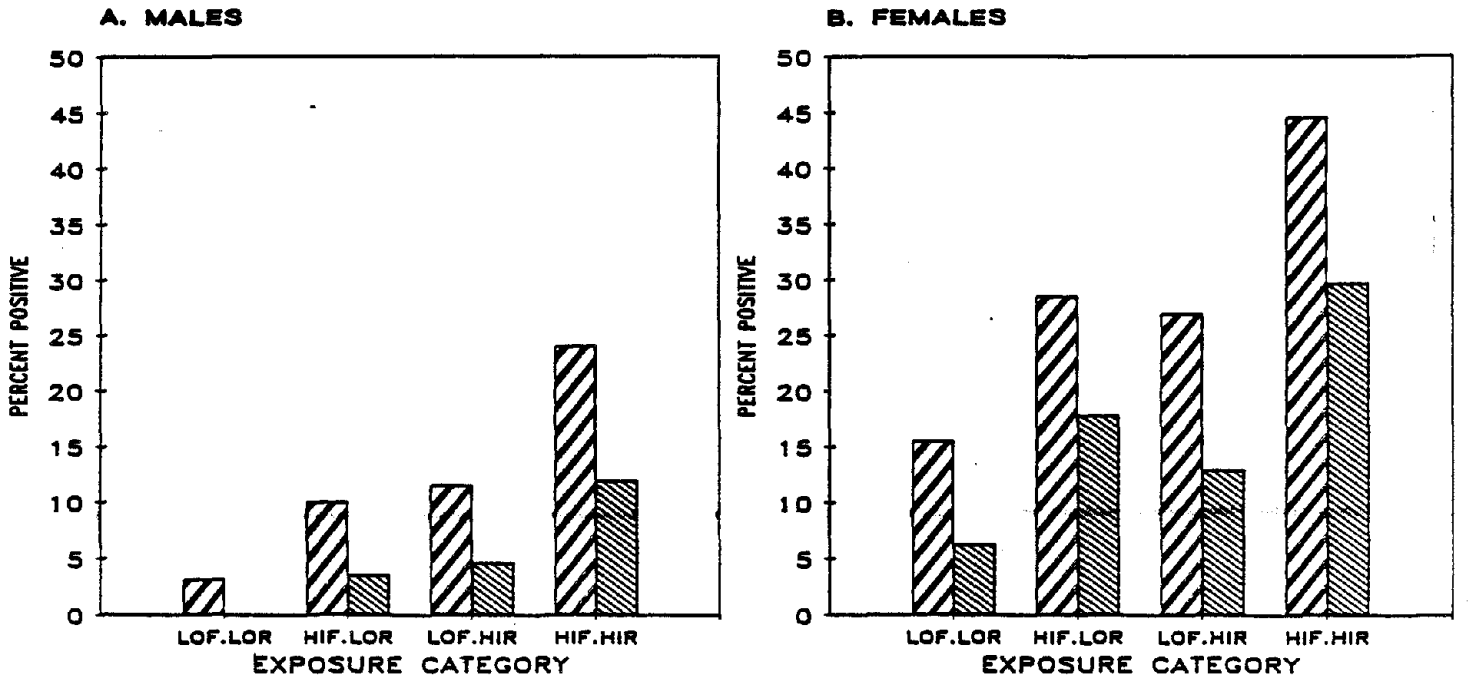
Chi square (M-H) *p <0.05 **p <0.01 ***p <0.001
(Total of 188 males and 151 females in 21 Jobs)
Number of jobs in which there were any cases

The odds ratio for LOF.HIR, and HIF.LOR females was statistically significant for any hand wrist CTDs on Interview (Table 5.14). There was insufficient power to detect any significant differences between the sexes within specific exposure categories but the overall odds for females was 2.2 times that of males on PE and Interview ($p < 0.05$).

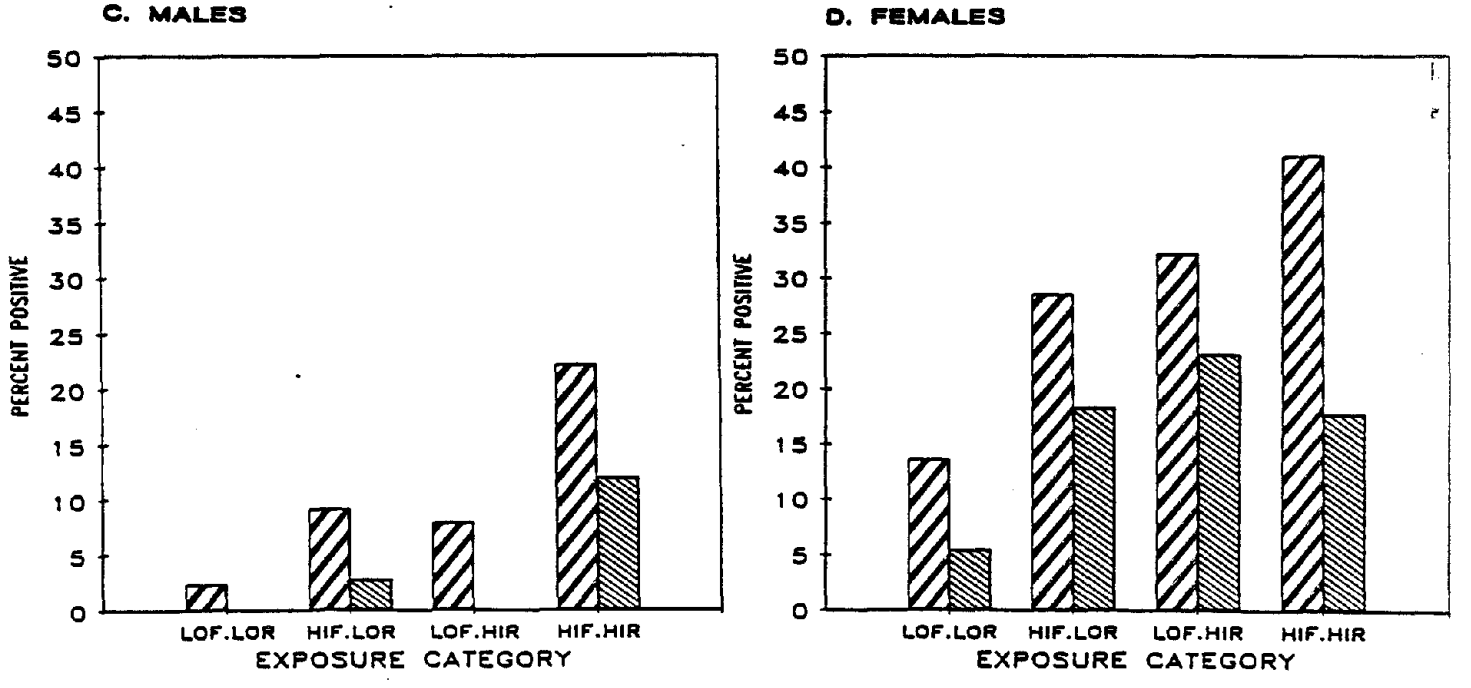
Subjects in all three other exposure categories had higher odds of having hand wrist disorders than those in the LOF.LOR category (Table 5.15). The odds ratios were statistically significant for males in both high repetitive groups on Interview and for both sexes in the HIF.HIR category on PE and interview. HIF.HIR workers had more than 16 times the odds of hand wrist disorders than LOF.LOR workers ($p < 0.0001$). The combined odds ratio for the HIF.HIR group is substantially higher than for either sex alone. This is because females in 2 HIF.HIR jobs did not have female controls so were excluded from the female specific analysis but included in the combined analysis. Among female Punch Press operators and Hand Grinders, 56% and 30% had hand wrist CTDs on PE and Interview.

FIGURE 5.6
ANY HAND WRIST CTDS

FINAL EXPOSURE CLASSIFICATION



INITIAL EXPOSURE CLASSIFICATION



LEGEND

INTERVIEW

PE & INTERVIEW

TABLE 5.15

ANY HAND WRIST CTDS BY FINAL EXPOSURE CLASSIFICATION
ODDS RATIOS (OR)

		EXPOSURE			
INTERVIEW		LOF.LOR	HIF.LOR	LOF.HIR	HIF.HIR
MALES					
Yes	(n)	3	14	5	20
No	(n)	90	120	38	63
Crude OR		1.0	3.4	3.9	9.5***
Plant Adjusted OR		1.0	2.3	8.2*	7.3***
FEMALES					
Yes	(n)	10	16	27	33
No	(n)	54	40	73	41
Crude OR		1.0	2.2	2.0	4.3***
Plant Adjusted OR		1.0	1.6	2.0	4.1
PE & INTERVIEW		LOF.LOR	HIF.LOR	LOF.HIR	HIF.HIR
MALES					
Yes	(n)	0	5	2	10
No	(n)	93	134	41	73
Crude OR		1.0	7.7	11.3	26.7***
Plant Adjusted OR		1.0	7.4	6.0	4.9*
FEMALES					
Yes	(n)	4	9	13	22
No	(n)	60	47	87	52
Crude OR		1.0	2.9	2.2	6.3***
Plant Adjusted OR		1.0	2.0	2.0	6.0*
SEX COMBINED					
Crude OR		1.0	3.0	4.5*	9.8****
Plant Adjusted OR		1.0	2.4	2.7	16.6****

*p <0.05 **p <0.01 ***p <0.001 ****p <0.0001

Overall prevalence of any hand wrist CTDs among males did not differ significantly by age group (Table 5.16). Among females, there was a significant age trend on Interview ($p < 0.05$) and on PE and Interview ($p < 0.01$), although the increase does not appear to occur until after the age of 40.

TABLE 5.16

PREVALENCE OF ANY HAND WRIST CTDS
STRATIFIED BY AGE, SEX AND EXPOSURE GROUP

STUDY NUMBER		LOF.LOR		HIF.LOR		LOF.HIR		HIF.HIR		TOTAL	
		M	F	M	F	M	F	M	F	M	F
20-29		23	14	30	10	7	21	26	17	86	62
30-39		31	21	51	27	12	38	32	29	126	115
40-49		13	17	31	12	15	14	14	19	73	62
50-59		24	9	25	7	9	22	10	6	68	44
60+		2	3	2	0	0	5	1	3	5	11
		POSITIVE ON INTERVIEW									
20-	N	1	1	2	3	2	4	7	3	12	11
	%	4.3	7.1	6.7	30.0	28.6	19.0	26.9	17.6	14.0	17.7
30-	N	2	5	4	6	2	10	9	11	17	32
	%	6.5	23.8	7.8	22.2	16.7	26.3	28.4	37.9	13.5	27.8
40-	N	0	2	2	5	1	5	3	12	6	24
	%	0.0	11.8	6.5	41.7	6.7	35.7	21.4	63.2	8.2	38.7
50-	N	0	2	5	2	0	7	1	5	5	16
	%	0.0	22.2	20.0	28.6	0.0	31.8	10.0	83.3	9.4	36.4
60+	N	0	0	1			1		2	1	3
	%	0.0	0.0	50.0			20.0		66.7	20.0	27.3
		POSITIVE ON PE & INTERVIEW									
20-	N	0	1	1	3	0	1	4	3	5	8
	%	0.0	7.1	3.3	30.0	0.0	4.8	15.4	17.6	5.8	12.9
30-	N	0	1	1	2	2	2	4	7	7	12
	%	0.0	4.8	2.0	7.4	16.7	5.3	12.5	24.1	5.6	10.4
40-	N	0	0	1	4	0	3	2	5	3	12
	%	0.0	0.0	3.2	33.3	0.0	21.4	14.3	26.3	4.1	19.4
50-	N	0	2	2	1	0	6	0	5	2	14
	%	0.0	22.2	8.0	14.3	0.0	27.3	0.0	83.3	2.9	31.8
60+	N	0	0	0			1	0	2	0	3
	%	0.0	0.0	0.0			20.0	0.0	66.7	0.0	27.3

Logistic regression techniques were used to evaluate the association between exposure and hand wrist CTDs on PE and Interview while controlling for sex (female=1, male=0), age, years on the specific job and plant effect (Table 5.17). Plant and sex were statistically significant ($p < 0.0001$) and included in all models. (For clarity of presentation plants are not listed in this table. Neither age or years on the job were statistically significant predictors. However there were statistically significant interactions between sex and years on the job (sex*years) as well as age and years on the job ($p < 0.05$). The exposure predictors in the logistic regression analysis ($p < 0.0001$) closely parallel the observed odds ratios in the stratified analysis Table 5.15).

TABLE 5.17

PREDICTORS OF ANY HAND WRIST CTDS ON PE & INTERVIEW
MULTIPLE LOGISTIC REGRESSION ANALYSIS, N=652

(Plants included in all models)

MODEL	I		II FINAL EXPOSURE		III INITIAL EXPOSURE	
PREDICTOR	COEFFICIENT (ST ERROR)	ODDS RATIO	COEFFICIENT (ST ERROR)	ODDS RATIO	COEFFICIENT (ST ERROR)	ODDS RATIO
SEX	1.2431 (.52292)	3.5	.77709 (.70967)	2.2	1.1136 (.52512)	3.0
AGE	0.01513 (.023429	1.0	-.00169 (.02497)	1.0	-.01810 (.02417)	1.0
YEARS JOB	-.14887 (.12719)	0.9	-.19004 .13187	0.8	-.21117 .12984	0.8
AGE*YEARS	.00265 (.00245)	1.0	.00304 (.00253)	1.0	.00380 (.00250)	1.0
SEX*YEARS	.09192 (.04767)	1.1	.11068 (.04843)	1.1	.10263 (.04882)	1.1
HIF.LOR			1.6572 (.61855)	5.2	1.5411 (.62090)	4.7
LOF.HIR			1.0434 (.60932)	2.8	1.5503 (.58377)	4.7
HIF.HIR			2.7925 (.62846)	16.3	2.2198 (.58871)	9.2
-2 LOG LIKELIHOOD	373.11		343.01		352.88	

Statistically significant predictors: Sex, Plants, Age*Years, Sex*Years, Exposure

In order to assess comparability of findings on physical exam between examiners (4), hand wrist diagnoses (Appendix 7) were stratified by examiner and exposure category. Significant differences were identified for hand tendinitis in the HIF.HIR group ($p < 0.02$) and DeQuervain's disease in the LOF.HIR group ($p < 0.05$). When these diagnoses were stratified by specific job and examiner, there were no significant differences observed.

A. Hand Wrist CTDs (Excluding Localized Osteoarthrosis)

When symptomatic localized osteoarthrosis (LOA) was excluded from consideration as a CTD (12 females, 5 males), there were 111 subjects (17.0%) with symptom criteria for hand wrist CTDs (pain, tingling and or numbness) on Interview (10.3% of males and 25.2% of females, $p < 0.0001$). There were 53 subjects (8.1%) with hand wrist CTDs on PE and Interview (3.9% of males and 13.3% of females, $p < 0.0001$). Prevalence of these disorders were not evenly distributed across exposure categories (Figure 5.7). Stratified results are presented by sex (Table 5.18), exposure group by sex (Table 5.19), age group (Table 5.20) and plant (Table 5.21).

TABLE 5.18

HAND WRIST CTDS (EXCLUDING LOA):FEMALE TO MALE COMPARISON
JOB ADJUSTED ODDS RATIOS

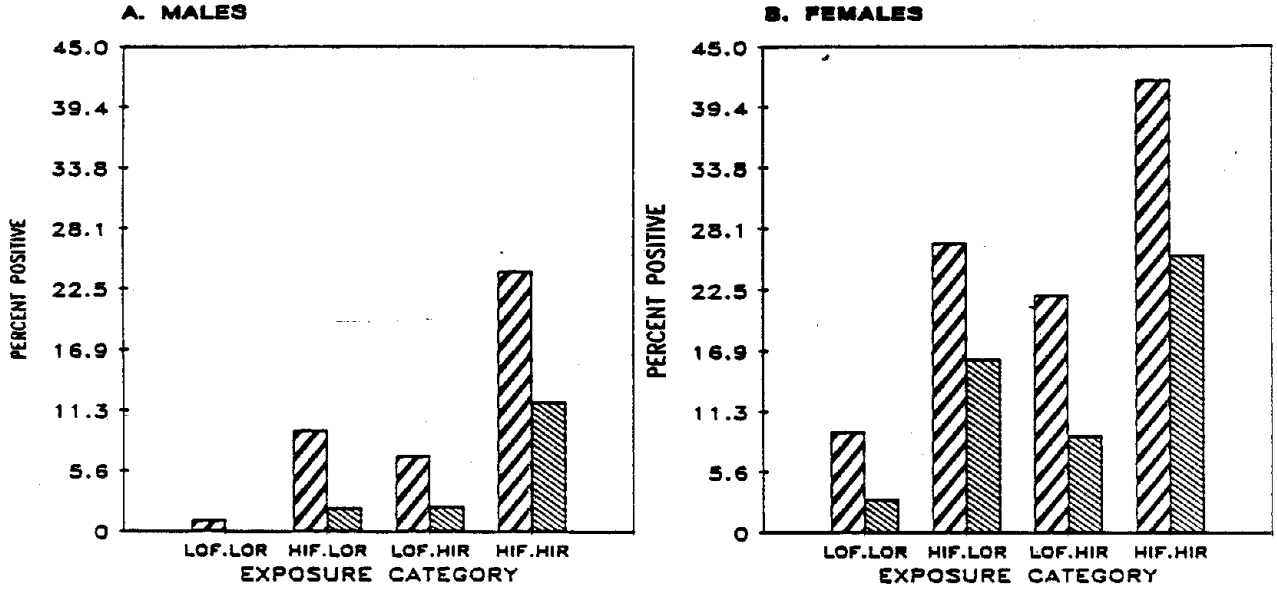
	LOF.LOR	HIF.LOR	LOF.HIR	HIF.HIR	TOTAL
JOBS	(7)	(8)	(3)	(3)	(21)
INTERVIEW	2.7	3.1	15.3**	2.1	3.2***
#	(4)	(7)	(2)	(3)	(16)
PE & INTERVIEW	5.8	2.6	2.8	1.6	2.2
#	(1)	(6)	(1)	(3)	(11)

Chi square (M-H) *p <0.05 **p <0.01 ***p <0.001
(Total of 188 males and 151 females in 21 Jobs)
Number of jobs in which there were any cases

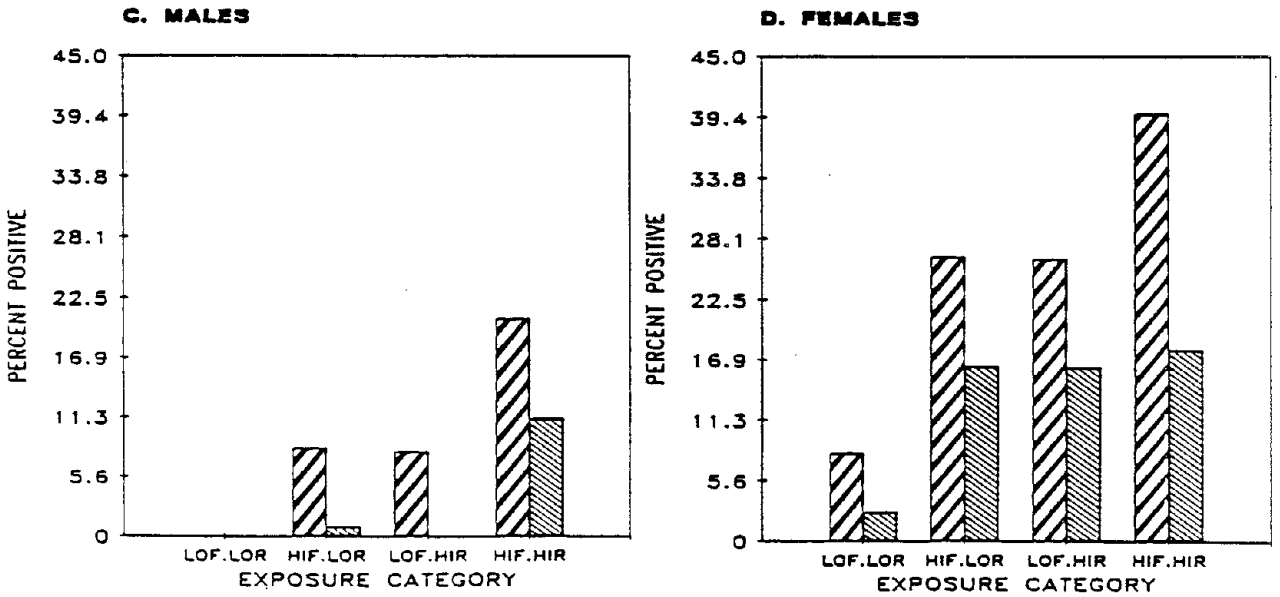
FIGURE 5.7

HAND WRIST CTDS (EXCLUDING LOA)

FINAL EXPOSURE CLASSIFICATION



INITIAL EXPOSURE CLASSIFICATION



Females in the LOF.HIR category reported significantly more hand wrist CTDs on Interview than males. This was largely attributable to the Burr Bench job at Plant 3 where 7/10 females and 4/12 males reported hand wrist CTDs on Interview ($p < 0.05$). Statistically significant gender differences were not detected on PE and Interview (Table 5.18). Plant adjusted odds ratios (Table 5.19) indicate increased risk for hand wrist CTDs (excluding LOA) in all exposure categories compared to the LOF.LOR category. Among males on Interview, the statistically significant odds ratios ranged from 5.0 in the LOF.HIR group to 10.6 in the HIF.HIR group. On PE and Interview, the risk for HIF.HIR males was 5 times that for the LOF.LOR group ($p < 0.05$). Among females, the HIF.HIR group had more than a 6 fold increased risk of having hand wrist CTDs (excluding LOA) on Interview ($p < 0.05$) and a 5 fold risk on PE and Interview, though not statistically significant.

In the sex combined analysis, the odds ratio for the HIF.HIR group was 30.3 ($p < 0.0001$). The high prevalence of these disorders among female Punch Press operators (44.4%) and female Hand Grinders (30%) is reflected in the sex combined odds ratio for the HIF.HIR group.

TABLE 5.19

HAND WRIST CTDS (EXCLUDING LOA) BY FINAL EXPOSURE CLASSIFICATION
ODDS RATIOS (OR)

		EXPOSURE			
INTERVIEW		LOF.LOR	HIF.LOR	LOF.HIR	HIF.HIR
MALES					
Yes	(n)	1	13	3	20
No	(n)	92	126	40	63
Crude OR		1.0	8.8**	6.9	29.2****
Plant Adjusted OR		1.0	8.9*	5.0*	10.6***
FEMALES					
Yes	(n)	6	15	22	31
No	(n)	58	41	78	43
Crude OR		1.0	3.5*	2.7*	7.0****
Plant Adjusted OR		1.0	2.5	2.7	6.4*
PE & INTERVIEW		LOF.LOR	HIF.LOR	LOF.HIR	HIF.HIR
MALES					
Yes	(n)	0	3	1	10
No	(n)	93	136	42	83
Crude OR		1.0	4.8	6.6	23.5**
Plant Adjusted OR		1.0	2.7	3.3	4.9*
FEMALES					
Yes	(n)	2	9	9	19
No	(n)	62	47	91	55
Crude OR		1.0	5.9*	3.1	10.7***
Plant Adjusted OR		1.0	4.1	2.9	5.2
SEX COMBINED					
Crude OR		1.0	5.1*	5.8*	16.3****
Plant Adjusted OR		1.0	3.0	3.6	30.3****

*p <0.05 **p <0.01 ***p <0.001 ****p <0.0001

There were no statistically significant age trends observed for overall prevalence of hand wrist CTDs (excluding LOA) for either males or females by age group (Table 5.20).

TABLE 5.20

PREVALENCE OF HAND WRIST CTDS (EXCLUDING LOA)
STRATIFIED BY AGE, SEX AND EXPOSURE GROUP

STUDY NUMBER		LOF.LOR		HIF.LOR		LOF.HIR		HIF.HIR		TOTAL	
		M	F	M	F	M	F	M	F	M	F
20-29		23	14	30	10	7	21	26	17	86	62
30-39		31	21	51	27	12	38	32	29	126	115
40-49		13	17	31	12	15	14	14	19	73	62
50-59		24	9	25	7	9	22	10	6	68	44
60+		2	3	2	0	0	5	1	3	5	11
				POSITIVE ON INTERVIEW							
20-	N	0	1	2	2	1	3	7	3	10	9
	%	0.0	7.1	6.7	20.0	14.3	14.3	26.9	17.6	11.6	14.5
30-	N	1	4	4	6	1	9	9	11	15	30
	%	3.2	19.0	7.8	22.2	8.3	23.7	28.1	37.9	11.9	26.1
40-	N	0	1	2	5	1	4	3	12	6	22
	%	0.0	5.9	6.5	41.7	6.7	28.6	21.4	63.2	8.2	35.5
50-	N	0	0	4	2	0	6	1	4	5	12
	%	0.0	0.0	16.0	28.6	0.0	27.3	10.0	66.7	7.4	27.3
60+	N	0	0	1			0	0	1	1	1
	%	0.0	0.0	50.0			0.0	0.0	33.3	20.0	9.1
				POSITIVE ON PE & INTERVIEW							
20-	N	0	1	1	2	0	1	4	3	5	7
	%	0.0	7.1	3.3	20.0	0.0	4.8	15.4	17.6	5.8	11.3
30-	N	0	1	0	2	1	2	4	7	5	12
	%	0.0	4.8	0.0	7.4	8.3	5.3	12.5	24.1	4.0	10.4
40-	N	0	0	1	4	0	2	2	5	3	11
	%	0.0	0.0	3.2	33.3	0.0	14.3	14.3	26.3	4.1	17.7
50-	N	0	0	1	1	0	4	0	3	1	8
	%	0.0	0.0	4.0	14.3	0.0	18.2	0.0	50.0	1.5	18.2
60+	N	0	0	0			0	0	1	0	1
	%	0.0	0.0	0.0			0.0	0.0	33.3	0.0	9.1

The overall prevalence of hand wrist CTDs (excluding LOA) on PE and Interview ranged between 2.6% at Plant 7 to 12.5% at Plant 3 (Table 5.21). No statistically significant difference between plants was observed in the stratified analysis.

