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Carpal Tunnel Syndrome

Prevention Through Intervention

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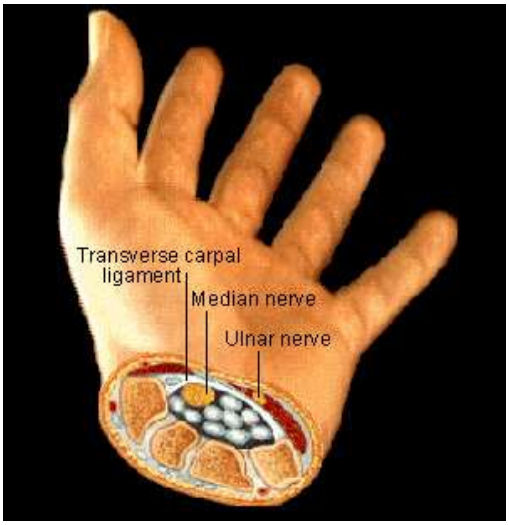

The carpal tunnel is a narrow, rigid passageway of bones at the base of the hand (wrist), while the top is formed by the Transverse Carpal Ligament (see figure 1). Tendons pass between these two structures allowing movement of the fingers. The median nerve (a nerve that runs down the arm and forearm) passes through the carpal tunnel and into the hand and gives sensation to the thumb, index finger, long finger, and half of the ring finger. The tendons are important because they allow movement of the fingers, thumb, and hand (i.e. grasping). These tendons are covered by a substance called tenosynovium, which is a slippery covering that allows the tendons to glide next to each other as they are worked.

Figure 1: Structures within the carpal tunnel
Source: Medical Multimedia Group [1]

Carpal Tunnel Syndrome

Carpal tunnel syndrome (CTS) is a disorder characterized by tingling and pain in the hand and fingers due to damage to the median nerve. The pain may radiate up the arm as far as the elbow; although, not usually into the elbow itself. The median nerve is one of three major nerves of the upper arm that contains motor, sensory, and autonomic fibers. Injury of the median nerve results in a disruption of nervous function in the first three and one-half digits and the thenar eminence (body of muscle on the palm of the hand just beneath the thumb.) (Figure 2).

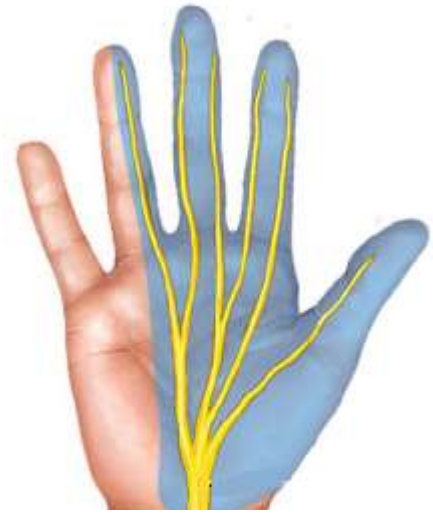

Figure 2: Diagram showing the innervation of the median nerve
Source: Yahoo Health [2]

Compression (squeezing) of the median nerve in the carpal tunnel is the most common nerve entrapment syndrome. CTS is usually idiopathic (of unknown cause - 47% of cases), but it may also result from a variety of processes that decrease the space of the carpal tunnel.

CTS is characterized by pinching of the median nerve within the carpal tunnel. This pinching is caused by the swelling of protective sheaths (tenosynovium) surrounding the tendons within the carpal tunnel. When the muscles become irritated from the exposures listed in the next section they begin to swell in size. The protective sheaths surrounding the tendons secrete a lubricating fluid called

synovium. By secreting synovium, the amount of space within the carpal tunnel is further reduced which causes the muscle tendons to rub upon each other and become even more irritated. As a result, more synovium is secreted to reduce the irritation. What results is the disorder known as CTS. Since the tendons are now irritated and inflamed, and the protective sheaths have secreted synovium, the amount of space within the carpal tunnel is limited. This results in impingement (pinching) of the median nerve which also passes through the carpal tunnel. It is this impingement that results in the tingling and pain that one experiences.

Double Crush Syndrome

Refers to compression of the median nerve at more than one location. This is typically seen in the wrist and in the neck/shoulder area. If you're suffering from CTS, please be sure your doctor has thoroughly examined you to determine if your CTS is due to a Double Crush Syndrome. A hand specialist may overlook a Double Crush originating in the neck. A proper