TABLE 5.21

PREVALENCE OF HAND WRIST CTDS (EXCLUDING LOA)
ON PE & INTERVIEW BY PLANT

FINAL EXPOSURE CLASSIFICATION

	LOF.LOR	HIF.LOR	LOF.HIR	HIF.HIR	TOTAL
PLANT 1					
Yes (n)	0	3	0	3	6
No (n)	12	33	35	9	89
% Yes	0.0	8.3	0.0	25.0	6.3
PLANT 2					
Yes (n)	0	0	0	9	9
No (n)	21	22	12	20	75
% Yes	0.0	0.0	0.0	31.0	10.7
PLANT 3					
Yes (n)	2	6	9	2	19
No (n)	37	32	53	11	133
% Yes	5.1	15.8	14.5	15.4	12.5
PLANT 4					
Yes (n)	0	0	1	2	3
No (n)	18	14	19	19	70
% Yes	0.0	0.0	5.0	9.5	4.1
PLANT 5					
Yes (n)	0	1	0	8	9
No (n)	18	20	14	41	93
% Yes	0.0	4.8	0.0	16.3	8.8
PLANT 6					
Yes (n)	0	0	-	5	5
No (n)	28	22	-	13	63
% Yes	0.0	0.0	0.0	27.8	7.4
PLANT 7					
Yes (n)	0	0	-	5	5
No (n)	28	22	-	13	63
% Yes	0.0	0.0	0.0	27.8	7.4
TOTAL					
Yes (n)	2	12	10	29	53
No (n)	135	183	133	128	599
% Yes	1.3	6.2	7.0	18.5	8.1

The predictors in the logistic regression analysis (Table 5.22) were quite similar to the odds ratios observed in the stratified analysis (Table 5.20). Exposure, plant and sex (F:M) were the only significant predictors. There were no significant interaction terms. The models that predicted association between sex and hand wrist disorders (odds ratio=4.7) did not take into account job differences within exposure categories. The predicted odds ratio for the HIF.HIR category compared to the HIF.LOR category was 4.2 (exp(3.2504-1.8046)) and compared to the LOF.HIR category, it was 7.2 (exp(3.2504-1.2740)). When FORCE (0, 1 variable), irrespective of repetitiveness, was entered into Model I, the odds ratio for High Force was 4.5 ($p < 0.001$). When REPETITIVENESS (0, 1 variable) was entered into Model I, the odds ratio for High Repetitiveness was 2.3 ($p < 0.05$).

TABLE 5.22

PREDICTORS OF HAND WRIST CTDS (EXCLUDE LOA): PE & INTERVIEW
MULTIPLE LOGISTIC REGRESSION ANALYSIS. N=652

(Plants included in all models)

MODEL	I		II FINAL EXPOSURE		III INITIAL EXPOSURE	
PREDICTOR	COEFFICIENT (ST ERROR)	ODDS RATIO	COEFFICIENT (ST ERROR)	ODDS RATIO	COEFFICIENT (ST ERROR)	ODDS RATIO
SEX	1.8362 (.39802)	6.3	1.5087 (.39657)	4.5	1.8016 (.40817)	6.1
AGE	- .00673 (.01715)	1.0	.00952 (.01831)	1.0	-.00177 (.01735)	1.0
YEARS JOB	.00323 (.02992)	1.0	- .01219 (.03093)	1.0	- .00154 (.03051)	1.0
PLANT 2	1.4708 (.59781)	4.4	.37345 (.64108)	1.5	1.3373 (.60792)	3.8
PLANT 3	.78158 (.50795)	2.2	1.1228 (.52287)	3.1	.85095 (.51639)	2.3
PLANT 4	- .56693 (.73308)	0.6	- 1.0737 (.77938)	0.3	- .79816 (.74785)	0.5
PLANT 5	1.5655 (.61868)	4.9	.39366 (.64947)	1.5	1.0033 (.62179)	2.7
PLANT 6	.68920 (.64782)	2.0	-.20597 (.72494)	0.8	.23819 (.67759)	1.3
PLANT 7	.24379 (.87370)	1.3	-.20727 (.90154)	0.8	.10515 (.88817)	1.1
HIF.LOR			1.8171 (.78727)	6.2	1.6469 (.79904)	5.2
LOF.HIR			1.2680 (.79819)	3.6	1.8272 (.77574)	6.2
HIF.HIR			3.2908 (.79659)	26.9	2.7188 (.76138)	15.2
-2 LOG LIKELIHOOD	332.25		299.06		308.74	

Statistically significant predictors: sex, plants, exposure

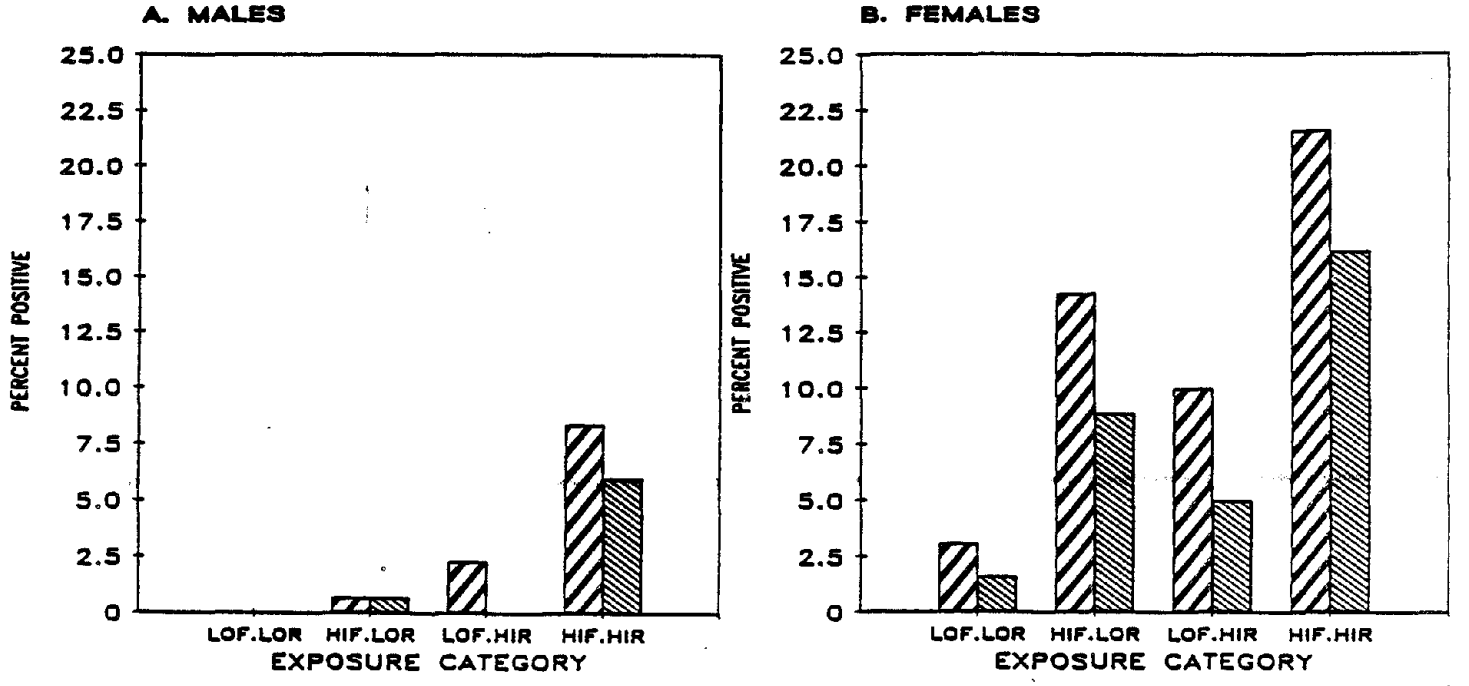
1. Hand Wrist Tendinitis

There were 45 subjects (6.9%) who met the criteria for tendinitis (2.5% of males and 12.2% of females) on Interview. On both PE and Interview, there were 29 subjects (4.4%) with hand wrist tendinitis. The prevalence of tendinitis was not evenly distributed between categories (Figure 5.8).

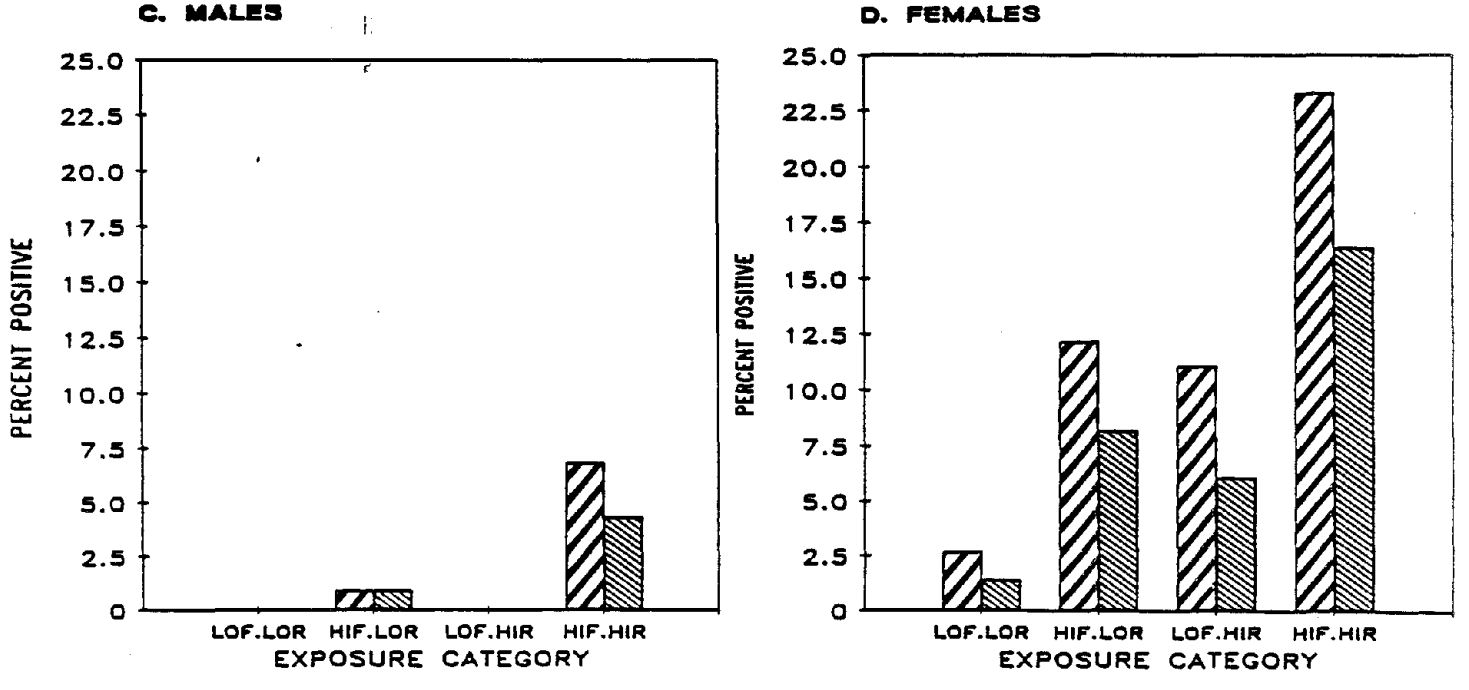
FIGURE 5.8

HAND WRIST TENDINITIS

FINAL EXPOSURE CLASSIFICATION



INITIAL EXPOSURE CLASSIFICATION



LEGEND

INTERVIEW

PE & INTERVIEW

Limiting the analysis to jobs where gender comparisons were possible, females tended to have more tendinitis than males in each category (Table 5.23). Although there was insufficient information to detect significant differences within exposure categories, overall the differences were statistically significant.

TABLE 5.23

HAND WRIST TENDINITIS:FEMALE TO MALE COMPARISON
JOB ADJUSTED ODDS RATIOS

	LOF.LOR	HIF.LOR	LOF.HIR	HIF.HIR	TOTAL
JOBS	(7)	(8)	(3)	(3)	(21)
INTERVIEW	5.8	3.5	8.4	2.5	3.2**
#	(1)	(5)	(2)	(3)	(11)
PE & INTERVIEW	5.8	1.6	7.4	2.2	4.3*
#	(1)	(3)	(1)	(3)	(8)

Chi square (M-H) *p <0.05 **p <0.01
(Total of 188 males and 151 females in 21 Jobs)
Number of jobs in which there were any cases

Crude and plant adjusted odds ratios were elevated for the three exposure groups on Interview and on PE and Interview (except LOF.HIR males) (Table 5.24). The plant adjusted odds ratio for HIF.HIR females on Interview was 8.9 ($p < 0.05$). The sex combined odds ratio for HIF.HIR on PE and Interview was 29.4 ($p < 0.001$). Among female Punch Press operators and Hand Grinders, 17% and 30% had tendinitis on PE and Interview, respectively. No statistically significant trend by age group was observed (Table 5.25).

TABLE 5.24

HAND WRIST TENDINITIS BY FINAL EXPOSURE CLASSIFICATION
ODDS RATIOS (OR)

		EXPOSURE			
INTERVIEW		LOF.LOR	HIF.LOR	LOF.HIR	HIF.HIR
MALES					
Yes	(n)	0	1	1	7
No	(n)	93	138	42	76
Crude OR		1.0	2.3	5.3	18.3**
Plant Adjusted OR		1.0	2.7	3.3	4.2
FEMALES					
Yes	(n)	2	8	10	16
No	(n)	62	48	90	58
Crude OR		1.0	5.2	3.4	8.6**
Plant Adjusted OR		1.0	2.6	2.8	8.9*
PE & INTERVIEW		LOF.LOR	HIF.LOR	LOF.HIR	HIF.HIR
MALES					
Yes	(n)	0	1	0	5
No	(n)	93	138	43	78
Crude OR		1.0	2.3	-	13.1*
Plant Adjusted OR		1.0	2.7	-	3.2
FEMALES					
Yes	(n)	1	5	5	12
No	(n)	63	51	95	62
Crude OR		1.0	6.2	3.2	12.2**
Plant Adjusted OR		1.0	4.5	2.9	5.8
SEX COMBINED					
Crude OR		1.0	5.0	5.7	18.9***
Plant Adjusted OR		1.0	6.1	3.3	29.4***

*p <0.05 **p <0.01 ***p <0.001

TABLE 5.25

PREVALENCE OF HAND WRIST TENDINITIS
STRATIFIED BY AGE, SEX AND EXPOSURE GROUP

STUDY NUMBER		LOF.LOR		HIF.LOR		LOF.HIR		HIF.HIR		TOTAL	
		M	F	M	F	M	F	M	F	M	F
20-29		23	14	30	10	7	21	26	17	86	62
30-39		31	21	51	27	12	38	32	29	126	115
40-49		13	17	31	12	15	14	14	19	73	62
50-59		24	9	25	7	9	22	10	6	68	44
60+		2	3	2	0	0	5	1	3	5	11
		POSITIVE ON INTERVIEW									
20-	N	0	1	0	1	1	1	1	2	2	5
	%	0.0	7.1	0.0	10.0	14.3	4.8	3.8	11.8	2.3	8.1
30-	N	0	1	0	2	0	4	5	6	5	13
	%	0.0	4.8	0.0	7.4	0.0	10.5	15.6	20.7	4.0	11.3
40-	N	0	0	1	3	0	2	1	4	2	9
	%	0.0	0.0	3.2	25.0	0.0	14.3	7.1	21.1	2.7	14.5
50-	N	0	0	0	2	0	3	0	3	0	8
	%	0.0	0.0	20.0	28.6	0.0	13.6	0.0	50.0	0.0	18.2
60+	N	0	0	0			0	0	1	0	1
	%	0.0	0.0	0.0			0.0	0.0	33.3	0.0	9.1
		POSITIVE ON PE & INTERVIEW									
20-	N	0	1	0	1	0	1	1	1	1	4
	%	0.0	7.1	0.0	10.0	0.0	4.8	3.8	5.9	1.2	6.5
30-	N	0	0	0	0	0	1	3	5	3	6
	%	0.0	0.0	0.0	0.0	0.0	2.6	9.4	17.2	2.4	5.2
40-	N	0	0	1	3	0	0	1	2	2	5
	%	0.0	0.0	3.2	25.0	0.0	0.0	7.1	10.5	2.7	8.1
50-	N	0	0	0	1	0	3	0	3	0	7
	%	0.0	0.0	0.0	14.3	0.0	13.6	0.0	50.0	0.0	15.9
60+	N	0	0	0			0	0	1	0	1
	%	0.0	0.0	0.0			0.0	0.0	33.3	0.0	9.1

The exposure predictors in the logistic regression analysis (Table 5.26) are similar to those observed in the stratified analysis for hand wrist tendinitis on PE and Interview (Table 5.24). The risk of

having tendinitis decreased with age and years on the job (not statistically significant). However, statistically significant interactions were observed between both sex and age with years on the job. The predicted association between tendinitis and exposure was statistically significant ($p<0.0001$). The predicted risk of having tendinitis in the HIF.HIR group (while controlling for other factors was 37.6 times that in the LOF.LOR group. The predicted risk in the HIF.HIR group was 4.3 times greater than the HIF.LOR group and 11.8 times greater than in the LOF.HIR group.

When Force (0,1 variable) was entered into model I (irrespective of repetitiveness), the odds ratio was 4.7 $p<0.005$). When Repetitiveness (0,1) was entered into Model I (irrespective of force), the odds ratio for Repetitiveness was 2.3 and not statistically significant.

TABLE 5.26

PREDICTORS OF HAND WRIST TENDINITIS: PE & INTERVIEW
MULTIPLE LOGISTIC REGRESSION ANALYSIS, N=652

(Plants included in all models)

MODEL	I		II FINAL EXPOSURE		III INITIAL EXPOSURE	
PREDICTOR	COEFFICIENT (ST ERROR)	ODDS RATIO	COEFFICIENT (ST ERROR)	ODDS RATIO	COEFFICIENT (ST ERROR)	ODDS RATIO
SEX	1.1847 (.80877)	3.3	.55643 (.83202)	1.7	.97994 (.80367)	2.7
AGE	-.01914 (.03432)	1.0	-.01255 (.03722)	1.0	-.02804 (.03541)	1.0
YEARS JOB	-.20094 (.17308)	0.8	-.28329 (.17966)	0.8	-.31325 (.17845)	0.7
AGE*YRS	.00272 (.00337)	1.0	.00397 (.00357)	1.0	.00488 (.00349)	1.0
SEX*YRS	.14263 (.08855)	1.2	.16244 (.09409)	1.2	.16775 (.08768)	1.2
HIF.LOR			2.1654 (1.2309)	8.7	2.1602 (1.1406)	8.7
LOF.HIR			1.1569 (1.1299)	3.2	1.2611 (1.1291)	3.5
HIF.HIR			3.6278 (1.1609)	37.6	3.1906 (1.0967)	24.3
-2 LOG LIKELIHOOD	194.24		174.46		175.00	

Statistically significant predictors: sex, plants, age*years, sex*years, exposure

2. Carpal Tunnel Syndrome

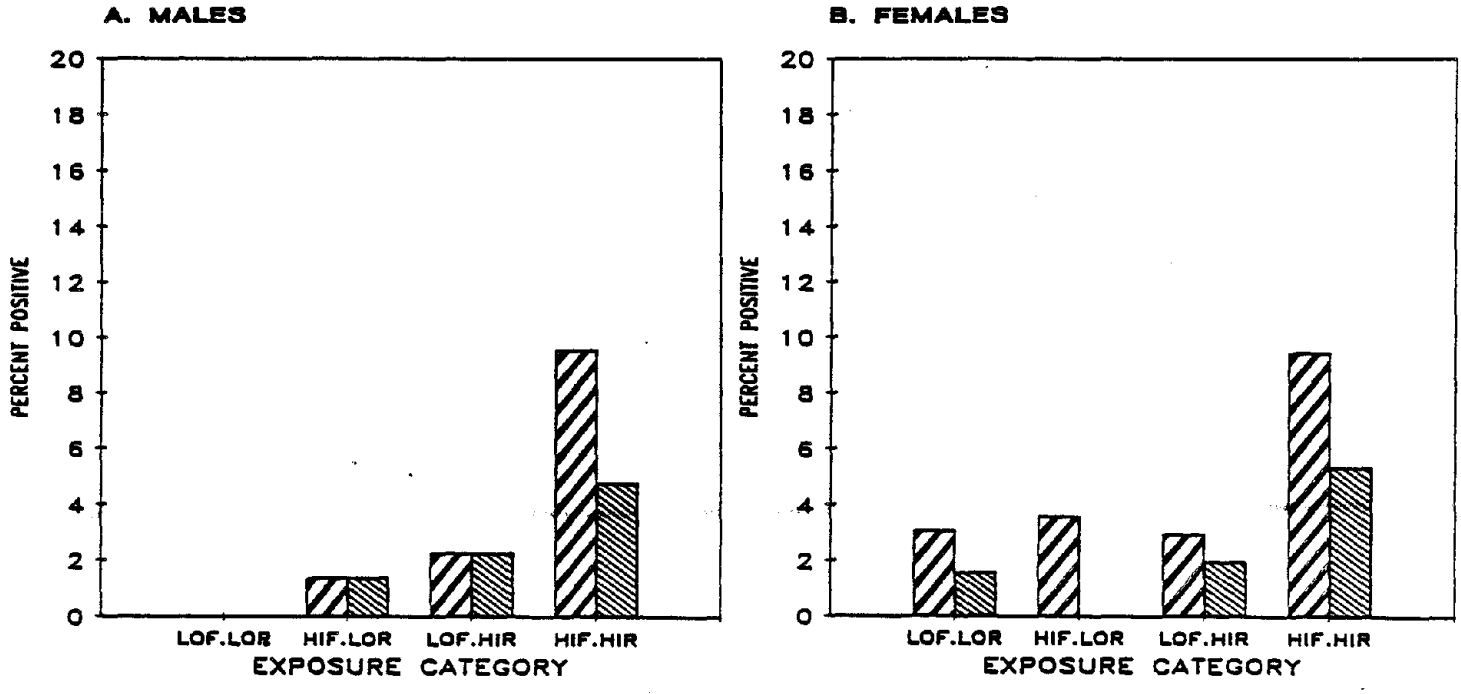
There were 25 subjects (3.8%) who met the criteria for carpal tunnel syndrome on Interview (3.1% of males and 4.8% of females) and 14 subjects (2.1%) who met the criteria on both PE and Interview (2.0% of males and 2.4% of females) (Figure 5.9).

There were 7 specific jobs on Interview and 5 specific jobs on PE and Interview with cases of carpal tunnel syndrome in which females and males can be compared for risk associated with carpal tunnel syndrome. Job adjusted odds ratios for females were 1.6 on Interview and 0.9 on PE and Interview (not statistically significant).

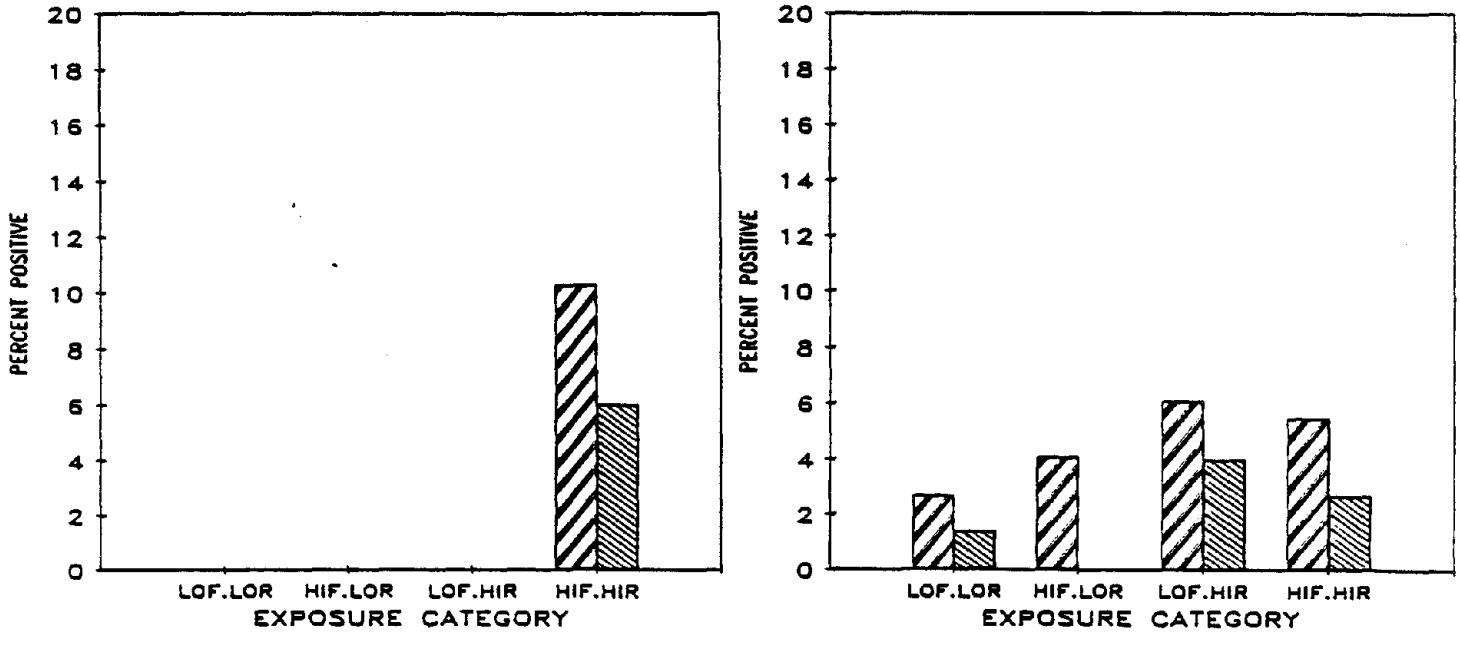
FIGURE 5.9

CARPAL TUNNEL SYNDROME

FINAL EXPOSURE CLASSIFICATION



INITIAL EXPOSURE CLASSIFICATION



LEGEND

INTERVIEW

PE & INTERVIEW

Crude and plant adjusted odds ratios for HIF.HIR were statistically significant on Interview and PE and Interview (Table 5.27). The risk of having carpal tunnel syndrome (CTS) in the HIF.HIR group was more than 12 times that in the LOF.LOR group on Interview and more than 14 times on PE and Interview.

TABLE 5.27

CARPAL TUNNEL SYNDROME BY FINAL EXPOSURE CLASSIFICATION
SEX COMBINED ODDS RATIOS (OR)

		EXPOSURE			
INTERVIEW		LOF.LOR	HIF.LOR	LOF.HIR	HIF.HIR
Yes	(n)	2	4	4	15
No	(n)	155	191	139	142
Crude OR		1.0	1.6	2.2	8.2**
Plant Adjusted OR		1.0	1.0	1.3	12.4**
PE & INTERVIEW		LOF.LOR	HIF.LOR	LOF.HIR	HIF.HIR
Yes	(n)	1	2	3	8
No	(n)	156	193	140	149
Crude OR		1.0	1.6	3.3	8.4*
Plant Adjusted OR		1.0	1.8	1.9	14.3*

*p <0.05 **p <0.01 ***p <0.001 ****p <0.0001

No statistically significant trend by age group was observed (Table 5.28).

Predictors in the logistic regression analysis (Tables 5.29 and 5.30) suggested no significant association between sex or plant or any interaction terms and carpal tunnel syndrome on PE and Interview. Additionally, carpal tunnel syndrome was positively associated with age but negatively associated with years on the job. Neither of these predictors were statistically significant.

TABLE 5.28

PREVALENCE OF CARPAL TUNNEL SYNDROME
STRATIFIED BY AGE, SEX, EXPOSURE GROUP

STUDY NUMBER	LOF.LOR		HIF.LOR		LOF.HIR		HIF.HIR		TOTAL	
	M	F	M	F	M	F	M	F	M	F
20-29	23	14	30	10	7	21	26	17	86	62
30-39	31	21	51	27	12	38	32	29	126	115
40-49	13	17	31	12	15	14	14	19	73	62
50-59	24	9	25	7	9	22	10	6	68	44
60+	2	3	2	0	0	5	1	3	5	11
	POSITIVE ON INTERVIEW									
	M	F	M	F	M	F	M	F	M	F
20- N	0	0	1	0	0	0	2	0	3	0
%	0.0	0.0	3.3	0.0	0.0	0.0	7.7	0.0	3.5	0.0
30- N	0	1	0	1	1	1	3	3	4	6
%	0.0	4.8	0.0	3.7	8.3	2.6	9.4	10.3	3.2	5.2
40- N	0	1	0	1	0	1	3	4	3	7
%	0.0	5.9	0.0	8.3	0.0	7.1	21.4	21.1	4.1	11.3
50- N	0	0	1	0	0	1	0	0	1	1
%	0.0	0.0	4.0	0.0	0.0	4.5	0.0	0.0	1.5	2.3
60+ N	0	0	0			0	0	0	0	0
%	0.0	0.0	0.0			0.0	0.0	0.0	0.0	0.0
	POSITIVE ON PE & INTERVIEW									
20- N	0	0	1	0	0	0	0	0	1	0
%	0.0	0.0	3.3	0.0	0.0	0.0	0.0	0.0	1.2	0.0
30- N	0	1	0	0	1	0	2	2	3	3
%	0.0	4.8	0.0	0.0	8.3	0.0	6.3	6.9	2.4	2.6
40- N	0	0	0	0	0	1	2	2	2	3
%	0.0	0.0	0.0	0.0	0.0	7.1	14.3	10.5	2.7	4.8
50- N	0	0	1	0	0	1	0	0	1	1
%	0.0	0.0	4.0	0.0	0.0	4.5	0.0	0.0	1.5	2.3
60+ N	0	0	0			0	0	0	0	0
%	0.0	0.0	0.0			0.0	0.0	0.0	0.0	0.0

TABLE 5.29

PREDICTORS OF CARPAL TUNNEL SYNDROME: PE & INTERVIEW
MULTIPLE LOGISTIC REGRESSION ANALYSIS, N=652

(Plants included in all models)

MODEL	I		II		III	
			FINAL EXPOSURE		INITIAL EXPOSURE	
PREDICTOR	COEFFICIENT (ST ERROR)	ODDS RATIO	COEFFICIENT (ST ERROR)	ODDS RATIO	COEFFICIENT (ST ERROR)	ODDS RATIO
SEX	.29751 (.71019)	1.3	.15996 (.70739)	1.2	.24110 (.71678)	1.3
AGE	.02583 (.02815)	1.0	.04678 (.03104)	1.0	.02913 (.02819	1.0
YEARS JOB	- .07769 (.05970)	0.9	- .10565 (.06173)	0.9	- .07913 (.06082	0.9
HIF.LOR			.58937 (1.2427)	1.8	-7.6769 (-18.848)	0.0
LOF.HIR			.99450 (1.1993)	2.7	1.4660 (1.1360)	4.3
HIF.HIR			2.7424 (1.1276)	15.5	2.1716 (1.0726)	8.8
-2 LOG LIKELIHOOD	130.23		118.24		116.39	

Statistically significant predictors: exposure

TABLE 5.30

PREDICTORS OF CARPAL TUNNEL SYNDROME: PE & INTERVIEW
FORCE VERSUS REPETITIVENESS
MULTIPLE LOGISTIC REGRESSION ANALYSIS, N=652

(Plants included in all models)

MODEL	I		II		III	
			FINAL:REPETITVENESS		FINAL:FORCE	
PREDICTOR	COEFFICIENT (ST ERROR)	ODDS RATIO	COEFFICIENT (ST ERROR)	ODDS RATIO	COEFFICIENT (ST ERROR)	ODDS RATIO
SEX	2.97513 (.71019)	1.3	.00385 (.00536)	1.0	.26795 (.68581)	1.3
AGE	.02583 (.02815)	1.0	.02577 (.02814)	1.0	.037518 (.02948)	1.0
YEARS JOB	- .07769 (0.05970)	0.9	- .08447 (.05804)	0.9	- .08915 (.06132)	0.9
EXPOSURE			1.6957 (.70795)	5.5	1.0794 (.63843)	2.9
-2 LOG LIKELIHOOD	130.23		123.21		127.09	

Statistically significant predictors: Repetitiveness $p < 0.05$

The risk of having CTS on PE and Interview in the HIF.HIR group was 5.7 times that in the LOF.HIR group. The combination of high repetitiveness and high force (HIF.HIR) increases the magnitude of association (odds ratio for HIF.HIR=15.5). However Repetitiveness appeared to be a more important risk factor than Force (Table 5.30). The odds ratio for Repetitiveness (0,1 variable) was 5.5 ($p < 0.05$). The odds ratio for Force, irrespective of repetitiveness, was 2.9 and not statistically significant.

The 14 cases of CTS identified on PE and Interview were distributed over 11 of the 39 jobs (Table 5.32). Five (35.7%) had CTS and tendinitis on the same side(s) identified on PE and Interview.

TABLE 5.31

SPECIFIC JOBS WITH CASES OF CARPAL TUNNEL SYNDROME ON PE AND INTERVIEW

JOB	EXPO-SURE	% CTS PE & I	SIDE	% CTS INTERVIEW	TENDINITIS
Buffing	HIF.HIR	8.3%	Both	8.3%	Yes
Punch Press	HIF.HIR	4.5%	Both	13.6%	Yes
Wax Assembly	LOF.LOR	5.0%	Left	10.0%	No
Mounted Point	LOF.HIR	10.0%	Right	10.0%	No
Burr Bench	LOF.HIR	4.5%	Both	4.5%	No
Cutoff	HIF.HIR	7.7%	Both	7.7%	No
Hem Legs	HIF.HIR	4.8%	Right	4.8%	No
Stat grind	HIF.HIR	5.3%	Both	15.8%	Yes
Hand grind (Peewee)	HIF.HIR	15.4%	Left,Right	15.4%	Yes
Pump Assembly	HIF.HIR	5.6%	Both	5.6%	Yes
Auto Machine op	HIF.LOR	8.0%	Both, Right	8.0%	No

Summary estimates of force and repetitiveness for these jobs were presented in Chapter 4. Additional descriptive information was obtained from reviewing videotapes (Table 5.32) to generate hypotheses about other job factors that may contribute to the observed associations between CTS and exposure. No measures of vibration were obtained during job evaluation.

TABLE 5.32

ADDITIONAL JOB CHARACTERISTICS FOR JOBS WITH CASES OF CARPAL TUNNEL SYNDROME ON PE AND INTERVIEW

JOB	HAND TOOLS	MECHANICAL STRESS	VIBRATION	PRIMARY POSTURES
Buffing	None	None	Stationary Buff Wheel	51% ulnar, 14%flexion, 17% pinch
Punch Press	Suction Cup	Palm button Guards	None	27% ulnar, 29%flexion 30%pinch
Wax Assembly	Brush Heat rod Eye dropper	None	None	55% ulnar, 40% flexion 98% pinch, 34% flexion with ulnar deviation
Mounted Point	None	None	Small Point	59% ulnar, 1% flexion 98% pinch
Burr Bench	Small hand grinder	Parts	Grinder	25% ulnar, 12% flexion 60% pinch
Cutoff	None	Parts	Stationary cutting wheel	42% ulnar, 19% flexion 12% pinch, 14% flexion with ulnar deviation
Hem Legs	None	None	None	33% ulnar, 27% flexion 77% pinch, 14% flexion with ulnar deviation
Stat Grind	None	Parts	Stationary grinding wheel	30% ulnar, 20% flexion 13% flexion with ulnar
Peewee Hand Grind	grinder	Parts	Hand grinder	56% ulnar, 1% flexion
Pump Assembly	Tapper	None	None	44% ulnar, 20% flexion 76% pinch
Autoflange	None	None	None	8% ulnar, 1% flexion

5.4.2B Hand Wrist Postures

Commonly cited postural risk factors for hand wrist CTDs include ulnar deviation, wrist flexion or hyperextension, and pinching (Chapter 2, Table 2.1). Comparisons of cycle time spent in any of these postures or combinations of postures were made by exposure group and gender (Figure 5.10). "Pinch" included pulp, lateral and palm pinches. "Awkward" included wrist flexion or hyperextension or ulnar or radial deviation. The hand with the greatest percentage of cycle time spent in the posture was used. Postural risk factors varied considerably both within job (between workers performing the same job) and within exposure category (between jobs in the same exposure category). Percent of cycle time spent in pinching was greater for females than males in all exposure groups. Overall, females spent 53.7% of the time in a pinch compared to 21.8% for males ($p < 0.0001$). The correlation between sex and pinch was .54 and the correlation between LOF.HIR was .55 suggesting a substantial degree of multicolinearity between these factors.

Postural comparisons were also made between jobs in which there were cases of tendinitis (figure 5.11) and carpal tunnel syndrome (figure 5.12) on PE and Interview and those jobs in which there were no such cases. No postural differences werre noted in the tendinitis comparisons. The "carpal tunnel syndrome jobs" had slightly more ulnar deviation and pinching than the "non-carpal tunnel syndrome jobs."

FIGURE 5.10

HAND WRIST POSTURES BY EXPOSURE GROUP & SEX
PERCENT CYCLE TIME IN AWKWARD POSTURES

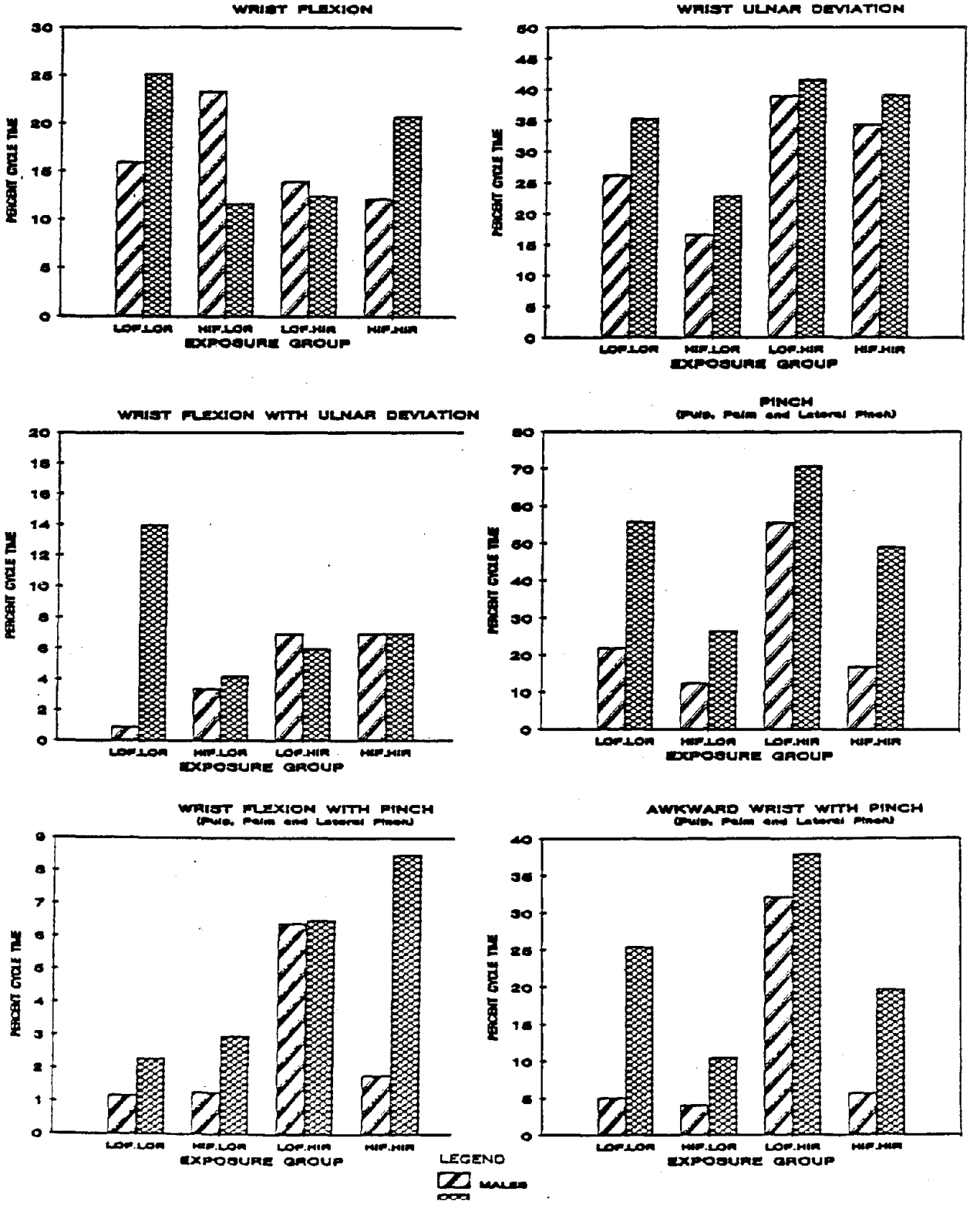


FIGURE 5.11

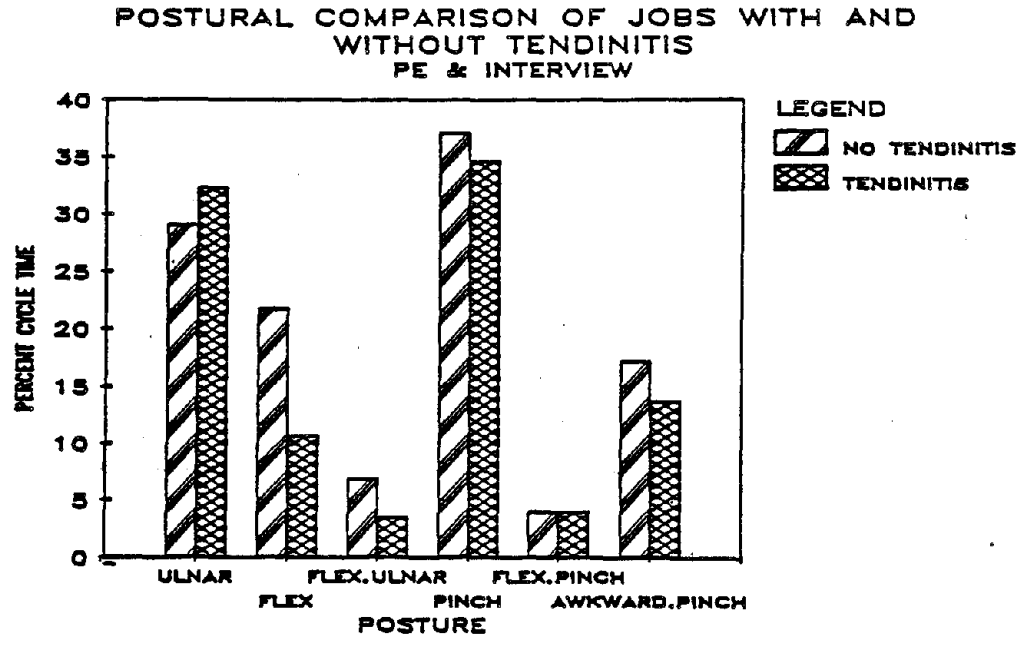
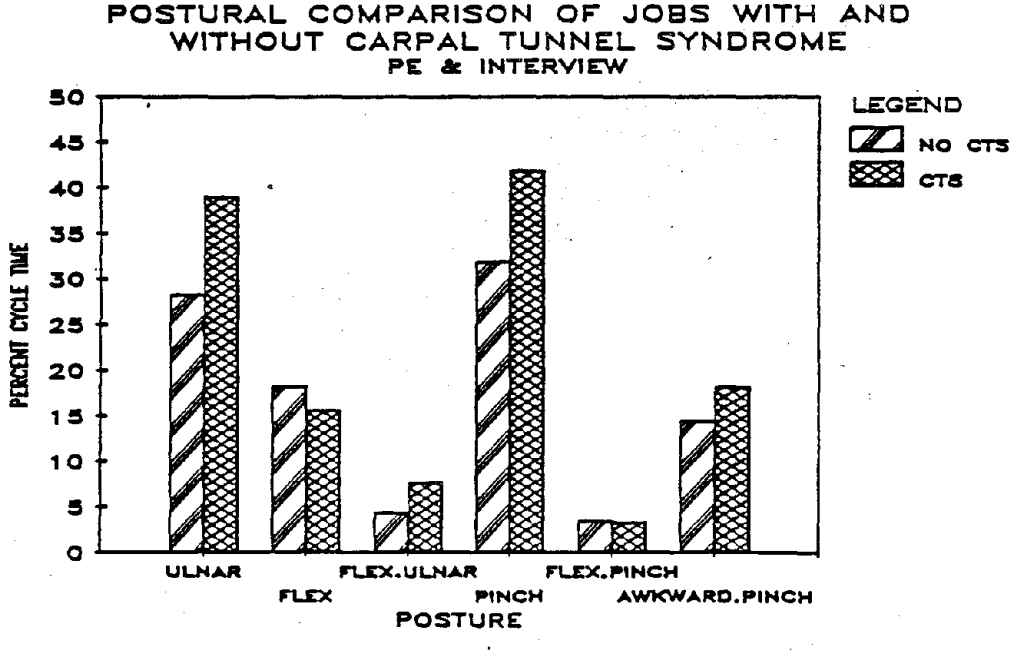


FIGURE 5.12



When postural variables were entered into the logistic regression analyses of tendinitis, none of the variables influenced the coefficients. However, for CTS and Any Hand Wrist CTD (excluding LOA), pinch was the only postural variable that affected the coefficients (no difference with tendinitis). There was a statistically significant interaction between sex and pinch. In general, the effect of pinch and sex*pinch in the models was to reduce the odds ratios for sex (F:M) and increase the odds rations for the exposure variables (Table 5.33).

TABLE 5.33

PINCH AND HAND WRIST CTDS: PE & INTERVIEW MULTIPLE LOGISTIC REGRESSION ANALYSIS: N=652 FINAL EXPOSURE CLASSIFICATION

	ANY HAND WRIST		EXCLUDE LOA		CARPAL TUNNEL SYNDROME	
PREDICTOR	COEFFICIENT (ST ERROR)	ODDS RATIO	COEFFICIENT (ST ERROR)	ODDS RATIO	COEFFICIENT (ST ERROR)	ODDS RATIO
SEX (F.M.)	.33556 (.69539)	1.4	.95945 (.95539)	2.6	-1.2159 (1.217)	0.3
PINCH	.00758 (.01640)	1.0	.02641 (.02220)	1.0	-.02579 (.02643)	1.0
SEX*PINCH	- .01833 (.01668)	1.0	.03105 (.02217)	0.9	.04923 .03016	1.1
HIF.LOR	2.0365 (.77532)	7.7	1.8922 (.89576)	6.6	.87431 (1.5384)	2.4
LOF.HIR	1.0981 (.62139)	3.0	1.2745 (.80173)	3.6	.95521 (1.2113)	2.6
HIF.HIR	3.0995 (.75138)	22.2	3.3805 (.88422)	29.4	3.2621 (1.3697)	26.1
-2 LOG LIKELIHOOD						
without exposure	369.92		325.02		127.48	
with exposure	341.06		296.64		115.08	
p value	<0.0001		<0.00001		<0.01	

+ All models include plants, age, years on job
+ Also includes sex*years and age*years

5.5 Summary

In summary, 31% of the study population had upper extremity CTDs on Interview and 18% had upper extremity CTDs on PE and Interview.

The prevalence of hand wrist CTDs in the study population was 20% on Interview and and 10% on PE and Interview. Compared to the LOF.LOR group, the risk of having hand wrist CTDs was greater in the other three groups (Table 5.34).

The HIF.HIR group consistently had a significantly increased risk for all hand wrist CTDs, tendinitis and carpal tunnel syndrome. The high odds ratios for the HIF.HIR group suggested an interaction between repetitiveness and force. Force appeared to be a more important risk factor than repetitiveness in the multiple logistic regression analyses for any hand wrist CTDs, hand wrist excluding LOA, and tendinitis. However, repetitiveness appeared to be more important than force as a risk factor for carpal tunnel syndrome.

Overall, females in the study population had approximately 2 times the prevalence of CTDs as males. However, the associations between sex and CTDs were neither consistent for the various types of CTDs nor uniform between exposure groups. In general, the job specific odds ratios for females compared to males were lower on PE and Interview than on Interview alone. No significant association was detected between sex and carpal tunnel syndrome. Postures varied within jobs and within exposure categories. Females used "pinch" significantly more than males. Statistically significant sex*pinch interactions were observed in the logistic regression models.

TABLE 5.34

SUMMARY ODDS RATIOS FOR VARIOUS HAND WRIST CTDS ON PE & INTERVIEW FINAL EXPOSURE CLASSIFICATION

PLANT ADJUSTED ODDS RATIOS

	ANY HAND/ WRIST CTD	HAND/WRIST NO LOA	TENDINITIS	CARPAL TUNNEL SYNDROME
HIF.LOR	2.4	3.0	6.1	1.8
LOF.HIR	2.7	3.6	3.3	1.9
HIF.HIR	16.6****	30.3****	29.4***	14.3*
SEX +	2.2*	2.2	4.3*	0.9

LOGISTIC REGRESSION ODDS RATIOS ++++

	ANY HAND/ WRIST CTD	HAND/WRIST NO LOA	TENDINITIS	CARPAL TUNNEL SYNDROME
HIF.LOR	5.2	6.2	8.7	1.8
LOF.HIR	2.8	3.6	3.2	2.7
HIF.HIR ++	16.3****	26.9****	37.6***	15.5**
SEX +++	2.2*	4.5**	1.7	1.2

Chi square * p<0.05 ** p<0.01 *** p<0.001 **** p<0.0001

\+ Based on job adjusted odds ratios
++ p values are for exposure as a group (three 0,1 variables)
+++ specific jobs not taken into account
++++ 5 plant (0,1), sex (0 male, 1 female), age, years on job, 3 exposure (0,1) variables in the model.

Age was negatively associated with hand wrist (Exclude LOA) CTDs but positively associated with hand wrist tendinitis and carpal tunnel syndrome, although the associations were modest and not statistically significant. The number of years on the study jobs was positively associated with all hand wrist CTDs but negatively associated with carpal tunnel syndrome (not statistically significant). Other individual factors that were thought to be potential confounders were either not significantly associated with exposure or with disease and were not considered further. These included recreational activities, relevant diseases, reproductive history of females, hours worked at the time of evaluation, interviewer and examiner.

CHAPTER 6

DISCUSSION

The null hypothesis of no difference in the prevalence of upper extremity CTDs between exposure categories, reflecting different force and repetitiveness job attributes, has been rejected in this investigation. The magnitude and pattern of associations between CTDs and exposure varies by anatomical location of the disorders. Posture was not a major confounding variable.

In the following sections, these findings will be qualified, taking into account methodological limitations including study design, misclassification of exposure and health effects, selection bias, information bias and observer bias. Assessment of confounders, associations , comparisons with other similar studies, conclusions and recommendations for further research will also be discussed.

6.1 Study Design

6.1.1 Prevalence

A cross sectional study design was used to estimate exposure and prevalence of CTDs simultaneously. One advantage of this approach was that job and health status information was available from primary and contemporary rather than secondary and historic data sources (production records, job histories, plant medical records).

Cross sectional studies are most useful in identifying the risk factors of a relatively frequent disease with a long duration which is often undiagnosed or unreported, and for assessing the need for

intervention services (Kleinbaum et al, 1982). One limitation of the design in this study was that some CTDs appeared to be episodic or of short duration. Secondly, a selective survival bias may have occurred with more severe or long standing cases of CTDs being unavailable for study because they were no longer working on the job or in the plant. Third, some cases may have transferred from high risk to low risk jobs following onset of CTDs leading to misclassification.

Prevalence data alone cannot be used to ascertain the direction of the relationship between exposure and disease (cause and effect). Consequently, subject recall of date of onset was relied upon to determine if the CTD had originated while working on the study job. This retrospective component increased the probability that exposure measures reflected subject status at the time the disorder was induced (MacMahon and Pugh, 1970).

6.1.2 "Plant Effect"

The study was conducted at 7 different industrial sites. The disadvantage of this approach was that it increased the complexity of analysis insofar as many potential plant specific factors may have affected the physical stresses associated with jobs but could not be directly identified or measured. Statistical control for these speculative "plant effects" was necessary. In addition to differences in exposure attributes of interest (Chapter 4), various sociological factors may have played a part in the plant effect, including differences in labor-management relations, cultural characteristics and selection into and out of the workforce. There was a decision to avoid conducting the study at plants where there were active labor-management disputes in progress. Other factors were beyond the scope

of the study to evaluate or control. It is reasonable to assume that plants who were willing to participate in this study participated because they perceived that they had a CTD problem. However, the areas where the CTD problem was believed to be worse by plant management were freqently not included in this study.

6.1.3 Plant and Job Selection.

By requiring a large number of workers to be performing the same jobs in four different exposure categories, small plants were excluded from consideration. Also, specific jobs (particularly assembly line jobs) which may have had a high prevalence of CTDs but an insufficient number of workers were excluded from consideration. Observer bias in the selection of jobs was minimized (although probably not eliminated) by blinding the "selectors" to health problems identified by either management or workers on those jobs. Prior knowledge of CTDs on specific jobs may have resulted in choosing one of several jobs that met the same exposure category criteria because of preconceptions about cause and health effect. Preconceptions can be right or wrong thereby resulting in systematic bias in estimates of associations although not in their direction.

6.1.4 Subject Selection.

Workers who had not been on the study job for at least a year and those not working at the time of subject selection (within several weeks of health evaluation) were excluded.

It was believed that workers with less seniority may have brought CTDs previously obtained on another job to the one under study. Also, workers new to the job, or just returning after prolonged absence, may have experienced transient physical difficulty in adjustment. While

this exclusion may have reduced the likelihood of overestimating CTD prevalence, it could also have increased the likelihood of underestimating CTD prevalence if only "survivors" (particularly in high physical stress jobs) were available for study. The finding that carpal tunnel syndrome was negatively associated with years on the job supports this hypothesis. Wherle (1976) noted that the mean time on the job was 2 months before onset of carpal tunnel syndrome symptoms among automotive upholstery sewers. In many US plants, it has been common practice to place workers with these symptoms on restricted jobs or off work. The effect would be an underestimation of prevalence.

Subject selection was restricted to active workers because of the impracticality of identifying and examining those who had left the job or workplace. The extent to which workers had left the job or plant because of CTDs was not known because employee rosters usually included only active workers. However, in Plant 6, workers on medical leave were included in the employee roster. In this plant, 7 of the 20 pump assemblers initially chosen for health evaluations were off work because of carpal tunnel syndrome and/or tendinitis. The effect of this exclusion was to underestimate the prevalence of CTDs among pump assemblers. There was no reason to believe that Plant 6 was totally unique in having a number of workers unavailable for study for similar reasons.

6.2 Misclassification of Exposure

Results were presented for both final and initial exposure classifications. In general, the findings were similar. The differences were that the strength of associations between CTDs and the HIF.HIR group were increased with the final classification while the

strength of associations between sex and CTDs within exposure categories was decreased.

6.2.1 Repetitiveness

Repetitiveness was categorized as "high" and "low" on the basis of estimated cycle time and percent of cycle time performing the same fundamental cycle. Other measures of repetitiveness that were not used include number of movements or movements with awkward postures per day (Drury and Wick, 1984). This is similar to the total number of fundamental cycles per day (irrespective of differences in the types of fundamental cycles). If total movements or total fundamental cycles per day had been used, it is conceivable that some of the "low repetitive" jobs would have been considered "high repetitive." Examples include solder touchup at Plant 1, wax assembly and gauging at Plant 3. Each of these jobs had at least 3 different tasks within the cycle and each task usually had several fundamental cycles. However the hand movements and postures used in the different tasks were different, requiring the use of different muscles and tendons. Theoretically, the overall burden on specific soft tissues would be less than if the same tissues were continually loaded.

6.2.2 Force

Forcefulness was difficult to classify into "high" and "low" categories. Force requirements varied tremendously. Jobs with long cycle times but intermittent high forces may have had a relatively low mean force and large standard deviation. The "adjusted force" ((Variance/Mean Force)+ Mean Force) was used as a weighted measure in an attempt to reconcile this problem. No EMG estimates of force were

obtained for some LOF.LOR jobs. It is conceivable that they exerted more force than the default values assigned to them. If misclassification occurred, it would probably reduce the observed associations.

Surface electromyography has been used extensively in biomechanical studies but there have been debates regarding the reliability of EMGs in estimating dynamic force (Basmajian, 1979). With the angle of the joint unchanged, there is a linear relationship between strength of the muscle and amplitude of EMG. When the angle of the joint reaches certain limits, results within the same muscle may not accurately reflect the force exerted (Basmajian, 1979).

Occasionally, motion.artifact as well as electrical interference from some machines (particularly problematic at Plant 3) was encountered in this study. Awareness of these potential problems while abstracting data from videotapes minimized (but probably did not eliminate) motion or machine interference artifact error.

Calibration of EMGs to known forces was performed for each worker in postures similar to the primary working postures of the hand. Occasionally, calibrations were not performed for all working postures. When this occurred, the calibrations for the most similar postures were used to estimate force. Another difficulty was estimating force levels which exceeded the level of forces obtained during calibration or when the bar graphs went beyond the top of the video screen. Either of these factors would result in under the estimation of force.

Force estimates were based on forearm flexor muscle activity. It was believed that the antagonistic or synergistic relationship between forearm flexors and extensors would allow approximation of force requirements of the extensor muscles. The extrinsic muscles provide

the major force in a power grip. Forces of the intrinsic muscles involved in precision handling, and the thenar muscles activity during opposition and flexion of the thumb, would not have been captured in the force estimates.

Despite the real and potential problems and limitations involved in EMG estimates of force requirements in the workplace, it is the best tool currently available for this purpose. The alternative would be to rely on weighing parts. This alternative would be incapable of estimating how much force was required to squeeze the trigger of an airgun, push a palm button, or pull cloth through a sewing machine.

6.2.3 Variation within Jobs.

At least 3 "representative" workers were analyzed performing each study job. The classification of jobs into exposure categories was based on combined summary estimates for these three workers over three cycles. Within some jobs, there was considerable variability between the three workers and their job requirements. This was more often the case with low repetitive jobs than high repetitive jobs. Job analysis was not performed on all subjects who received health evaluations. Individual variation within jobs for all subjects was not taken into account in the analysis. Irrespective of job misclassification, individuals performing the "same job" may have actually belonged in different exposure categories.

The variability between individuals with similar or identical jobs is probably greatest for posture. This is not suprising when one recognizes that stature often has a major impact on the specific postures assumed by individual workers during specific job activities.

Force within a job, while not as variable as posture, was more variable than repetitiveness.

In general, the effect of exposure misclassification would be to decrease differences between exposure groups and decrease the magnitude of associations with CTDs. Of those jobs which changed exposure categories between initial and final classification there was no transfer of jobs from LOF.LOR to HIF.HIR or vice versa (Table 4.5).

6.3 Misclassification of Health Status

There are several ways in which misclassification of health status may have occurred: information bias or measurement error, subject recall error and observer bias.

6.3.1 Measurement Error.

A "test-retest" approach to assess reliability of the physical examination was rejected because it would be affected by changes in condition. Some of the resisted tests on the physical examination produce considerable discomfort in the subject who has a tendon related disorder with the potential of increasing the initial pain. If the subject was examined twice within a short time, the intensity of discomfort would increase. If the same subject was examined a week or two later, the condition may have improved or worsened during that time.

Plant 3 medical records were available for the 159 subjects evaluated with the field instruments and were examined in an effort to assess test validity. The plant medical department had undergone changes in personnel and policy during the two years prior to the study evaluations including hiring a hand specialist on a part time basis and encouraging the nursing staff to actively identify and document health

problems. The plant medical records were designated as the true indicator while the field instruments were designated as the test indicator. Sensitivity of the test indicator as to region of body and symptoms with a CTD was estimated to be 93.7% and specificity was estimated to be 73% (Fine et al, 1984).

Subjects may have been misclassified as negative on physical exam because the physical exam was not sensitive enough to detect early manifestations of CTDs. As Wickstrom (1982) pointed out, one of the difficulties in conducting this type of investigation is that severe cases are not to be expected in active workers. Rather, one must look for early signs, often much more subtle, of declining health in those not too incapacitated to work.

On the other hand, there were a number of individuals with physical findings who reported no recurring symptoms on Interview. For example 5 subjects (3 male and 2 female) had positive physical findings suggestive of carpal tunnel syndrome but were considered negative in the analysis because they were asymptomatic. Five subjects (2 male and 3 female) had physical findings suggestive of DeQuervain's Disease but reported no recurring symptoms on Interview. They were treated as negative in the analysis. If these subjects had been treated as positive, the strength of the observed associations would have increased because they worked on jobs where these CTDs were identified on PE and Interview.

Also, there were 2 subjects with carpal tunnel syndrome on PE and Interview (1 male burr bench, 1 female pump assembler) who did not meet the general CTD criteria of more than 20 times or lasting more than one week in the previous year. Similarly, there were 3 females with tendinitis on PE and Interview (core press, buffing, hand grind) who

did not meet the duration criteria. Had these subjects been included, the observed associations, particularly for HIF.HIR would have been of a larger magnitude.

In addition to concern about how reliable the measurement of health status is, the validity of the measurement of health status must be addressed. With the exception of DJD included in the definition of CTD's, most of the disorders are caused by chronic inflammation or its sequelae. The clinical detection of chronic inflammation rests on the detection of increased pain with the active resistance of the muscle-tendon unit. Hadler (1984) describes "the diagnosis of tenosynovitis by physical exam" as straightforward. While there was often tenderness at some point along the tendon-muscle unit, in this study the other signs of chronic inflammation such as swelling, crepitus, and erythema were rare. While the standard clinical physical examination criteria was to define the specific disorders, the relationship between these criteria and more objective measures of chronic inflammation has not been firmly established. This is technically very difficult to investigate because noninvasive objective measures of chronic inflammation do not currently exist. An alternative approach would be to detemine if the criteria for CTDs reliably identify a group of workers with significantly higher rates of impairment and disability and whether decreases in job force and repetitiveness result in a lower prevalence of CTDs.

Fatigue clearly can cause localized pain in the tendon-muscle unit. It is possible that some of the milder cases reflect fatigue rather than chronic inflammation. The separation of pain from chronic

inflammation and fatigue represents a difficult challenge for epidemiological studies of active workers.

6.3.2 Subject Error.

The interviews relied on subject recall of medical history and symptoms. Consents for release of medical records were obtained from approximately 75% of the study population. Medical records were obtained and reviewed for those reporting a history of rheumatoid arthritis, diabetes mellitus or other conditions that may have presented with symptoms consistent with CTDs. Six subjects with verified rheumatoid arthritis were removed from the final study population. It was possible that individuals did not know if they had medical conditions of interest. It is unlikely that knowledge of diseases would vary by exposure category.

It is also possible that some workers may have minimized or exaggerated their symptoms based on preconceptions of how their jobs were affecting their health. Exaggeration in the "exposed" group would have resulted in overestimation of associations.

The physical examination instrument was administered with a number of consistency checks, such that negative findings on some range of motion testing were as important as positive findings on others in arriving at conclusions about an individual's health status.

6.3.3 Observer Bias.

A number of blinding measures were used to minimize observer bias. The interviewers did not ask questions about occupational factors until the end of the interview. Examiners were blinded to knowledge of subjects' jobs. Nor did they have access to interview information regarding prior health history, occupational history or symptoms until

after the examination. Even with these precautions, some observer bias may have been present. It was occasionally difficult to keep subjects from talking about their jobs until the end of the interview or examination. Observer bias would probably have led to overestimation of the associations reported in this investigation.

6.4. Possible Confounders; Demographic, Lifestyle Factors, and Posture

There was no convincing evidence that prior health history or recreational activities were related to exposure and were not treated as confounders.

Overall, there were no significant differences in age or mean years worked on the study jobs by exposure category. Jobs in the various exposure categories probably were viewed by workers as approximately equally desirable because workers could bid on jobs by seniority in most plants. Thus jobs which were considered more "stressful" by workers probably also had other redeeming features.

In the logistic regression analyses, age was negatively associated with hand wrist (excluding LOA) CTDs but positively associated with hand wrist tendinitis and carpal tunnel syndrome. Age, by itself, or when included with other predictors, was never a statistically significant predictor of CTDs. These findings support those of Falck and Aarnio (1983) with respect to carpal tunnel syndrome and Kourinka and Koskinen (1979) with respect to wrist muscle-tendon disorders.

In the logistic regression analyses, the number of years worked on the study job was positively associated with "any hand wrist CTDs" and hand wrist tendinitis but negatively associated with "hand wrist (excluding LOA) CTDs" and carpal tunnel syndrome. These associations were not statistically significant. The negative association with

carpal tunnel syndrome supports the argument that the study population had a substantial number of survivors (workers with CTS changed jobs or left the plant). An alternative explanation would be that carpal tunnel syndrome was a transient problem that disappears with more time on the job. However, the cases of carpal tunnel syndrome identified on PE and Interview were not new to the job.

6.4.1 Gender

Males and females were not equally distributed across exposure categories or within jobs. Males tended to predominate in HIF.LOR jobs and females tended to predominate in LOF.HIR jobs. Therefore gender was treated as a potential confounder.

In order to estimate the association between gender and CTDs in the analysis, restriction to those jobs in which both females and males were available was employed in several analyses. The odds ratios for females compared to males in the LOF.HIR category were consistently high although not always statistically significant. The burr bench job at Plant 3 was a major contributor to these high odds ratios in this category. This job was a composite of two jobs using the same kinds of hand tools: burr bench (all males) and blending (largely females). A review of videotapes of two burr benchers and one blender suggest that there may be differences between these two jobs (more handling of parts by blenders). However, it is not known whether the differences observed on the three videotaped jobs are fully representative of differences between all blenders and all burr benchers evaluated for health status.

The lack of statistically significant association between female gender and carpal tunnel syndrome in this study population is contrary

to most clinical case study reports in the medical literature.

A related finding was a negative (not statistically significant) association between symptoms of carpal tunnel syndrome and bilateral oophorectomy, hysterectomy and birth control pill use among females (Table 5.7). In a case control study, Cannon et al (1981) reported a significant positive association between bilateral oophorectomy and carpal tunnel syndrome. Medical record confirmation of reproductive status was not obtained in either study. However it is unlikely that women would be misinformed about current use of birth control pills or hysterectomy. They are less likely to know whether both ovaries were removed. One of the weaknesses in the Cannon study was that controls were not evaluated for the presence of unreported CTS. It is also curious that Cannon found no association between estrogen replacement therapy and CTS because women with bilateral oophorectomies tend to receive such replacement therapy. The potential association between estrogen replacement therapy and CTS among women was not considered in the present study.

The prevalence of CTDs among females was approximately two to three times that of males. However the observed associations between sex and different CTDs varied and were inconsistent across exposure categories. It was impossible to determine whether the observed associations were in fact a function of gender or whether they represented actual differences in the work performed by males and females even on the same job.

For example, wrist postures required on a job are often determined by the height of the work surface with respect to the location of the worker. A tall male may use less wrist flexion or ulnar deviation than

a female (or shorter male) in performing the same job. In this example, what might be assumed to be a sex difference would in reality be a difference in working posture. These types of potential differences and individual variations were not considered in this study.

Given these limitations, statistically significant positive associations between sex and all CTDs except carpal tunnel syndrome were observed.

6.4.2 Posture

Postural risk factors such as pinch in CTS were not strong confounders in the multivariate analyses between odds of CTDs and exposure categories. The major interaction appears to be with gender. Where posture was a factor, when it was introduced into the models it increased the strength of the association between exposure category and CTDs.

6.5 Comparisons with Similar Studies

The work of Kourinka and Koskinen (1979), Luopajarvi (1979) and Viikari-Juntura (1983) involved the use of techniques similar to this investigation in estimating the prevalence of upper extremity disorders in industrial populations. The overall prevalence of hand wrist CTDs (excluding LOA) on PE and Interview among females was 13.6%. This is somewhat lower than the 18% prevalence reported by Kourinka and Koskinen (1979) in a scissor making factory. These findings were also lower than those reported by Luopajarvi et al (1979) of 56% prevalence of hand wrist disorders among female packers versus 14% among shop assistants. However, the range for females in this study was from 3.3% among LOF.LOR females to 25.7% among HIF.HIR females. Within certain

jobs, the prevalence among females was 44.4% (punch press) and 30% (hand grind).

Viikari-Juntura (1983) reported a 4.4% overall prevalence of of tendinitis among slaughterhouse workers (not stratified by exposure) which was similar to the 5.1% identified in this study. In this study the plant*sex combined prevalence was 0.7% among the LOF.LOR group, 3.9% in the HIF.LOR group, 3.5% in the LOF.HIR group and 12% in the HIF.HIR group. Viikari-Juntura suggested that the relatively low prevalence of disorders found in the slaughterhouse workers may be explained by a high selection/ survivor factor. This factor may have played a part in the lower prevalence observed for hand wrist tendinitis and carpal tunnel syndrome in this investigation as well.

6.6 Conclusions

The overall aim of this investigation was to determine whether there were associations between cumulative trauma disorders (particularly of the hand and wrist) and the industrial job attributes of force and repetitiveness using primary rather than secondary data. The hypothesis of no association was rejected. The overall prevalence of upper extremity CTDs estimated in this study was high (31% on Interview and 18% on PE and Interview). The prevalence of hand wrist disorders was 20% on Interview and 10% on PE and Interview. The prevalence of hand wrist CTDs was not uniform across all exposure categories.

Hand wrist CTDs were strongly associated with high force-high repetitive work and to a lesser extent associated with high repetitiveness or high force alone, irrespective of other factors. Given (1) the interaction of gender and posture, and (2) the variation

within job and exposure category, it is important to be cautious about the role of posture in causing CTDs. Non epidemiological studies would suggest that for some CTD's, such as carpal tunnel syndrome, posture is an important causal factor.

The prevalence of CTDs varied between plants with the direction of the associations, if not the magnitude, similar between exposure groups. This suggests that irrespective of the type of industry or product, jobs with similar force and repetitiveness attributes identified in this study would have similar risks for CTDs.

These findings were not explained by confounding. There was no significant association between exposure and health history or regular recreational activities. No significant association was observed between female reproductive status and carpal tunnel syndrome. Age and years on the job were associated with most CTDs, although they were not statistically significant risk factors.

Associations between exposure and CTDs were noted for both sexes. Sex appeared to be a significant confounder with some CTDs. This observed association may be related to unmeasured work attributes (postural requirements, differences in actual work performed on the same job). Further investigation is required to assess the importance of sex and posture in the development of CTDs.

These findings can be helpful in directing workplace interventions in the worker-exposure-disease cycle because they suggest a strategy for primary prevention. Primary prevention requires intervention in the worker-exposure-disease cycle at the level of the job. Through job modification, a reduction in force, repetitive and/or postural stresses may result in a reduction in the prevalence of CTDs. The work of Corlett (1976), Karlqvist (1984), Drury and Wick (1984) and Webb (1984)

suggest that this is a viable way of reducing worker discomfort although not necessarily disease.

These findings suggest a two fold strategy for intervention. First, identification of jobs with attributes similar to those found in this investigation can direct attention to probable high risk jobs for priority attention. Secondly, it should be possible to develop a prospective ergonomics program in which health status can be followed with a structured interview rather than extensive clinical examinations.

A comparison of odds ratios for those reporting recurring hand wrist pain or discomfort on Interview and the odds ratios for those identified as having hand wrist CTDs (excluding LOA) on PE and Interview supports the argument for the second part of the primary prevention strategy (Table 6.1). The magnitude and statistical significance of the associations differ but the directions do not. This is despite the fact that the odds ratios for recurring hand wrist pain or discomfort make no adjustments for age, years on the job, plant, onset, duration, traumatic origin, prior health history or any other factor than current exposure category. The differences in magnitude may be related to a higher prevalence of complaints among the LOF.LOR group that were not related to their current exposure status. The implication of this finding is that complaints of hand wrist discomfort alone (asking workers if their hands and wrists hurt) may be reliable indicators of potential disease.

TABLE 6.1

RECURRING DISCOMFORT COMPARED TO HAND WRIST CTDS (EXCLUDING LOA)

	FINAL EXPOSURE CLASSIFICATION			
	LOF.LOR	HIF.LOR	LOF.HIR	HIF.HIR
MALES				
Recurring Discomfort	1.0	2.8*	4.9***	5.0****
PE and Interview	1.0	2.7	3.3	4.9*
FEMALES				
Recurring Discomfort	1.0	1.7	1.6	3.4**
PE and Interview	1.0	4.1	2.9	5.2
COMBINED				
Recurring Discomfort	1.0	1.8*	2.9***	3.9****
PE and Interview	1.0	3.0	3.6	30.3****
Logistic Regression (Model II)	1.0	6.2	3.6	26.9****

*p <0.05 **p <0.01 ***p<0.001 ****p <0.0001

Primary prevention is generally preferable to secondary or tertiary intervention as a public health strategy. This is certainly the case with respect to occupational cumulative trauma disorders where secondary (early detection of disease) and tertiary (treatment) approaches have been largely unsuccessful (Ferguson, 1984). This investigation demonstrates that primary prevention is possible because risk factors have been identified which can be sought and found before illness occurs. Insofar as these risk factors are physical attributes of jobs, the investigation suggests that these interventions can be directed at job design. This study does not support an intervention strategy based on physical examination to identify "high risk" or "susceptible" individuals.

6.7 Indications for Further Research

This investigation has not adequately addressed the association between sex and CTDs. One way to assess the relative importance of sex and job attributes in the development of CTDs is to conduct an investigation with detailed job analysis of the way different individuals perform the same job. This detailed job analysis needs to focus particularly on posture. Posture was not fully addressed in this investigation particularly because within job variation in posture was great. While force was addressed, it was also found to vary considerably within exposure category. Future epidemiological investigations will need to address the problem of measuring posture and force on a larger subsample of subjects.

This investigation has not addressed psychosocial determinants of CTDs, the natural history of CTDs in industry, treatment of CTDs, or the effectiveness of job intervention or other control strategies in reducing the prevalence of CTDs in industry. Future research is required in these areas.

The findings of this investigation provide the groundwork required for a prospective job intervention study with baseline and periodic measures of health status to be used to evaluate the effectiveness of those interventions in the reduction of upper extremity cumulative trauma disorders.

REFERENCES

Acheson, RM and Collart, AB. New Haven survey of joint diseases XVII: relationship between some systemic characteristics and osteoarthritis in the general population. Ann Rheum Dis 34:379-387, 1975.

Adams, JC. Outline of Orthopedics (9th ed). Churchill Livingston, Edinburg, 1981.

Adson, AW. Cervical Ribs: differential diagnosis, and indications for section of the insertion of the scalene anticus muscle, J Intl Coll Surg XVI (5):546-559, 1951.

Allander, E. Prevalence, incidence and remission rates of some common rheumatic diseases and symptoms. Scand J Work Environ Health 3:145-153, 1974.

American Academy of Orthopedic Surgeons. Measuring And Recording Joint Motions. American Academy of Orthopedic Surgeons, 1963.

Anderson, CK et al. Excess days lost as an index for identifying jobs with ergonomic stress. (University of Michigan Center for Ergonomics, submitted for publication, August, 1984).

Anderson, JAD and Duthie, JJR. Rheumatic complaints in dockyard workers, Ann Rheum Dis 22:401-409, 1963.

Anderson, JAD. System of job analysis for use in studying rheumatic complaints in industrial workers. Ann Rheum Dis 31:226,1972.

_____Occupation as a modifying factor in the diagnosis and treatment of rheumatic diseases. Curr Med Res Opin 2(9):521-528, 1974.

Anderson, S et al. Statistical Methods for Comparative Studies. John Wiley & Sons, New York, 1980.

Armstrong, TJ. Carpal tunnel syndrome and the female worker. Amer Industr Hygiene Conference, Portland, 1981.

Armstrong, TJ and Chaffin, D. Some biomechanical aspects of the carpal tunnel. J Biomech 12:567-570, 1979.

Armstrong, T., Chaffin, D., and Foulke, J. A methodology for documenting hand positions and forces during manual work. J. Biomechanics 12:132-133, 1979.

Armstrong, T., J. Foulke, B., Joseph and S. Goldstein, An investigation of cumulative trauma disorders in a poultry processing plant. Am. Ind. Hyg. Assoc. J., 43:103-116, 1982.

Armstrong, TJ. Carpal tunnel syndrome and selected personal attributes. J Occup Med 21(7):481-486 1979.

Armstrong, TJ, et al. A methodology for documenting hand positions and forces during manual work. J Biomechanics 12(2):131-133, 1979.

Armstrong, TJ, et al. Investigation of cumulative trauma disorders in a poultry processing plant. Amer Indust Hygiene Assn J 43:103-116, 1982.

Armstrong, TJ. An Ergonomic Guide to Carpal Tunnel Syndrome. Amer Industr Hygiene Assn, Akron 1983. Armstrong, TJ et al. Some

histological changes in carpal tunnel contents and their biomechanical implications. J Occup Med 26(3):197-201, 1984.

Barnes, CG and Currey, HLF. Carpal tunnel syndrome in rheumatoid arthritis, a clinical and electrodiagnostic survey. Ann Rheum Dis 26:226-233, 1967.

Barnes, R. Motion and time study, design and measurement of work. New York: John Wiley and Sons, 116:139-145, 1972.

Barranco, SD and Strelka, EP. Carpal tunnel syndrome. Virginia Med J 103:122-124, 1976.

Basmajian, JV. Muscles Alive, Their Functions Revealed by Electromyography (4th ed), Williams and Wilkens, Baltimore, 1979.

Bateman, JE. Thoracic outlet syndrome. Clin Orthop Rel Res 58:75-82, 1968.

_____.Nerve lesions about the shoulder. Orthop Clin North Amer 11(2):307-326, 1980.

_____.Neurologic painful conditions affecting the shoulder. Clin Orthop Rel Res 173:44-53, 1983.

Bechtol, CO. Biomechanics of the shoulder. Clin Orthop Rel Res 146:37-41,1980.

Bernhard, GC. Arthritis in industry update, J Occup Med 24(4): 277-289, 1982.

Beyers, JA and Wright, IS: The hyperabduction syndrome, Circulation IV:161-172, 1951.

Birkbeck, MQ and Beer, TC. Occupations in relation to the carpal tunnel syndrome. Rheum Rehabil 14(4):218-220, 1975.

Bjelle, A et al. Clinical and ergonomic factors in prolonged shoulder pain among industrial workers. Scand J Work Environ Health 5:205-210, 1979.

_____Occupational and individual factors in acute shoulder neck disorders among industrial workers. Br J Industr Health 38:356-363, 1981.

Bjorkquist, SE, et al. Carpal tunnel syndrome in ovariectomized women. Acta Obstet Gynecol Scand 56:127-130, 1977.

Bland, D et al. The painful shoulder. Semin Arthritis Rheum 7(1):21-47, 1977.

Blood, W. Tenosynovitis in industrial workers. Br Med J:468, October 12, 1942.

Bluestone, R. Practical Rheumatology, Diagnosis and Management, Addisons-Wesley Publ., Menlo Park, CA, 1980.

Booth, RE and Marvel, JP. Differential diagnosis of shoulder pain. Orthop Clin N Amer 6:353-379, 1975.

Bora Jr, FW and Osterman, AL. Compression neuropathy. Clin Orthop Rel Res 163:20-31, 1982.

Boyd, HB, et al. Tennis elbow. J Bone Joint Surg 55A (6):1183-7, 1973.

Boyle, AC. Disorders of the shoulder joint. Br Med J 3:283-285, 1969.

Bradley, K. and S. Synderland, The range of movement at the wrist joint. Anatomical record, 116:139-145, 1953.

Bralliar, F. Electromyography, its use and misuse in peripheral nerve lesions. Orthop Clin North Amer 12(2):229-238, 1981.

Brain, WR et al. Spontaneous compression of both median nerves in carpal tunnel. Lancet 1:277-282, 1947.

Brewer, BJ. Aging of the rotator cuff. Amer J Sports Med 7(2): 102-110, 1979.

Brickner, WM. Brachial plexus pressure by normal first rib. Ann Surg 85:858-872, 1927.

Brown, PW. Peripheral nerve lesions. Musculoskeletal Disorders; Regional Examination and Differential Diagnosos, RD D'Ambrosia (ed), JB Lippincott, Phila., 147-171, 1977.

Brown, R and Lingg, C. Musculoskeletal complaints in industry: annual complaint rate and diagnosis, absenteeism and economic loss, Arth & Rheum 4: 283-302, 1961.

Brown, EZ and Snyder, S. Carpal tunnel syndrome caused by hand injuries. Plastic Recon Surg 56 (1): 41-43, 1975.

Brown, CD et al. Occupational repetitive strain injuries: guidelines for diagnosis and management. Med J Aust 140:329-332, 1984.

Bunnel, S. Surgery of the Hand. JB Lippincott, Phila., 1944.

---------4th ed., 1964.

Bush, K. Management of shoulder problems in general practice. Practitioner 227:1155-1163, 1983.

Cailliet, R. Hand Pain and Impairment (2nd ed.). FA Davis Co., Phila., 1981.

_____.Neck and Arm Pain (2nd ed). FA Davis Co., Phila., 1981.

_____.Shoulder Pain (2nd ed). FA Davis Co., Phila., 1981.

_____.Soft Tissue Pain and Disability. FA Davis Co., Phila., 1980.

Campbell, CS. Gamekeeper's thumb. J Bone Joint Surg 37B(1):148-149, 1955.

Carlson, WS et al. Instrumentation for measurement of sensory loss in the fingertips. J Occup Med 21(4):260-264, 1979.

Cannon, L et al. Personal and occupational factors associated with carpal tunnel syndrome. J Occup Med 23(4): 225-258, 1981.

Castelli, WA et al. Intraneural connecting tissue proliferation of the median nerve in the carpal tunnel. Arch Phys Med Rehab 61:418-422, 1980.

Cohen, AS. Rheumatology and Immunology. Grune and Stratton, Inc., NY, 1979.

Cohen, CA. Scapulocostal syndrome: diagnosis and treatment. South Med J 3(4): 433-437, 1980.

Conn, J et al. Hypothenar hammer syndrome: post traumatic digital ischemia. Surgery 68(6):1122-1123, 1970.

Corlett, EN and Bishop, RP. A technique for assessing postural discomfort. Ergonomics 19(2):175-182, 1976.

Corelett, E., S. Madeley and I. Manenica, Posture targeting: A technique for recording working postures. Ergonomics 22:357-366, 1979.

Conrad, HR. Tenosynovitis. Ohio St Med J 27:713-716, 1931.

Conrad, RH and Hooper, WR. Tennis elbow: it's course, natural history, conservative and surgical treatment. J Bone Joint Surg 55A (6):1177-1182, 1973.

Coury, BG and Drury, CG. Optimum handle position in a box-holding task. Ergonomics 25(7):645-662, 1982.

Coventry, MB. Problems of Painful Shoulder. J Amer Med Assn 151: 177-185, 1953.

Craven, PR and Green, DP. Cubital tunnel syndrome. J Bone Joint Surg 62A(6):986-988, 1983.

Crenshaw, AH and Kilgore, WE. Surgical treatment of bicipital tenosynovitis. J Bone Joint Surg 48-A(8): 1496-1502, 1966.

Cruess, RL. Rheumatoid arthritis of the shoulder. Orthop Clin North Amer 11(2):333-48, 1980.

Cunningham, LS and Kelsey, JL. Epidemiology of musculoskeletal impairments and associated disability. Amer J Public Health 74(6):574-579, 1984.

Curry, HLF. Mason and Currey's Clinical Rheumatology (3rd ed). JB Lippincott, Phila., 1980.

Cyriax, J. Textbook of Orthopaedic Medicine I, (7th ed). Bailliere Tindal, London, 1979.

DeLacerda, FG. Shoulder girdle myofascial syndrome. Occ Health Safety

51 (11):45-46, 1982.

Del Pizzo, W et al. Ulnar nerve entrapment syndromes in baseball players. Amer J Sports Med 5(5):182-185, 1977.

Denman, EE. The anatomy of the space of Guyon. Hand 10(1):69-76, 1978.

DeOrsay, RH et al. Pathology and treatment of ganglions. Amer J Surg 36(1):313-319, 1937.

DePalma, AF and Callery, GE. Bicipital tenosynovitis. Clin Orthop Rel Res 3:69-85, 1954.

DeVries, HA. "Efficiency of electrical activity" as a physiological measure of the functional state of muscle tissue. Amer J Phys Med 47(1):10-22, 1968.

Dodge, JH et al. Age-specific prevalence of radiographic abnormalities of the joints of the Tecumseh, Michigan Community Health Study area, 1962-1965. J Chronic Dis 23:151-159, 1970.

Dobyns, JH et al. Bowler's thumb: diagnosis and treatment. J Bone Joint Surg 54a(4):751-755, 1972.

_____. Sports stress syndromes of the hand and wrist. Amer J Sports Med 6(5):236-254, 1978.

Drury, CD and Wick, J. Ergonomic applications in the shoe industry. Proceedings Intl Conf Occup Ergonomics:489-493, Toronto, May 7-9, 1984.

Dupont, C et al. Ulnar tunnel syndrome at the wrist. J Bone Joint Surg 47A(4):757-761, 1965.

Duncan, J and Ferguson, F. Keyboard operating postures and symptoms in operating. Ergonomics 17(5):651-662, 1974.

Eckman, PB et al. Ulnar neuropathy in bicycle riders. Arch Neurol 32:130-131, 1975.

Eichoff, E. Pathogenese der tendovaginitis stenosens. Bruns Bestre Klin Chir. 139: 746-755, 1927.

Ellis, M. Tenosynovitis of the wrist. Br med J: 777-779, Sept. 29, 1951.

Engin, AE. On the biomechanics of the shoulder, J Biomechan 13:575-590, 1980.

Fahey, JJ and Bollinger, JA. Trigger finger in adults and children. J Bone Joint Surg:36A(6):1200-1218, 1954.

Falck, B and Aarnio,P. Left-sided carpal tunnel syndrome in butchers. Scand J Work Environ Health 9:291-297, 1983.

Falconer, MA and Weddell, G. Costoclavicular compression of the subclavian artery and vein, Lancet 2:539-543, 1943.

Feindel, W. Cubital tunnel compression in tardy ulnar palsy. Canad Med Assn J 78:351-353, 1958.

Feldman RG et al. Peripheral nerve entrapment syndromes and ergonomic factors. Am J Industr Med 4:661-681, 1983.

Ferguson, D. Repetitive injuries in process workers. Med J Aust 2:408-412, 1971.

_____. An Australian study of telegraphist's cramp. Br J Industr Med 28:280-285, 1971.

_____. The "new" industrial epidemic. Med J Aust 140:318-319, 1984.

Fine, LJ et al. "An alternative way of detecting cumulative trauma disorders of the upper extremity in the workplace," 1984 Intl Conf Occup Ergonomics: 425-429, Toronto, May 7-9, 1984.

Finkelstein, H. Stenosing tendovaginitis at the radial styloid process. J Bone Joint Surg:12:509-540, 1930.

Fitton, JM et al. Lesions of the flexor carpi radialis tendon and sheath causing pain at the wrist. J Bone Joint Surg 50B (2):359-363, 1968.

Flax, HJ. Differential diagnosis of lesions producing stiff shoulder. Amer J Phys Med 60 (1):20-29, 1981.

Fleiss, J. Statistical Methods for Rates and Proportions (2nd ed), Wiley and Sons, NY, 1981.

Flicker, PL. The Painful Shoulder. Primary Care 7 (2):271-285, 1980.

Flowerdew, R and Bode, O. Tenosynovitis in untrained farmworkers. Br Med J 2: 367-368, 1942.

Foster, DR and Cameron, DC. Hypothenar hammer syndrome. Br J Radiol 54:995-996, 1981.

Foulke, J et al. An EMG preamplifier system for biomechanical studies. J. Biomechanics 14:437-438, 1981.

Gainer, JV and Nugent, GR. Carpal tunnel syndrome: report of 430 operations, South Med J 70 (3):325-328, 1977.

Ganel, A et al. Gamekeeper's thumb: injuries of the ulnar collateral ligament of the metacarpophalangeal joint, Brit J Sports Med 14 (2):92-96, 1980.

Gardner, R. Tennis elbow: diagnosis, pathology and treatment. Clin Orthop 72:248-253, 1970.

Gelberman, RH et al. The carpal tunnel syndrome. J Bone Joint Surg 63A (3):380-383, 1981.

Gelmers, HS. The significance of Tinel's sign in the diagnosis of carpal tunnel syndrome. Acta Neurochir 49:255-258, 1979.

_____. Primary carpal tunnel stenosis as a cause of entrapment of the median nerve. Acta Neurochir 55:317-320, 1981.

Goldie, I. Epicondylitis lateralis humeri, a pathogenetical study. Acta Chir Scand Suppl 339: 119, 1964.

Goldstein, SA. Biomechanical Aspects of Cumulative Trauma to Tendons and Tendon Sheaths. PhD dissertation, Center for Ergonomics, University of Michigan, 1981.

Gould, JS and Wissinger, A. Carpal tunnel syndrome in pregnancy. South Med J 71(2): 144-145, 1978.

Gray, RG and Gottleib, NL. Hand flexor tenosynovitis in rheumatoid arthritis. Arth and Rheum 20(4):1003-1008, 1977.

Griffiths, DLL. Tenosynovitis and tendovaginitis. Br Med J:645-647, March 22, 1952.

Hadler, N et al. Hand structure and function in an industrial setting. Arth and Rheum 21: 210-220, 1978.

_____.Clinical investigation into influence on pattern of use of regional musculoskeletal disease. Arth and Rheum 20: 1019-25, 1977.

_____.Industrial rheumatology. Arth and Rheum 20(4): 1019-25, 1977.

Hagberg, M. Electromyographic signs of shoulder muscular fatique in two elevated arm positions. Am J Phys Med 60 (3):111-121, 1981.

_____. Occupational musculoskeletal stress and disorders of the neck and shoulder: a review of possible pathophysiology. Intl Arch Occup Environ Health 53:269-278, 1984.

Hagg, G and Suurkula, J. Relation s between shoulder neck disorders and myoelectric signs of local muscle fatique in female assembly workers. Proc 1984 Intl Conf Occup Ergonomics: 324-327, Toronto, May 7-9, 1984.

Harris, ED. Rheumatoid arthritis: clinical spectrum. Textbook of Rheumatology, W Kelley (Ed). Saunders and Co, Phila, 1981.

Harris, W. Occupational pressure neuritis of the deep palmer branch of the ulnar nerve. Br Med J: 98, Jan 12, 1929.

Hartz, CR et al. The pronator teres syndrome: compression neuropathy of the median nerve. J Bone Joint Surg 63A (6):885-890, 1981.

Herberts, P and Kadefors, A. A study of painful shoulders in welders,

Acta Orthop Scand 47:481-387, 1976.

Herberts, P et al. Shoulder pain in industry: an epidemiological study on welders. Acta Orthop Scand 52:299-306, 1981.

Hochberg, FH et al. Hand difficulties among musicians. J Amer Med Assn 249(14): 1869-1872, 1983.

Hochberg, MC. Adult and juvenile rheumatoid arthritis: current epidemiologic concepts. Epid Reviews 3:27-44, 1981.

Howard, NJ. Peritendinitis crepitans. J Bone Joint Surg 19 (2):447-459, 1937.

Howell AE and Leach, RE. Bowler's thumb. J Bone Joint Surg 52A (2):379-381, 1970.

Hunt, JR. Occupational neuritis of the deep palmer branch of the ulnar nerve. J Nervous Mental Disorders 35 (11):673-689, 1908.

_____. The thenar and hypothenar types of neural atrophy of the hand. Amer J Med Sci 141:224-241, 1911.

Hymovich, L and Lindholm, M. Hand, wrist and forearm injuries: the result of repetitive motions. J Occup Med 8 (11): 573-577, 1966.

Inglis A et al. Median nerve neuropathy at the wrist. Clin Orthop 83:48, 1972.

Jacobson, C. and L. Sperling. Classification of the hand-grip. J. Occ. Med. 18:395-398, 1976.

Japanese Assn Industrial Health Committee on Cervicobrachial syndrome. The report of the Committee. Jap J Indust Health 15:304-311, 1973.

Johnson, EW et al. Wrist dimensions: correlation with median sensory latencies. Arch Phys Med Rehabil 64:556-557, 1983.

Jung, Y et al. Diabetic hand syndrome. Metabolism 20 (11): 1008-1015, 1971.

Kaplan, PE. Carpal tunnel syndrome in typists. J Amer Med Assn 250 (6): 821-822, 1983.

Karlqvist, L. Cutting operation at canning bench: a case study of hand tool design. Proc 1984 Intl Conf Occup Ergonomics: 452-456, Toronto, May 7-9, 1984.

Keen, WW. The symptomatology, diagnosis and surgical treatment of cercical ribs. Am J Med Sci 133 (2): 173-218, 1907.

Kellgren, JH and Lawrence, JS. Osteoarthrosis and disk degeneration in an urban population. Ann Rheum Dis 17:388-397, 1958.

Kelsey, J et al. Musculoskeletal Disorders, Their Frequency of Outcome and Their Impact in the Population of the United States. Prodist, NY, 1978.

Kendall, D. Aetiology, diagnosis and treatment of paraesthesiae in the hands. Br Med J 2:1633-1640, 1960.

Kim, LYS. Palmer digital nerve stimulation to diagnose carpal tunnel syndrome. Orthop Rev 12 (6):59-63, 1983.

Kleinbaum, DG and Kupper, LL. Applied Regression Analysis and Other Multivariable Methods. Duxbury Press, North Scitivate, Mass, 1978.

Kleinbaum, D et al. Epidemiologic Research: Principles and Quantitative Methods. Lifelong Learning Publ, Belmont, California, 1982.

Kleinert, HE and Hayes, JE. The ulnar tunnel syndrome. Plastic Reconstr Surg 47 (1):21-24, 1971.

Komoike, Y et al. A report of health examinations on keypunchers, typists and others X: reinstatement of patients with cervicobrachial syndrome. Sumitomo Bull Ind Health 10:159-171, 1974.

_____. Etiology and symptoms of four cases of occupational cervicobrachial syndrome developing maladaptation in post. Sumitomo Bull Ind Health 11:148-151, 1975.

Kraft, GL and Halvorson, GA. Median nerve residual latency: normal value and use in diagnosis of carpal tunnel syndrome. Arch Phys Med Rehabil 64:221-226, 1983.

Kourinka, I and Koskinen, P. Occupational rheumatic diseases and upper limb strain in manual jobs in a light mechanical industry. Scand J Work Environ Health 5 (suppl 3): 39-47, 1979.

Kourinka, I. Subjective discomfort in a simulated repetitive task. Ergonomics 26 (11): 1089-11-1, 1983.

Kremer, RM and Ahlquist, R.E: Thoracic outlet compression syndrome. Amer J Surg 130: 612-616, 1975.

Kurppa, K et al. Tennis elbow. Scand J Work Environ Health 5 (suppl 3): 15-18, 1979.

Kvarnstrom, S. Occurrance of musculoskeletal disorders in a manufacturing industry with special attention to occupational shoulder disorders. Scand J Rehabil Med Suppl 8, 1983.

Lamphier, TA et al. DeQuervain's disease. Ind Med Surg 34:847-856, 1965.

Lanfear, RT and Clarke, WB. The treatment of tenosynovitis in industry. Physiotherapy 58: 128-129, 1972.

Lapidus, PW and Guidotti, FP. Lateral and medial epicondylitis of the hymerus. Industr Med 39 (4):171-173, 1970.

Lascelles, R et al. The thoracic outlet syndrome. Brain 100: 601-612, 1977.

Lawrence, JS and Aitken-Swan. Rheumatism in miners I, rheumatic complaints. Br J Industr Med 9:1-18, 1952.

Lawrence, JS. Rheumatism in cotton operatives, Br J Industr Med 18:270-276, 1961.

_____. Rheumatism in Populations. Heinemann Medical Books Ltd, London, 1977.

Leao, L. DeQuervain's disease. J Bone Joint Surg 40A (5):1063-1070, 1958.

Lee, KS and Wu, L. Physical stress evaluations of microscopists using electromyography. Proc 1984 Intl Conf Occup Ergonomics: 397-401, Toronto. 1984.

Levine, EJ. Relief of acute occupational tenosynovitis. Ohio St Med J 64 (11):1275-1276, 1968.

Linos, A et al. The epidemiology of rheumatoid arthritis in Rochester, Minnesota: a study of incidence, prevalence and mortality. AM J EPID 1:87-98, 1980.

Lippman, RK. Bicipital tenosynovitis. NY St J Med:2235-2241, October 15, 1944.

_____. Frozen shoulder, periarthritis, bicipital tenosynovitis. Arch Surg 47:283-296, 1943.

Lipscomb, PR. Chronic nonspecific tenosynovitis and peritendinitis. Surg Clin North Amer 24:780-797, 1944.

Lister, G. The Hand (2nd ed). Churchill Livingston, Edinburg, 1984.

Little JM and Ferguson, DA. The incidence of the hypothenar hammer syndrome. Arch Surg 105:684-685, 1972.

Locksmith, MD et al. Rheumatism in mining communities in Marion County, West Virginia. Amer J Epid 90(1):17-29, 1969.

Lord, JW. Thoracic outlet syndrome, real or imaginary? NY St J Med:1488-1489, September 1981.

Lord, JW and Rosati, LM. Neurovascular compression syndromes of the upper extremity. CIBA Clinical Symposia 10:35-62, 1958.

Lowry, CW et al. Digital vessel trauma from repetitive impact in baseball catchers. J Hand Surg 1 (3):236-238, 1976.

Lublin, JS. Unions and firms focus on hand disorders that can be caused by repetitive tasks. Wall Street J:17, Jan. 14, 1983.

Luopajarvi, R et al. Prevalence of tenosynovitis and other injuries of the upper extremities in repetitive work. Scand J Work Environ Health 5 (suppl 3): 48-55, 1979.

Macnicol, MF. The results of operation for ulnar neuritis. J Bone Joint Surg 61B (2):159-164, 1979.

MacMahon, B and Pugh, TF. Epidemiology: Principles and Methods. Little, Brown Co, Boston, 1970.

Maeda, K. Occupational cervicobrachial disorders in assembly plants. Kuruma Med J 22: 231, 1975.

_____. Expansion of the occupations which induce neck-shoulder-arm disorders and some problems in taking measures against the disorders from experience in labor hygiene consultation activities. Sumitomo Sangyo Eisei 10:135-143, 1974.

Marin, EL et al. Carpal tunnel syndrome: median nerve stress test. Arch Phys Med Rehabil 64:206-208, 1983.

Marinacci, AA and Von Hagen, KO. Misleading all median hand. Arch Neurol 12:80-83, 1965.

Massey, EW. Carpal tunnel syndrome in pregnancy. Obstet Gynec Surg 33(3): 145-147, 1978.

Massey, EW and Riley, TL. Non-traumatic mononeuropathies: a review. Military Med 146:30-36, 1981.

Mathews, P. Ganglia of the flexor tendon sheaths in the hand. J Bone Joint Surg 55B (3):612-617, 1973.

Mathur, JG. Carpal tunnel syndrome in general practice. Aust Fam Physician 10:542-44, 1981.

Matsen III, FA and Kirby, RM. Office evaluation and management of shoulder pain. Orthop Clin North Amer 13 (3):453-475, 1982.

Maudsley, RH. The painful wrist. Practitioner 215:42-45, 1975.

Mayfield, FH and True, CW. Chronic injuries of peripheral nerves by entrapment. Neurological Surgery (Jr Youmans,ed):1141-1149. WB Saunders Co, Phila, 1973.

McCann, J and Davis, R. Carpal tunnel syndrome, diabetes and pyridoxal. Aust N Z J Med 8:638, 1978.

McCarroll Jr, HR. Nerve injuries associated with wrist trauma. Orthop Clin North Amer 15 (2):279-287, 1984.

McLaughlin, HL. Lesions of the musculotendinous cuff of the shoulder III: observations on the pathology, course and treatment of calcific deposits. Ann Surg 124 (2):354-362, 1946.

_____. Rupture of the rotator cuff. J Bone Joint Surg 44A (5):979-983, 1962.

McCleery, RS et al. Subclavius and anterior scalene muscle compression as a cause of intermittnet obstruction of the subclavian vein. Ann Surg 133 (5):588-602, 1951.

Melville, MD. The differential diagnosis of nerve compression syndromes in the arm and hand. Hand 4 (2):111--114, 1972.

Meyer, AW. Unrecornized occupational destruction of the tendon of the long head of the biceps brachii. Arch Surg 2:130-144, 1921.

_____. Chronic functional lesions of the shoulder. Arch Surg 35:646-674, 1937.

_____. Spontaneous dislocation and destruction of tendon of the long head of biceps brachii: 59 instances. Arch Surg 17:493-506, 1928.

Meulengracht, E and Schwartz, M. The course and prognosis of periarthrosis humeroscapularis with special regard to cases with general symptoms. Acta Med Scand 143 (5):350-360, 1952.

Miller, BK. How to spot and treat carpal tunnel syndrome early. Nursing 80: 50-53, March 1980.

Mills, GP. Treatment of tennis elbow. Br Med J:12-13, Jan 7, 1928.

Mitchell, DM and Fries, JF. An analysis of the American Rheumatism Association criteria for rheumatoid arthritis. Arth and Rheum 25 (5): 481-487, 1982.

Moidel, RA. Bowler's thumb. Arth and Rheum 24 (7):972-973, 1981.

Moldaver, J. Brief note Tinel's sign: its characteristics and significance. J Bone Joint Surg 60A (3):412-414, 1978.

Monga, TN and Laidlow, DM. Carpal tunnel syndrome measurement of sensory potentials using ring and index fingers. Amer J Phys Med 61 (3):123-129, 1982.

Morris, HH and Peters, BH. Pronator syndrome: clinical and electrophysiologic features of 7 cases. J Neurol Neurosurg Psychiat 39:461-464, 1976.

Morrison, DL. Tennis elbow and radial tunnel syndrome: differential diagnosis and treatment. J Amer Osteopath Assn 80 (12):823-826, 1981.

Moskowitz, RW. Osteoarthritis: a clinical overview. Epidemiology of the Rheumatic Diseases: 267-276. Amer Rheum Assn. Gower Medical Publ, New York, 1984.

Muchart, R. Stenosing tendovaginitis of abductor pollicis longus and extensor pollicus mrevis at the radial Styloid. Clin Orthop 33: 201-

209, 1964.

Mulder, D. The neuropathies associated with diabetes mellitus. Neurol 11: 275, 1961.

Murray-Leslie, CF and Wright, V. Carpal tunnel syndrome, humeral epicondylitis and cervical spine: a study of clinical and dimensional relations. Br Med J 1:1439-1442, 1976.

Murley, AGH. The painful elbow. Practitioner 215:36-41, 1975.

Naffziger,HC and Grant, WT. Neuritis of the brachial plexus mechanical in origin. Clin Orthop Rel Res 51:7-15, 1967.

National Swedish Board of Occupational Safety and Health. Work Postures and Working Movements: Ordinance AFS 1983:6. Arbetarskyddsstyrelsen, Stockholm, 1984.

Neer, CS. Impingement lesions. Clin Orthop Rel Res 173:70-77, 1983.

Neter, J and Wasserman, W. Applied Linear Statistical Models. RD Irwin, Inc, Homewood, Illinois, 1974.

Nelson, PA. Treatment of patients with cervicodorsal outlet syndrome, J Amer Med Assn 163 (17): 1570-1576, 1957.

Neviaser, RJ. Adhesive capsulitis and the stiff and painful shoulder. Orthop Clin North Amer 11 (2):327-331, 1980.

_____. Lesions of the biceps and tendinitis of the shoulder. Orthop Clin North Amer 11 (2):343-348, 1980.

_____. Tears of the rotator cuff. Orthop Clin North Amer 11 (2):295-305, 1980.

_____. Painful conditions affecting the shoulder. Clin Orthop North Amer 173:63-69, 1983.

Nichols, HM. Anatomic structures of the thoracic outlet. Clin Orthop Rel Res 51:17-25, 1967.

Ochsner, A et al, Scalenus anticus (Naffziger) syndrome. Amer J Surg 28:699-695, 1935.

Omer, GE. Physical diagnosis of peripheral nerve injuries. Orthop Clin North Amer 12 (2):207-227, 1981.

Overton, LM. The causes of pain in the upper extremity: a differential diagnosis study.Clin Orthop Rel Res 51:27-44, 1967.

Partridge, REH and Duthie, JJR. Rheumatism in dockers and civil servants: a comparison of heavy manual and sedentary workers. Ann Rheum Dis 27:441-453, 1968.

_____et al. Rheumatic complaints among workers in iron foundries. Ann Rheum Dis 27:441-453, 1968.

Perrott, JW. Anatomical factors in occupational trauma. Med J Aust 1 (3) 73-82, 1961.

Peterson, RR. Prevention! a new approach to tendinitis. Occup Health Nurs:19-23, May 1979.

Phalen, G. The carpal tunnel syndrome, clinical evaluation of 598 hands. Clin Orthop Rel Res 83: 29, 1972.

_____. The carpal tunnel syndrome. J Bone Joint Surg 48A (2):211-228, 1966.

Phillips, R. Carpal tunnel syndrome as a manifestation of systemic disease. Ann Rheum Dis 26: 59, 1967.

Pick, RY. DeQuervain's disease: a clinical triad. Clin Orthop Rel Res 143:165-166, 1979.

Plato, CC and Norris, AH. Osteoarthritis of the hand; longitudinal studies. Amer J Epid 110 (6):740-746, 1979.

Pozner, H. A report on a series of cases of simple acute tenosynovitis. J R Army Med Corps 78: 142, 1942.

Priel, V. A numerical definition of posture. Human Factors 16:576-584, 1974.

Rabourn, R. Investigation of individual work methods as etiological factors of carpal tunnel syndrome. (Master's thesis) Industrial and Operations Engineering, University of Michigan, 1977.

Radin E et al. Patterns of degenerative arthritis: preferential involvement of the distal finger joints. Lancet 1: 377, 1971.

Ramazzini, B. Diseases of Workers, 1713. (English trans WC Wright, 1940). Hafner Publ Co, NY, 1964.

Rasch, PJ and Burbaker, ML. The problem of tennis elbow. J Amer Osteopath Assn 57:268-71, 1957.

Rathburn, JB and Macnab, I. The microvascular pattern of the rotator cuff. J Bone Joint Surg 52B: 540-553, 1970.

Reddy, MP. Ulnar nerve entrapment syndrome at the elbow. Orthop Rev 12 (11):69-73, 1969.

Reed, J and Harcourt, H. Tenosynovitis: an industrial disability. Amer J Surg 62: 392-396, 1943.

Renfrews, S. Fingertip sensation., Lancet 1:396-97, 1969.

Rhodes, R. Letter. Amer J Surg, 73: 248, 1947.

Richardson, AT. The painful shoulder. Practitioner 215:27-35, 1975.

Rienstein, L. Hand dominance in carpal tunnel syndrome. Arch Phys Med Rehabil 62:202-203, 1981.

Riddell, DH. Thoracic outlet syndrome: thoracic and vascular aspects. Clin Orthop Rel Res 51:53-63, 1967.

Ritter, MA and Inglis, AE. The extensor indicis proprius syndrome. J Bone Joint Surg 51A (8):1645-1648, 1969.

Roles, N and Maudsley, RH. Radial Tunnel Syndrome. J Bone Joint Surg 54(B): 499-508, 1972.

Roos, DB and Owens, JC. Thoracic outlet syndrome. Arch Surg 93:71-74.

Rothfleisch, S and Sherman, D. Carpal tunnel syndrome : biomechanical aspects of occupational occurence and implications regarding surgical management. Orthop Rev 7: 107, 1978.

Rothman, RH and Parke, WW. The vascular anatomy of the rotator cuff. Clin Orthop 41:176-186, 1965.

Roto, P and Kivi, P. Prevalence of epicondylitis and tenosynovitis among meatcutters. Scand J Work Environ Health 10:203-205, 1984.

Russe, O. An Atlas of Examination, Standard Measurements and Diagnosis in Orthopedics and Traumatology. Hans Huber, Publ, Bern, 1972.

Saario, L. The range of movement of the shoulder joint at various ages. Acta Orthop 33 (4): 24-25, 1963-64.

Sabour, M and Fadel, H. The carpal tunnel syndrome-a new complication ascribed to the pill. Amer J Obstr Gynecol 107:1266, 1970.

Sandzen, S. Carpal tunnel syndrome. Amer Fam Pract 24(5): 190-204, 1981.

Sarrafian, SK. Gross and functional anatomy of the shoulder. Clin orthop Rel Res 173:11-19, 1983.

Schlesinger, EB. The thoracic outlet syndrome from a neurosurgical point of view. Clin Orthop Rel Res 51:49,52, 1967.

Schlesselman, James. Case-Control Studies. Oxford University Press. New York, 1982.

Seyffarth, H. Primary myositis in m. pronator teres as a cause of lesion in the n mediasus, the pronator syndrome. Acta Psychiat Neurol Scand suppl 74:251-254, 1951.

Shea, JD and McClain, EJ. Ulnar nerve compression syndromes at and below the wrist. J Bone Joint Surg 51A (6):1095-1103, 1969.

Silver, D. Thoracic outlet syndrome. Missouri Med 77 (4): 189-198, 1980.

Simon, WH. Soft tissues disorders of the shoulder. Orthop Clin North Amer 6 (2): 521-539, 1975.

Simons, DG. Muscle Pain Syndromes, Part I. Amer J Phys Med 54 (1):289-311, 1975.

Sinclair, A. Tennis Elbow in industry. Brit J Industr Med 22:144-148, 1965.

Smith, EM et al. Carpal tunnel syndrome: contribution of flexor tendons. Arch Phys Med Rehabil 58:379-385, 1977.

Stewart, OJ et al. Influence of resistance, speed of movement and forearm position of recruitment of the elbow flexors. Amer J Phys Med 60 (4): 165-179, 1981.

Steiner, C. Tennis elbow. J Amer Osteop Assn 75 (1-6):575-581, 1976.

Struckel, RS and Garrick, JS. Thoracic outlet syndrome in athletes. Amer J Sports Med 6 (2):35-39, 1978.

Stamford, BA. Validity and reliability of subjective ratings of perceived exertion during work. Ergonomics 19 (1):53-60, 1976.

Sunderland, S. The nerve lesion in the carpal tunnel syndrome. J Neurol Neurosurg Psychiat 39:615-626, 1976.

Swajian, GR. Carpal tunnel syndrome: a five year study. J Amer Osteop Assn 81 (1):49-51, 1981.

Swanson, AB et al. Ulnar nerve compression due to an anomalous muscle in canal of Guyon. Clin Orthop Rel Res 83:64-67, 1972.

Szabo, RM et al. Sensibility testing in patients with carpal tunnel syndrome. J Bone Joint Surg 66A (1):60-64, 1984.

Tanzer, R. The carpal tunnel syndrome. J Bone Joint Surg 41 (a): 626, 1959.

Thompson, A et al. Peritendintitis crepitans and simple tenosynovitis: a clinical study of 544 cases in industry. Br J Indust Med 8: 150-160, 1951.

Tichauer, E. Some aspects of stress on the forearm and hand in industry. J Occup Med 8: 63-71, 1966.

_____. Ergonomic aspects of biomechanics. Industrial Environment-Its Evaluation and Control: 431-492, NIOSH, Wash DC, 1973.

_____. Biomechanics sustains occupational safety and health. Ind Engineering 8: 46, 1976.

_____. The Biomechanical Basis of Ergonomics. Wiley & Sons, New York, 1978.

_____. Ergonomic principles basic to hand tools. Amer Indust Hygiene J 38:622-633, 1977.

Tyson, R and Kaplan, G. Modern concepts of diagnosis and treatment of thoracic outlet syndrome. Orthop Clin North Amer 6: 507, 1975.

Urbaniak, JR and Roth, JH. Office diagnosis and treatment of hand pain. Orthop Clin North Amer 13 (3):477-495, 1982.

Urschel Jr, HC et al. Thoracic outlet syndrome. Ann Thoracic Surg 6 (1): 1-39, 1968.

Valtonen, E. The tension neck syndrome, it's etiology, clinical features and results of physical treatment. Ann Med Itn Fenn 57:139-142, 1968.

Viikarii-Juntura, E. Neck and upper limb disorders among slaughterhouse workers. Scand J Work Environ Health 9:283-290, 1983.

Wadsworth, T and Williams, J. Cubital tunnel external compression syndrome. Br Med J 1:662, 1973.

Waris, P. Occupational cervicobrachial syndromes: a review. Scand J Work Environ Health 6: suppl (3-4):3-14, 1980.

_____ et al. Epidemiologic screening of occupational neck and upper limb disorders. Scand J Work Environ Health 5 (suppl 3): 25, 1979.

Webb, RDG et al. Assessment of musculoskeletal discomfort in a large clerical office: a case study. Proc 1984 Intl Conf Occup Ergonomics: 392-396, Toronto, May 7-9, 1984.

Weiss, J. The painful shoulder. Textbook of Rheumatology (Kelley, Ed) : 437-488. Saunders & Co, Phila, 1981.

Welch, R. The causes of tenosynovitis in industry. Industr Med 41 (10):16-19, 1972.

_____. The measurement of Physiological Predisposition to tenosynovitis. Ergonomics 16 (5):665-558, 1973.

Wells, JA et al. Musculoskeletal disorders among letter carriers. J Occup Med 25 (11):814-820, 1983.

Wells, MS. Industrial incidence of soft tissue syndromes. Phys Ther Rev 41 (7):512-515, 1961.

Wener, MH et al. Occupationally acquired vibratory angioedema with secondary carpal tunnel syndrome. Ann Int Med 98 (1):44-48, 1983.

Wherle, J. Chronic wrist injuries associated with repetitive hand motions in industry. Occupational Health & Safety Technical Report, Dept IOE, University of Michigan, 1976.

Wickstrom, G. Drawbacks of clinical diagnosis in epidemiologic research on work-related musculoskeletal morbidity. Scand J Work Environ Health 8 (Suppl 1):97-99, 1982.

Wilgis, EFS. Techniques for diagnosis of peripheral nerve loss. Clin Orthop Rel Res 163:8-14, 1982.

Wilson, RN and Wilson, S. Tenosynovitis in industry. Practitioner 78:612-615, 1957.

Winter, DA. Biomechanics of Human Movement. Wiley-Interscience Publications, Whiley and Sons. New York, 1979.

Wongsam, PE at al. Carpal tunnel syndrome: use of palmer stimulation of sensory fibers. Arch Phys Med Rehabil 64:16-19, 1983.

Wood, MP and Linschied, RL. Abductor pollicus longus bursitis. Clin Orthop Rel Res 93:293-296, 1975.

Worcester, JN and Green, DP. Osteoarthritis of the acromioclavicular joint, Ann Thoracic Surg 6 (1):1-39, 1968.

Wright, IS. The neurovascular syndrome produced by hyperabduction of the arms. Amer Heart J 29 (1):1-19, 1945.

Yergason, RM. Supination sign. J Bone Joint Surg 13:160, 1930.

Youm, Y. et al. Kinematics of the wrist I. and experimental study of radial-ulnar deviation and flexion-extension. Journal of Bone and Joint Surgery, 60A:423-431.

APPENDIX I
PRIMARY INTERVIEW

ID# ___ ___ ___ ___

Upper Extremity Form Checklist:

1. Main Questionnaire ____
2. Neck Arm Shoulder Questionnaire ____
3. Elbow, Forearm Questionnaire ____
4. Hand, Wrist Questionnaire ____
5. Two Point Discrimination ____
6. Physical Exam ____

   Auxilliary Tests ____

   Angina Questionnaire ____

UNIVERSITY OF MICHIGAN
UPPER EXTREMITY STUDY

Questionnaire

ID# ___ ___ ___ ___

Name _____

Address _____

_____

Home Telephone Number _____

Social Security Number _____

ALL INFORMATION OBTAINED IN THIS STUDY WILL BE KEPT CONFIDENTIAL AND USED FOR MEDICAL RESEARCH PURPOSES ONLY.

1. Please complete this questionnaire as accurately as you can. If you have any questions please ask the interviewer.

2. Most questions can be answered by checking YES or NO like this: YES ✓ NO ___,

   Circling a word like this, (HIPS) KNEES

   or filling in a blank like this, 2 (years).

3. Answer each question but feel free to write any commetns in the margins of the pages.

THANK YOU FOR THE TIME AND THOUGHT YOU PUT INTO COMPLETING THIS QUESTIONNAIRE.

ID# ___ ___ ___ ___
(1-4)
For Office Use Only
Form 1
Card 01

ID# ___ ___ ___ ___ Interviewer ___ ___ (9-10)

Date: MO ___ ___ Day ___ ___ Year ___ ___ (11-16)

Time: ___ ___ : ___ ___ AM PM (18-22)

1. Sex: 1 Male ___ 2 Female ___ (24)

   Race: 2 Black ___ 1 White ___ 3 Hispanic ___ (25)

   4 Asian ___ 5 Am. Ind. ___ 6 Other ___

2. Date of Birth:

   MO ___ ___ DAY ___ YEAR ___ ___ AGE ___ ___ (26-31) (32-33)

3. Have you ever had any injuries to your hands wrists, arms, shoulders, neck, or back (including fractures, industrial accidents, automobile accidents, sports injuries)?

   YES ___ NO ___ (35)

3a. If yes, list year and circle type of injury.

	1 Fingers 2 Hand/3 Wrist		4 Arm/5 Elbow		6 Shoulder		7 Neck	8 Back	
	Left	Right	Left	Right	Left	Right			
Broken Bone/ Dislocation	___	___	___	___	___	___	___	___	(37-41)
Strain Sprain Muscle Pull	___	___	___	___	___	___	___	___	(42-46)
Specify Other	___	___	___	___	___	___	___	___	(47-51)

4. Have you ever been in a cast, 1 YES ___ 2 NO ___

   If yes, where? _____

5. Have you ever noticed that any of your joints were painful and swollen for at least a month for no apparent reason? (Apparent reason includes injuries, new job, hobbies, or sports). (55)

   1) YES ___ 2) NO ___

   If yes,

5a. Which joints bothered you.

FINGERS ___	Left ___	Right ___	(56)
WRISTS ___	Left ___	Right ___	(57)
ELBOWS ___	Left ___	Right ___	(58)
SHOULDERS ___	Left ___	Right ___	(59)
HIPS ___	Left ___	Right ___	
KNEES ___	Left ___	Right ___	(60)
ANKLES ___	Left ___	Right ___	(61)
TOES ___	Left ___	Right ___	(62)

5b. How old were you when you started having pain and swelling in your joints? _____ (63-64)

5c. How long does the pain and swelling usually last? (65-66)
___ ___ Weeks

5d. When was the last time you had pain and selling of your joints? (67)

1) Now ___
2) Less than a year ago but not now ___
3) 1-2 years ago ___
4) 3 or more years ago ___

5e. Have you ever had stiffness in your joints when first getting out of bed on most days for at least a month? (68)

1) YES ___ 2) NO ___

If yes, how long does it last? (69)

1) Less than 30 minutes ___ 2) More than 30 minutes ___

6. Have you ever been told by a doctor that you had any type of arthritis or other type of joint problems (Rheumatoid Arthritis, Osteoarthritis, or other rheumatoid diseases)? (70)

   1) YES ___ 2) NO ___ If yes, what? _____

7. Have you ever been told by a doctor that you had any of the following? Please check:

01 Carpal Tunnel Syndrome	YES ___ NO ___	(9-10)
02 Psoriasis	YES ___ NO ___	(11-12)
03 Chronic Skin Rash	YES ___ NO ___	(13-14)
04 Gall Bladder Problems	YES ___ NO ___	
05 Small or Large Bowel Disease	YES ___ NO ___	
06 Heart Attack or Angina	YES ___ NO ___	
07 Diabetes (sugar)	YES ___ NO ___	
08 Lupus (Systemic Lupus Erythematosus)	YES ___ NO ___	
09 Scleroderma	YES ___ NO ___	
10 Gout	YES ___ NO ___	
11 Ankylosing Spondylitis	YES ___ NO ___	
12 Gonorrhea (clap)	YES ___ NO ___	
13 Rieter Syndrome	YES ___ NO ___	
14 Ruptured Disk Back or Neck	YES ___ NO ___	
15 Other _____		

8. Have you ever been hospitalized OR had an operation? (15)
   1) YES ___ 2 NO ___ If yes, for what? _____

9. What medicine are you currently taking? 1) NONE ___ (16)

_____	_____	_____	2) Horm
_____	_____	_____	3) Inflam
_____	_____	_____	4) Pain
			5) Relax
			6) Other

10. Women Only:

10a. When was your last pregnancy? YEAR ___ ___	(18-19)
10b. Have you ever taken birth control pills regularly for 6 months? 1) YES ___ 2) NO ___	(20)
10c. If yes, are you still taking birth control pills? 1) YES ___ 2) NO ___	(21)
10d. How many years in total have you used birth control pills regularly? ___ ___	(22-23)

10e. Have you had a hysterectomy? 1) YES ___ 2) NO ___ (24)

10e1. If YES, were both your ovaries removed?
1) YES ___ 2) NO ___ (25)
YEAR ___ ___ (26-27)

11. Have you ever drunk alcoholic beverages (beer, wine, liquor)? (29)
1) YES ___ 2) NO ___

If YES:

11a. Have you drunk alcoholic beverages in the last 12 months? (30)
1) YES ___ 2) NO ___

11b. How often do you drink alcoholic beverages? (31)

1) Most days ___ 4) More than once/month ___
2) 3-5 times per week ___ 5) Less than once/month ___
3) 1-2 times per week ___ 6) Only on weekends ___

11c. On the average how many of the following do you drink?

Bottles/Cans of Beer: (32-33)
During the week ___ ___ Weekend ___ ___ Week

Glasses of Wine: (34-35)
During the week ___ ___ Weekend ___ ___ Weekend

Shots of Liquor: (36-37)
During the week ___ ___ Weekend ___ ___ Total

11d. How many years have you been drinking the above amount? ___ ___ (38-39)

11e. Have you ever drunk more heavily than you drink now? (40)

If yes, for how many years? ___ ___ YEARS (41-42)

IN THE NEXT 6 QUESTIONS, BY DISCOMFORT, WE MEAN CRAMPING, SWELLING, STIFFNESS, TINGLING (PINS AND NEEDLES) OR NUMBNESS.

12. In the last 2 years, have you had pain or discomfort in your: (45-51)

1)NECK 2)SHOULDER(S) 3)ARM(S) 4)ELBOW(S) 5)WRISTS(S)

6)HAND 7)FINGERS.... 1) YES ___ 2) NO ___

...if YES, please circle where you had pain or discomfort.

13. If you have pain or discomfort in more than 1 place:

13a. Where did the pain or discomfort first start? (52-53)

_____

13b. Where does it bother you the most? (54-55)

_____

14. During the past 24 months, have you had RECURRING neck, shoulder or upper arm problems? 1) YES ___ 2) NO ___ (57-61)

If yes, please circle the best description.

1)BURNING 2)STIFFNESS 3)PAIN 4)CRAMPING

5)TINGLING (Pins and Needles) 6)NUMBNESS 7)SWELLING

8)OTHER

14a. If you have more than one of the above complaints, which bothers you the most? _____ (62)

15. During the past 24 months, have you had any RECURRING difficulty with your FOREARM(S) or ELBOW(S)? (63-67)

1) YES ___ 2) NO ___ If yes, please circle best description.

1)BURNING 2)STIFFNESS 3)PAIN 4)CRAMPING

5)TINGLING (Pins and Needles) 6)NUMBNESS 7)SWELLING

8)REDNESS

15a. If you have more than one of the above complaints, which bothers you the most? _____ (68)

16. During the last 24 months, have you had any RECURRING difficulty with your HAND(S), WRIST(S) or FINGER(S)? (9-13)
1) YES ___ 2) NO ___

If yes, please circle best description.

1)BURNING 2)STIFFNESS 3)PAIN 4)CRAMPING

5)TINGLING (Pins and Needles) 6)NUMBNESS 7)SWELLING

8)REDNESS

16a. If you have more than one of the above complaints, which bothers you the most? _____ (14)

17. Do you consider yourself 1) Left Handed ___, 2) Right Handed ___, or 3) both ___? (15)

18. Which hand do you use most at work? (16)
1) LEFT ___ 2) RIGHT ___ 3) BOTH ___

19. Do you have any hobbies or sports activities that you regularly participate in? Please list. # HRS/WEEK?

_____ _____ (17-23) (24-30)
_____ _____ 1 = BSPT
_____ _____ 2 = OSPT 3 = K/S
_____ _____ 4 = MUSIC 6 = OTHER

20. How many hours have you worked today? ___HRS (32-33)

21. Which job are you currently performing? (35) (37-40) (35) EXPO

_____ (37-40) SPCJOB

22. How long have you been doing this job? (42-45) (42-45)

YEARS ___ ___ MONTHS ___ ___

23. What tools do you use on your job?

_____

24. What job have you done the longest in this plant?

_____

25. Have you changed jobs becaues of pain or discomfort in your neck, arm(s), elbow(s), wrist(s) or hand(s)? (47)

1) YES ___ 2) NO ___

25a. If yes, which job did you have because of this pain or discomfort? _____ (32-33)

26. Please list the kinds of jobs you had between high school and now and the number of years worked in each job. Only include those jobs where you worked for more than 6 months.

JOB	YRS
A.	
B.	
C.	
D.	
E.	
F.	
G.	
H.	
I.	

FOR OFFICE USE ONLY

MORE THAN 10 TIMES/HR USING YOUR HANDS

Lift/Lower	Twist by Hand	Pounding	Rubbing	Pull/Push	Power Hand Tools	Reach Overhead	Twist Upper Body	Pinch or Grasp

TWO POINT DISCRIMINATION

MODEL # _____

ID # _____

Date _____

Examiner _____

	RIGHT				LEFT			
	Index (L-R)		Little (R-L)		Index (L-R)		Little (R-L)	
A	1	2	1	2	1	2	1	2
B	1	2	1	2	1	2	1	2
C	1	2	1	2	1	2	1	2
D	1	2	1	2	1	2	1	2
E	1	2	1	2	1	2	1	2
F	1	2	1	2	1	2	1	2
G	1	2	1	2	1	2	1	2
H	1	2	1	2	1	2	1	2
I	1	2	1	2	1	2	1	2
J	1	2	1	2	1	2	1	2
K	1	2	1	2	1	2	1	2
L	1	2	1	2	1	2	1	2
M	1	2	1	2	1	2	1	2
N	1	2	1	2	1	2	1	2
O	1	2	1	2	1	2	1	2
P	1	2	1	2	1	2	1	2
Q	1	2	1	2	1	2	1	2
R	1	2	1	2	1	2	1	2
S	1	2	1	2	1	2	1	2
T	1	2	1	2	1	2	1	2
U	1	2	1	2	1	2	1	2
V	1	2	1	2	1	2	1	2
W	1	2	1	2	1	2	1	2
X	1	2	1	2	1	2	1	2
Y	1	2	1	2	1	2	1	2
Z	1	2	1	2	1	2	1	2

APPENDIX II

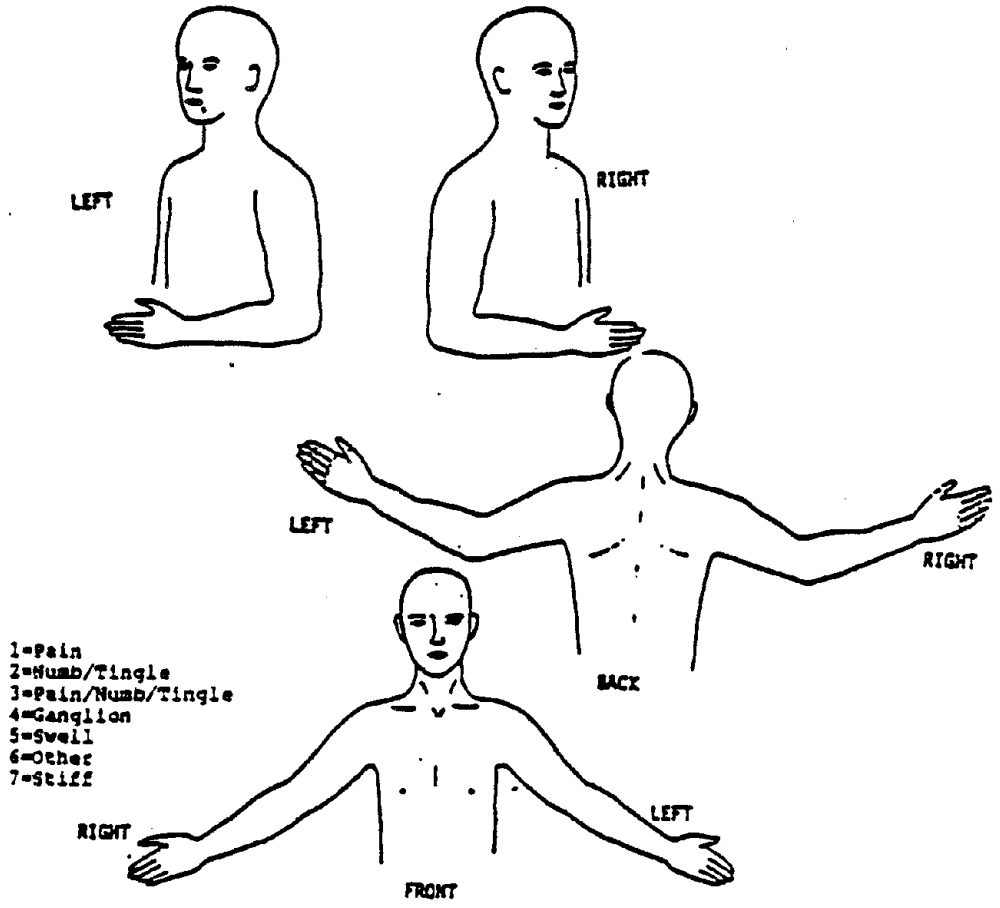
NECK, SHOULDER INTERVIEW

ID# ___ ___ ___ ___
(1-4)
FOR OFFICE USE ONLY
Form 2 Card 04

NECK, SHOULDER, UPPER ARM

14b. Which side bothers you? LEFT ___ RIGHT ___ BOTH ___ (9-17)

(18-26)
14c. Carefully shade in the areas where most of the difficulty occurs. (27-35)



1=Pain
2=Numb/Tingle
3=Pain/Numb/Tingle
4=Ganglion
5=Swell
6=Other
7=Stiff

ID# ___ ___ ___ ___
(1-4)
FOR OFFICE USE ONLY
Form 2 Card 04

NECK, SHOULDER, UPPER ARM (continued)

14d. When did you first notice the pain or discomfort? (36-37)

MONTH ___ ___ YEAR ___ ___

14e. When was the last time you had this problem? (38-41)

MONTH ___ ___ YEAR ___ ___

Do you have this problem now? 1 YES ___ 2 NO ___ (42)

14e1. If you no longer have this problem, why do you think it went away? (43) 1=OK 2=Still 3=Jobchg 4=Other

_____

_____

14f. How many of these episodes have you had in the last year? (44-46
___ ___ ___

14g. How long does the trouble usually last? (47)

1. Less than 1 hour ___
2. Less than 1 day ___
3. Less than 1 week ___
4. Less than 1 month ___
5. More than 1 month ___
6. More than 6 months ___

14h. Does it ever awaken you from sleep? 1. YES___ 2. NO___ (48)

14i. In the last year, have you had persistent difficulty in: (49) (50) (51)

1. Combing your hair? YES ___ NO ___
2. Reaching into your back pockets? YES ___ NO ___
3. Scratching your back? YES ___ NO ___
4. Tying your shoes? YES ___ NO ___
5. Holding tools? YES ___ NO ___
6. Moving your shoulder or arm? YES ___ NO ___
7. Twisting your neck? YES ___ NO ___
8. Bending your lower back? YES ___ NO ___

ID# ___ ___ ___ ___
(1-4)
FOR OFFICE USE ONLY
Form 2 Card 04

NECK, SHOULDER, UPPER ARM (continued)

14j. Does the pain or discomfort seem to spread? 1. YES ___ 2. NO ___ (52)

14j1. If yes, does it spread down the arm to the hand? (53)

1. YES ___ 2. NO ___ (54)
Up to the top of the head? 1. YES ___ 2. NO ___ (55)
From the chest? 1. YES ___ 2. NO ___ (56)

Is the pain or discomfort made worse by coughing, sneezing or deep breathing? 1. YES ___ 2. NO ___

14k. What activities make it worse:

at home? _____ (57)

at work? _____ (58)

14l. When you are away from work for more than 1 week, does the difficulty: 1. Increase ___ 2. Decrease ___ 3. Not change ___ (59)

14m. In the past year, how many days have you had to stay home from work because of pain or discomfort in your neck, shoulder(s) or upper arm(s)? ___ ___ (60-61)

14n. In the past year, how many days did you spend doing different jobs (light or restricted) because of pain or discomfort in your neck, shoulder(s) or upper arm(s)? ___ ___ (62-63)

14o. Have you had to stay overnight in a hospital because of the pain or discomfort in your upper arm(s), shoulder(s) or neck? 1. YES ___ 2. NO ___ (64)

14p. What medical treatment have you received for this problem (please check)? 0. NONE ___ (65)

1. PILLS ___ What kind? _____ (66) (67)
When (last time) _____ (68) (69)
2. SHOTS ___ What kind? _____ (70)
When (last time) _____
3. REST ___ When (last time) _____
4. HEAT ___ When (last time) _____
5. MASSAGE ___ When (last time) _____
6. OTHER ___ _____

APPENDIX III

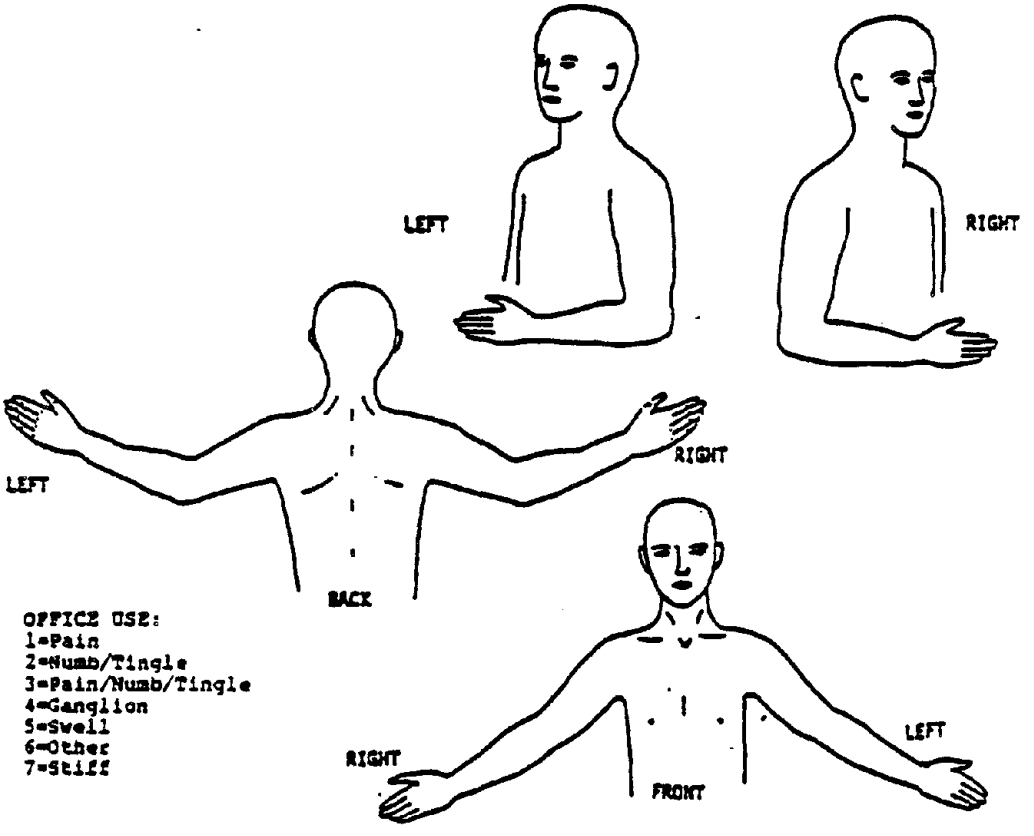
ELBOW, FOREARM INTERVIEW

ID# ___ ___ ___ ___
(1-4)
FOR OFFICE USE ONLY
CARD 05

ELBOW, FOREARM

15b. Which forearm or elbow bothers you? LEFT ___ RIGHT ___ BOTH ___ (9-35)

15c. Carefully shade in the areas where most of the difficulty occurs.



OFFICE USE:
1=Pain
2=Numb/Tingle
3=Pain/Numb/Tingle
4=Ganglion
5=Swell
6=Other
7=Stiff

ID# ___ ___ ___ ___
(1-4)
FOR OFFICE USE ONLY
CARD 05

ELBOW, FOREARM (continued)

15m. In the last year, how many days have you had to stay home from work because of pain or discomfort in your elbow or forearm? (56-57)

___ ___

15n. In the last year, how many days did you spend doing different jobs (light or restricted) because of pain or discomfort in your elbow(s) or forearm(s)? ___ ___ (58-59)

15o. Have you had to stay overnight in a hospital because of the pain or discomfort in your elbow or forearm? 1. YES ___ 2. NO ___ (60)

15p. What medical treatment have you received for elbow or forearm problems? 0.None ___ (62-66)

1. PILLS ___ Kind _____ Amount _____

   For how long? ___ ___ Months

2. SHOTS ___ Kind _____

   Number ___ When _____

3. SPLINT ___ When _____

   For how long? ___ ___ Months

4. HEAT ___ When _____

   For how long? ___ ___ Months

5. COLD ___ When _____

   For how long? ___ ___ Months

6. OINTMENT ___ When _____

   For how long? ___ ___ Months

7. MASSAGE ___ When _____

   For how long? ___ ___ Months

8. OTHER _____

   When _____ For how long? ___ ___ Months

ID# ___ ___ ___ ___
(1-4)
FOR OFFICE USE ONLY
CARD 05

ELBOW, FOREARM (continued)

15d. When did you first notice the problem? (36-37)

MONTH ___ ___ YEAR ___ ___

15e. When was the last time you had the problem? (38-41)

MONTH ___ ___ YEAR ___ ___

Do you have the problem now? 1. YES ___ 2. NO ___ (42)

15e1. If you no longer have this problem, why do you think it went away? (43)

_____

_____

15f. How many of these episodes have you had in the last year? (44-46)

___ ___

15g. How long does it usually last? (47)

1. Less than 1 hour ___ 2. Less than 1 day ___
3. Less than 1 week ___ 4. Less than 1 month ___
5. More than 1 month ___ 6. More than 6 months ___

15h. Does it ever awaken you from sleep? 1. YES ___ 2. NO ___ (48)

15i. Have you had any difficulty in turning a doorknob? (49)

1. YES ___ 2. NO ___

Picking up small objects? 1. YES ___ 2. NO ___ (50)

15j. Does it (elbow, forearm) hurt when you press it? (51)

1. YES ___ 2. NO ___

15k. What activities make it worse at home? _____ (53)

_____

at work? _____ (54)

15l. When you are away from work for more than 1 week, does the difficulty: 1. Increase ___ 2. Decrease ___ 3. Not Change ___ (55)

APPENDIX IV

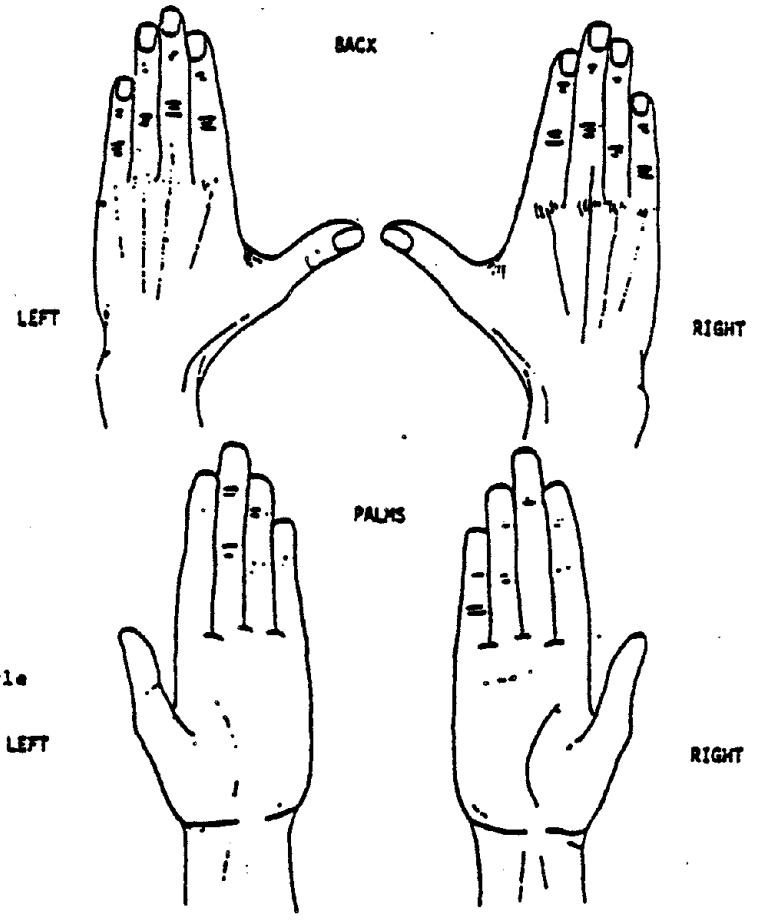
HAND, WRIST INTERVIEW

ID# ___ ___ ___ ___
(1-4)
FOR OFFICE USE ONLY
Form 04 Card 06

WRIST, HAND, FINGERS

16b. Which wrist? LEFT ___ RIGHT ___ BOTH ___ NONE ___ (9-17)
(18-26)
Which hand? LEFT ___ RIGHT ___ BOTH ___ NONE ___ (27-35)
(36-44)

16c. Carefully shade in the areas where most of the difficulty occurs.



OFFICE USE:
1=Pain
2=Numb
3=Pian/Numb/Tingle
4=Ganglia
5=Swell
6=Other
7=Stiff

ID# ___ ___ ___ ___
(1-4)
FOR OFFICE USE ONLY
Form 04 Card 06

WRIST, HAND, FINGERS (continued)

16d. When did you first notice the problem? (45-46)

MONTH ___ ___ YEAR ___ ___

16e. When was the last time you had this problem? (47-50)

MONTH ___ ___ YEAR ___ ___

Do you have the problem now? 1. YES ___ 2. NO ___ (51)

16el. If you no longer have this problem, why do you think it went away? (52)
1=OK
2=Still
3=Jobchg
4=Other

_____

16f. How many of these episodes have you had in the last year? (53-55)

___ ___ ___

16g. How long does the problem usually last? (56)

1. Less than 1 hour ___ 4. Less than 1 month ___ (57)
2. Less than 1 day ___ 5. More than 1 month ___ (58)
3. Less than 1 week ___ 6. More than 6 months ___ (59)

16h. Does it ever awaken you from sleep? (61)

1. YES ___ 2. NO ___

16i. Have you ever had a persistent feeling of weakness in your hands or fingers such as difficulty with:

Turning a key in lock? 1. YES ___ 2. NO ___ (62)

Turning a door knob? 1. YES ___ 2. NO ___ (63)

Dropping things or tools? 1. YES ___ 2. NO ___ (64)

16j. Does the pain or discomfort ever seem to spread?

1. YES ___ 2. NO ___

If yes, to where? Up the Forearm ___, (65)

Down to the thumb ___, (66)

Other _____ (67)

ID# ___ ___ ___ ___
(1-4)
FOR OFFICE USE ONLY
Form 04 Card 06

WRIST, HAND, FINGERS (continued)

16k. What activities make it worse

at home? _____ (68)

at work? _____ (69)

16l. Does the weather make the discomfort in your hands worse? (70)

1. Worse in the heat ___
2. Worse in the cold ___
3. No difference ___

16m. Have you ever had persistent difficulty in straightening out a bent finger? YES ___ NO ___ (9-10) (11-12) (13-14)

If yes, please circle which finger(s)

1) LEFT: 1. Thumb 2. Index 3. Middle 4. Ring 5. Little

2) RIGHT: 1. Thumb 2. Index 3. Middle 4. Ring 5. Little

16n. When you are away from work for more than 1 week, does the difficulty: (15)

1. Increase ___
2. Decrease ___
3. Not change ___

16o. In the last year how many days did you have to stay home from work because of this problem? ___ ___ (17-18)

16p. In the last year, how many days did you spend doing different jobs (light or restricted work) because of pain or discomfort in your wrist(s), hand(s), or finger(s)? (19-20)

___ ___

16q. Have you ever had to stay in a hospital overnight because of this problem? 1. YES ___ 2. NO ___ (22)

16r. Have you ever received any medical treatment for problems with your wrist(s), hand(s), or finger(s)? (23)

1. YES ___ 2. NO ___

ID# ___ ___ ___ ___
(1-4)
FOR OFFICE USE ONLY
Form 04 Card 06

16a. What relieves the pain or discomfort in your wrist(s), hand(s), or finger(s) (please check)? (24-39)

99 NOTHING ___

01 PILLS ___ Kind _____
Amount _____ For how long? ___ ___ Months

02 SHOTS ___ Kind _____ Number _____
For how long? ___ ___ Months

03 RESTING ___ When _____
For how long? ___ ___ Months

04 STRAIGHTENING OUT THE HAND ___

05 SHAKING THE HAND ___

06 RUBBING ___

07 HEAT ___ When _____
For how long? ___ ___ Months

08 COLD ___ When _____
For how long? ___ ___ Months

09 SALVE OR OINTMENT ___ When _____
For how long? ___ ___ Months

10 SPLINT ___ When _____
For how long? ___ ___ Months

11 SURGERY ___ When _____

12 OTHER ___

APPENDIX V

PHYSICAL EXAMINATION

ID#_____
DATE ___/___/___
TIME ___:___ AM PM
EXAMINER _____

I. INSPECTION

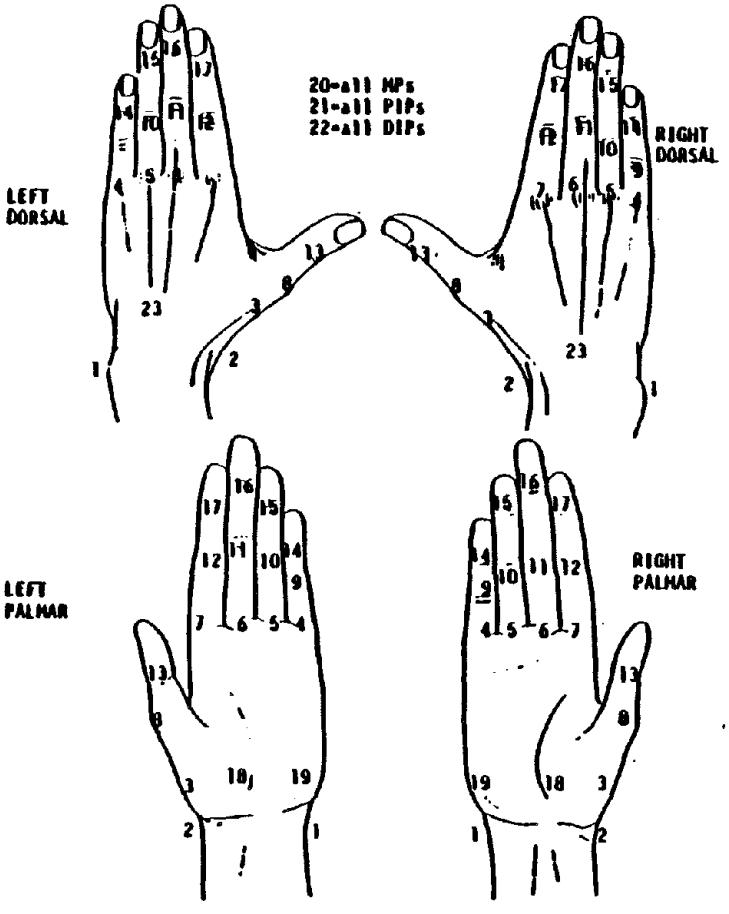
Physical Exam Recording Form - Upper Extremity

Area	99 Absent	10 Neck	2 Shoulder		3 Elbow		4 Forearm		5 Wrist	
			(1) L	(2) R	(1) L	(2) R	(1) L	(2) R	(1) L	(2) R
01 Nodules/Ganglion										
02 Bony Contours										
03 Muscle Wasting										
04 Swelling										
05 Tenderness										
06 Redness										
07 Blanching										
08 Postural Guarding										
09 Scars										
10 Gross Asymmetry										
11 Contracture/Deformity										

Specify Location of any Abnormality:

_____

ID# _ _ _ _ _ _



	(1) LEFT	(2) RIGHT
(1) Nodule/Ganglion		
(2) Bony Swelling		
(3) Soft Swelling		
(4) Redness		
(5) Tender on Palp		
(6) Deformity		
(7) Scars		
(8) Wasting		
Other		

KEY:

Record observation by D (Dorsal) or P (Palmar) and number of joint area.

II. RANGE OF MOTION

ID# _____

LOCATION	LEFT		ACTION	RIGHT	LOCATION
1	N /N P /P L /L	NECK	Forward Flexion 35°		
2	N /N P /P L /L		Extension 36°		
3	N /N P /P L /L		Lateral Rotation 60°	N /N P /P L /L	
4	N /N P /P L /L		Lateral Flexion 45°	N /N P /P L /L	
5	N P PN ST		Resisted Extension	N P PN ST	
6	N P PN ST		Resist L.Rotation	N P PN ST	
7	N /N P /P L /L	SHOULDER	Abduct/Elevate 170°	N /N P /P L /L	
8	N /N P /P L /L		Flexion/Extension 160/55°	N /N P /P L /L	
9	N /N P /P L /L		External Rotate 0-90°	N /N P /P L /L	
10	N /N P /P L /L		Internal Rotate 0-70°	N /N P /P L /L	
11	N P L		Shrug-Active	N P L	
12	N /N P /P L /L	FOREARM / ELBOW	Flexion 0-150°	N /N P /P L /L	
13	N /N P /P L /L		Extension 150-0°	N /N P /P L /L	
14	N /N P /P L /L		Pronate Forearm 0-70°	N /N P /P L /L	
15	N /N P /P L /L		Supinate Forearm 0-85°	N /N P /P L /L	

N=Normal
P=Pain (1=slight, 8=extreme)
L=Limited movement, record degree
PN=Pins and needles (1=yes)
ST=Strength (5=normal, 1=slight)
"/"=Active:record first, if abnormal, do passive record second

Coding: ST under PPASS
DN under LACTIV

II. RANGE OF MOTION (continued)

ID#_____

LOCATION	LEFT					ACTION	RIGHT				LOCATION
16	N	P	ST	PN	SHOULDER	Resisted Abduction	N	P	ST	PN	
17	N	P	ST	PN		Resist Lat. Rotation	N	P	ST	PN	
18	N	P	ST	PN		Rest Extension (Flex-90)	N	P	ST	PN	
19	N	P	ST	PN		Resist Med. Rotation	N	P	ST	PN	
20	N	P	ST	PN	FOREARM	Resist Pronation	N	P	ST	PN	
21	N	P	ST	PN		Resist Supination	N	P	ST	PN	
22	N	P	ST	PN	ELBOW	Resist Flexion	N	P	ST	PN	
23	N	P	ST	PN		Resist Extension	N	P	ST	PN	
24	N	P	ST	PN		Passive Flexion (75°)	N	P	ST	PN	
25	N	P	L			Passive Extension (70°)	N	P	L		
26	N	P	L			Passive Ulnar Dev. (30°)	N	P	L		
27	N	P	L			Passive Radial Dev. (20°)	N	P	L		
28	N	P	ST	PN	WRIST	Resist Flexion (Speed's)	N	P	ST	PN	
29	N	P	ST	PN		Resist Extension (Crozen)	N	P	ST	PN	
30	N	P	ST	PN		Resist Ulnar Dev.	N	P	ST	PN	
31	N	P	ST	PN		Resist Radial Dev.	N	P	ST	PN	

II. RANGE OF MOTION (continued)

SS# _____

LOCATION	LEFT		ACTION	RIGHT	LOCATION
32	N /N P /P L /L	FINGERS	Distal IPs	N /N P /P L /L	
33	N /N P /P L /L		Prox IPs	N /N P /P L /L	
34	N /N P /P L /L		MPs	N /N P /P L /L	
35	N P L ST		Thumb to Index	N P L	
36	N P L ST		Thumb to Little	N P L ST	
37	N P (#) ST (#)		Resist Lat. Abduction	N P (#) ST (#)	
38	N P L Crepitus		Passive Thumb Rom	N P L Crepitus	
39.	N P PN		Phalen's	N P PN	
40.	N P PN		Tinel's	N P PN	
41.	N P PN		Finkelsteins	N P PN	

ID #_____

III. PULSES

LEFT			RIGHT	
N___	ABN ___	RADIAL	N___	ABN ___
N___	ABN ___	BRACHIAL	N___	ABN ___

IV. REFLEXES

7 = hyper, 6 = ½sl, 5 = norm, 4 = ½sl, 3 = mod, 2 = tr, 1 = absent

LEFT		RIGHT
7 6 5 4 3 2 1	Triceps	7 6 5 4 3 2 1
7 6 5 4 3 2 1	Biceps	7 6 5 4 3 2 1
7 6 5 4 3 2 1	Brachioradial	7 6 5 4 3 2 1
7 6 5 4 3 2 1	Finger flexers	7 6 5 4 3 2 1

V. PINPRICK DERMATOMES: (Brachioradialis = 100)

LEFT	DORSAL	RIGHT
___	Index	___
___	Little	___
___	1st Metacarpal	___

VI. TEMPERATURE: Which is colder:

Left: 1 Arm ___ 2 Hand ___ 3 Same ___

Right: 1 Arm ___ 2 Hand ___ 3 Same ___

VII. HAND GRIP (Circle dominant)

Left:_____Kg Right:_____Kg

VIII. TWO-POINT DISCRIMINATION

Left: Index_____ Little_____

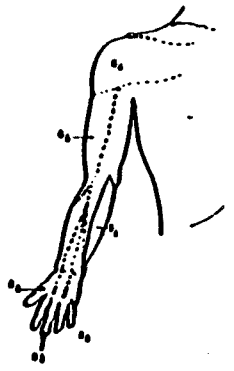
Right: Index_____ Little_____

Coding: 9.96-guessing
0.50-Neg Sens

IX. ADDITIONAL TESTS

A. NECK

1. If radicular signs, pin prick dermatomes.



LEFT			RIGHT	
N___	Abn___	C_4 (2)	N___	Abn___
N___	Abn___	C_5 (3)	N___	Abn___
N___	Abn___	C_6 (4)	N___	Abn___
N___	Abn___	C_7 (5)	N___	Abn___
N___	Abn___	C_8 (6)	N___	Abn___
N___	Abn___	T_1 (7)	N___	Abn___

2. Vibration

L Index___ sec.
R Index___ sec.

A. NECK

3. If c/o stiff neck, back pain and stiffness, check for Ank Spon.

A. cervical lordosis yes__ no__
B. dorsal kyphosis yes__ no__
C. sacroiliac tenderness yes__ no__
D. lumber lordosis yes__ no__
E. chest expansion yes__ no__

C. ELBOW, FOREARM

1. pain on resisted pronation
Mills test (extend elbow, clench fist, flex wrist, resist pronation).

Right N___ P___
LEFT N___ P___

D. HANDS

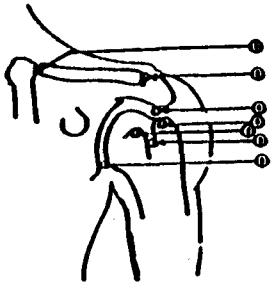
1. blanching fingers
Allen's test Right R___ U___
Left R___ U___

2. Numb, tingle, pain fingers

1N___ 2Pos___ a) Adson 1 N__ 2 Pos__
1N___ 2Pos___ b) Military 1 N__ 2 Pos__
1N___ 2Pos___ c) Hyperabduct 1 N__ 2 Pos__

B. SHOULDER

1. Pain on ROM - check trigger points.



N__ P__ 1.Supraspinatus N__ P__
N__ P__ 2.Subscapularis N__ P__
N__ P__ 3.Biceps groove N__ P__
N__ P__ 4.Subdeltoidbursa N__ P__
N__ P__ 5.Glenohumeral space N__ P__
N__ P__ 6.AC joint N__ P__
N__ P__7.Sternoclavicular N__ P__

[1=normal, pain 2-8, 9 N/A, 0 miss]

2. Shoulder shrugs or abduction.
Drop arm test: Left 1 N __ 2 Abn __
Right 1 N __ 2 Abn __

3. Check for angina (questionnaire)

ID# ___ ___ ___ ___

Have you ever been bothered by pain or discomfort in your chest?

YES ___ NO ___ (If no, please stop).

If Yes:

a. Have you had it during the past year? YES ___ NO ___

b. Which of the following bring on the pain or discomfort in your chest? (Check all that apply)

Exertion such as walking, lifting, stair climbing, housework. ___
Emotional upsets such as anger, excitement or fear? ___
Coughing or deep breathing? ___

c. Where do you feel the pain or discomfort?

Under the breast bone? ___
Left side of the chest? ___
Right side of the chest? ___
Different places? ___

d. How long does the pain or discomfort usually last?

Less than 10 minutes? ___
10-30 minutes? ___
Longer than 30 minutes? ___

e. Do any of the following relieve the pain or discomfort?

Stopping what you are doing? ___
Slowing down your activity? ___
Lying down? ___
Walking about? ___
Nitroglycerine? ___
Other heart medicine? ___
(Please name it _____)
Other pain medicine? ___
(Please name it _____)

f. Is the pain bad enough to require treatment? ___

g. How old were you when you first had chest pain? _____

APPENDIX VI

PROTOCOL

PROTOCOL

1. Once subjects have been selected for heatlh evaluation, they receive a letter from the University of Michigan Educational Resource Center (Appendix 7) describing the study and requesting their participation. Additionally, depending on the plant, a member of the research team will be available to answer questions from management and workers. A schedule for health evaluations is arranged with the plant liaison person. Private rooms are secured for interviews and physical examination. Scheduling is usually based on plant production needs to minimize disruptions.

2. Interview

   When the subject arrives at the interview room, the interviewer checks the subject on a master list. The interviewer is blinded to the job category of the subject. The interviewer then asks if the subject received a letter describing the study. If not, the interviewer briefly describes the purpose of the study before continuing.

   Next, the consent form and request for medical records (Appendix 8) is explained, stressing:

   1. Participation is voluntary
   2. Confidentiality
   3. Personal physicians will be notified of signfiicant health problems as soon as possible pending subject approval.
   4. In the event of physical injury resulting from the evaluation, emergency treatment, but no other medical care, will be provided.

   Additionally, the subject is requested to authorize release of medical records. The subject is informed that this is not required to proceed with the health evaluation.

   Once the subject has agreed to participate, the interviewer briefly explains the procdure for the evaluation: "First, I will ask for some general information about you and your medical history. Then I will focus more specifically on any problems you may have with your neck, shoulders, arms and hands. I will then ask about your current job and any previous jobs. When I am finished, I will introduce you to our examiner who will perform a brief physical exmaination."

   The interviewer proceeds to ask the questions as they appear on the primary interview and record the subjects responses.

   Information regarding occupational history is obtained after all other quesitons have been asked to minimize interviewer bias. Questions 14-16 are used to determinwe which secondary interview will be completed.

PROTOCOL FOR INTERVIEW

I. a. Sign consent form - page 1 (Did you get your letter explaining this study, if no - explain letter)

b. Main features to stress:

1. II-6 - Voluntary
2. II-7 - Confidential
3. II-10 - If any injury during examiantion first aid will be provided. This is unlikely because the examination will not hurt. No xrays or injections will be taken.
4. II-11 - If we find anything wrong we will furnish information to personal physician.

c. Page 2 - We may need release of information from physician to check our findings. If you don't want us to do this, write NO on Section III. Otherwise we need MD name, address, subject signature.

d. V - Fill out with subject.

II. Primary Interview

A. Ask only questions on primary interview first.
B. Record exact response, do not make assumed judgements about what you "think" was meant.

Specific Questions

A. Boxed questions are to be asked and answered only if response to main question was yes.
B. Put emphasis on underlining.

Primary Interview

3. If yes, fill out 3a. Specify year injury occurred as well as type and side. You can write in margins if necessary. Just get the information.

5. Stress for no apparent reason. Also stress painful AND swollen if fingers are painful and swollen: which fingers?

1=Thumb 2=index 3=middle 4=ring 5=little

also on fingers:

mp=knuckle pip=midle joints dip= joints nearest fingernail

6. If yes - what did the doctor tell you it was and what year was it diagnosed?

7. 15 "have you had any other serious illnesses? for any "yes" try to find out the year when it was diagnosed.

14, 15, 16: recurring means more than once or for more than a week if only once.
14a, 15a, 16a: the answer is pain or numbness or cramping, etc.

19 - hobbies. also record the average number of hours per week.

26. Ignore the right hand side of this page (lifting, etc. question 26 should read: "what jobs have you had in this plant?" start with current job in A and work backwards. Also ask "what kind of work did you do before coming to this plant". Please distinguish between this plant and prior work. The reason this question has been changed is that we only require the person to have been on the current job for at least one year.

III. Secondary Interviews

General

1. 14c Have subjects shade in.
2. 15c Check that where they have shaded in corresponds to what they say
3. 16c Example: (Right arm hurts - did they shade in the right arm on the diagram).

b. Instruct: Use only those pictures that you need to indicate where the problem is.

c. Write T or P etc., next to each area to distinguish between pain and tingling/numbness.

Neck Interview

14j: "Is the pain or discomfort made worse by coughing, sneezing or deep breathing?" should be asked of everyone with neck or shoulder pain, not just those whose pain spreads.

IV. 2 Point Discrimination to be done by interviewer after filling out interview forms.

a. Do index and little finger of both hands.

b. Familiarize subject with the test by practicing on 4 middle sections.

c. Point out that you want their first impressions, two seconds per letter

1. No wiggling of finger in slot
2. Have finger touch back of slot with finger horizontal (if finger at slant, will miss a point).
3. Speak loudly and clearly.
4. Eyes closed.

d. Turn on tape recorder, provide identification (ex: this is 2647, little finger, left hand, going from right to left).

e. Watch subject perform test, record results from tape during break.

f. If you can fill out the form at the same time, still use the tape for verification.

g. Obtain computer scores when you have time and staple them to two point sheet.

h. If the person missed a one point, retest that finger only once. We will give them the benefit of the doubt only once.

4. Physical Examination

After the interview is completed, the subject is taken to the private examining room and introduced to the research team examiner. The subject is requested to remove his/her shirt (females are provided with gowns) so that inspection and palpation can be performed.

Prior to beginning the examination, the subject is requested to recall the worst pain ever experienced or imagined and is told to consider that as an 8 on a scale of 1 to 8. The subject will be asked to indicate any pain or discomfort and its location as the examination proceeds.

Active range of motions required are demonstrated by the physician and the subject is asked to perform the same motions. A goniometer is used to measure angles which appear abnormal. The examiner proceeds through the examination as indicated in Appendix 5. All abnormalities are recorded at the time of discovery. Additional tests are performed as necessary.

At the end of the examination, the examiner gives the subject his/her initial impression, based on the presence or absence of findings, in general terms. The subject is advised to see a personal or plant physician if necessary.

APPENDIX VII

DIAGNOSTIC CRITERIA

DIAGNOSTIC CRITERIA

1. HAND/WRIST

A. Ulnar nerve compression

Interview: burning, tingling or numbness in 4th and 5th digits. Clumsiness in fine movements. Lasting more than 1 week or more than 20 times in previous year.

PE: Rule out cervical root disorder, rule out thoracic outlet syndrome. Decreased pinch strength. Weakness on resisted abduction and adduction of digits. Positive Tinel's. Abnormal two-point discrimination in ulnar distribution is possible.

B. DeQuervain's Disease (Finkelstein, Muckart, Lamphier)

Interview: pain in anatomical snuffboc, may radiate up forearm. No history of fracture or radial wrist fracture. Lasting more than one week or more than 20 times in last year.

PE: rule out radial nerve entrapment, positive Finkelstein test with pain score of 4 or greater.

C. Carpal tunnel syndrome (Phalen, Cailliet, Cyriax, Sandzen)

Interview: Pain, tingling or numbness in medial sensory distribution of the hand. Nocturnal exacerbation. Problems with dropping things. Lasting more than one week or more than 20 times in last year.

PE: Positive Phalen's test. Positive Tinel's test. Thenar atrophy in severe cases. Rule out pronator teres syndrome.

D. Degenerative Joint Disease (Localized osteoarthrosis) (Cyriax)

Interview: Stiffness, pain, maybe bony swelling of DIPs. No wrist involvement. Morning stiffness lasting less than 30 minutes.

PE: No tenderness, decreased flexion of DIPs, bony swelling of DIPs.

E. Trigger finger (Lister)

Interview: finger locks in extension or flexion, requires assistance in locking. Nodule on tendon.

PE: nodule at base of digit palpable. Locking in flexion or extension of digits.

F. Tendinitis, Tenosynovitis (Ellis, Thompson, Cailliet, Cyriax)

Interview: localized pain and or swelling over muscle-tendon structure lasting more than one week.

PE. Pain exacerbated by resisted motions, possibly fine crepitus on passive ROM, no pain on passive ROM. Pronounced asymmetrical grip strength.

2. ELBOW/FOREARM

A. Lateral Epicondylitis (Tennis Elbow) (Cyriax, Steiner)

Interview: pain at lateral epicondyle during rest or active motion of wrists and fingers. Lasting more than one week or 20 or more times in last year.

PE: Pain on resisted extension of wrist with fingers flexed. No pain or limitation on full passive ROM. Pain at epicondyle on palpation. Pain on resisted radial deviation of wrist but no pain on resisted ulnar deviation. Rule out radial nerve entrapment.

B. Medial Epicondylitis (Golfer's Elbow) (Cailliett, Cyriax, Kourinka).

Interview: Pain at medial epicondyle during rest or active motion of wrist and fingers. Lasting more than one week or 20 or more times in last year.

PE: No pain on passive ROM. Pain on resisted wrist flexion, resisted forearm pronation. Pain at medial epicondyle on palpation.

C. Olecranon Bursitis (Cyriax)

Interview: Pain and swelling at olecranon. Lasting more than one week or 20 or more times in last year.

PE: No pain on passive or resisted ROM. Swelling around olecranon on palpation. Rule out RH. arthritis (palpate for nodules).

D. Radial Nerve Entrapment (Cailliet, Steiner)

Interview: Pain or tingling/numbness in lateral aspect of forearm which may project to anatomical snuffbox or first CMC joint. Pain may also be referred to lateral epicondyle. Lasting more than one week or 20 or more times in last year.

PE: Elbow pain with resisted extension of middle finger with elbow extended. Characteristic radiating pain when palpate over site of entrapment. No cutaneous sensory impairment. Rule out lateral epicondylitis.

E. Pronator teres syndrome (Hartz)

Interview: Burning and pain in first three digits of hand and forearm. Lasting more than one week or 20 or more times in last year.

PE: Increased pain in forearm by resisted pronation with clenched fist and flexed wrist (Mill's test). Sensory impairment of thenar eminence. Rule out carpal tunnel syndrome.

3. SHOULDER DISORDERS (Cyriax, Cailliet, Waris)

A. Degenerative joint disease-Acromioclavicular joint

Interview: Generalized aching shoulder pain exacerbated by motion. Least difficulty in the morning but worse as the day progresses.

PE: Limitation is similar on active and passive ROM. Most discomfort is with mild abduction. Crepitus is common. Tenderness on palpation directly over AC articulation. Pain is reproduced as arm is abducted more than 90 degrees. Pain on shoulder shrug.

B. Degenerative joint disease-glenohumeral joint

Interview: Pain is very diffuse and nocturnal.

PE: Tenderness to palpation along joint line. No deltoid or supraspinatus pain. Passive ROM is full but painful. Active ROM is retarded on flexion and extension (Normal is 240 degrees in youth, 190 degrees at age 70) (Abduction in youth is 166 degrees, 116 degrees at age 70).

C. Bicipital tenosynovitis (Simon, Booth and Marvel, Bland, Weiss, Waris, Cruess)

Interview: Pain is localized to the bicipital groove area. It may radiate to anterior aspect of the arm. There is no distal parasthesia. There is nocturnal exacerbation. The subject is able to use the forearm when the upper arm is held against the chest. The subject notes pain on abduction and rotation. Lasting more than one week or 20 or more times in last year.

PE: Normal passive and active ROM. Positive Yergason's test, positive Speed's test.

D. Rotator Cuff Tendinitis (mainly supraspinatus)

Interview: Dull ache generally localized to the deltoid area without neck or arm radiation. There are no symptoms of distal paresthesia. There is nocturnal exacerbation. The subject may note a "catch" on movement. Lasting more than one week or 20 or more times in last year.

PE: Diffuse tenderness over the shoulder, especially over the humeral head and lateral to the acromion. If tenderness is localized, it is most often over the supraspinatus insertion. Weakness is uncommon.

-supraspinatus: shrugs shoulder on abduction, painful arc at 70-90 degrees, passive ROM normal, pain on resisted abduction.
-infraspinatus: pain on resisted lateral rotation. painful arc.
-subscapularis:pain on resisted medial rotation, painful arc.

Rule out Rh. arthritis (other joints affected bilaterally, diffusely full and swollen, decreased ROM in all directions, especially rotation and abduction).

E. "Frozen" Shoulder

Interview: chronic (more than one month) aching and occasional nocturnal exacerbation related to activity. In the acute phase up to two weaks and then grandual decrease in pain and decrease in ROM of glenohumeral joint.

PE: No point tenderness. Limited active and passive ROM, especially internal rotation. Rule out shoulder hand test with Allen test.

F. Thoracic Outlet Syndrome (Tyson, Lascelles, Cailliet, Waris)

Interview: Parasthesia usually ulnar distribution of hand and arm. Pain and sensation of "weakness" Deep dull ache in arm and hand. Problem holding small objects. Nocturnal exacerbation common. Lasting more than one week or 20 or more times in last year.

PE: Positive Adson, Hyperabduction or costoclavicular test. Decreased grip strength.

4. NECK/ SCAPULA (Waris, Maeda, Valtonen)

A. Tension Neck Syndrome (Costalscapular syndrome)

Interview: Neck pain or stiffness. No history of herniated cervical disk, injury or ankylosing spondylitis. Lasting more than one week or 20 or more times in last year.

PE: muscle tightness, palpable hardening and tender spots. Pain on resisted neck lateral flexion and rotation.

B. Cervical Root Syndrome (Waris)

Interview: Pain radiating from the neck to one or both arms with

numbness in the hand(s). Exacerbated by cough.

PE: Limited passive and active ROM. Radiating pain on passive motions. Positive foraminal test, Decreased pinprick in dermatome. Absence of joint findings.

C. Cervical Degenerative Joint Disease

Interview: pain and stiffness in neck with movement. No history of systemic disease.

PE: No decreased pinprick sensation in dermatomes. Active and passive ROM painful in the same direction. Pain is not exacerbated by resisted motions. No limitation on flexion. Equal limitation of lateral flexion and rotation- bilateral or unilateral.

APPENDIX VIII

CONSENT FORM

NIOSH HUMAN SUBJECTS RESEARCH PARTICIPANT DOCUMENT

I. PROJECT DESCRIPTION

1. Title: Quantification of Traumatogenic Risk Factor in Selected Occupations CDC No. 200-82-2507

2. Sponsor: National Institute for Occupational Safety and Health Cincinnati, OH

3. Investigators: Thomas J. Armstrong, Ph.D, Lawrence J. Fine, M.D. The University of Michigan, Ann Arbor, MI

4. Purpose and Benefits: Cumulative trauma disorders caused, precipated, or aggravated by repeated exertions with certain work postures and rates are a major cause of injury and lost time in some work situations. The purpose of this work is to further quantify the relationship between work rates and postures and cumulative trauma disorders. The results are intended to help establish guidelines for workplace designs that minimize the risk of cumulative trauma disorders.

II. CONSENT TO PARTICIPATE

I, _____, age _____, hereby voluntarily agree to cooperate in the above named study and to undergo the tests listed in Attachment A. The study has been discussed with me and I have been given a copy of this document. I understand that -

1. The procedures and tests to be followed are as stated in Attachment A, with those procedures which are experimental so identified.

2. Attendant discomforts and risks are as noted in Attachment A and, except as noted, are minimal and provision has been made for any necessary medical care, and I have been told what to do if I have any reaction.

3. Benefits are as indicated in the Purpose and Benefits section in Part I.

4. If alternative procedures advantageous to me are available, they are specified in Attachment A; and if they become available during the project, the procedure most advantageous for me will be indicated and used or an explanation will be given to me as to use of any other procedure.

5. My inquiries will be answered by the project director: Thomas J. Armstrong, Ph.D., Center for Ergonomics, Ann Arbor, MI 48109, (313) 763-3742 or by Lawrence J. Fine, M.D., School of Public Health, Ann Arbor, MI 48109, (313) 764-2594.

6. I am free to terminate my consent and to discontinue participation in the project at any time without prejudice to myself.

7. My identity and my relationship to any information (1) disclosed by me in completing any project questionnaire and (2) reported by me or derived from me during my participation in the above named project shall be kept confidential and will not be disclosed to others without my written consent except as required by law and except that such information will be used for statistical and research purposes in such a manner that no individual can be identified. I understand that if any information is found out concerning me that can endanger the health and safety of others, this information will be given to the proper authority.

8. If any of my medical records are required for purposes of this project, a separate written consent for release of the records will be requested from me.

9. There will be questions that I will be asked to answer, and my inquiries concerning the questions will be answered by Thomas J. Armstrong, Ph.D., Center for Ergonomics, Ann Arbor, MI 48109, (313) 763-3742 or Lawrence J. Fine, M.D., School of Public Health, Ann Arbor, MI 48109, (313) 764-2594.

10. I understand that in the event of physical injury resulting from the research procedures, other than emergency treatment, medical care is not provided. If you are injured as a result of negligence of a NIOSH employee, you may be able to obtain compensation under the Federal Tort Claims Act.

11. A report of any significant information from the study that specifically concerns me, including medical information, will be furnished by the project officer or his or her designated representative to me or my designated physician(s) upon completion of the study or earlier if appropriate.

12. I understand that the University will provide first-aid medical treatment in the unlikely event of physical injury resulting from research procedures. Additional medical treatment will be provided in accordance with the University's determination of its responsibility to do so. The University does not, however, provide compensation to a person who is injured while participating as a subject in research.

SIGNATURE _____ DATE _____

INVESTIGATOR _____

Name, Title, and Signature

APPENDIX IX

SAMPLE EMPLOYEE LETTER

Occupational Medicine Program
The University of Michigan

Department of Environmental and Industrial Health
School of Public Health
Ann Arbor, Michigan 48109

July 13, 1983

Dear Employee:

We are writing to inform you about a major health study which is getting underway in your plant. The University of Michigan in cooperation with the company and the union, is interested in identifying health problems of workers in the plant which involve the arm, wrist and hand; and figuring out ways to prevent them.

We will be conducting short interviews and physical examinations which will take about 1 hour to perform. No injections or xrays will be used in the examination. The exams will be conducted at the plant on work time, with no loss of pay.

Employees to be interviewed have been selected at random from different job classifications. Individual results will be confidential; no company, or union personnel may see them unless the employee gives written permission. Interviews will take place on July 25-27 in a private office in the plant. When the results of the study are available they will be available to the company, union and workers who participated.

If you are asked for an interview, your participation is voluntary and you may withdraw from the study at any time. However, the study will only be effective if a high percentage of workers take part. This study has the support of both and ---- and we hope that you will agree to participate.

Sincerely yours,

Lawrence J. Fine, M.D.
Associate Professor of
Occupational Medicine

Thomas J. Armstrong, Ph.D.
Associate Professor of
Industrial Hygiene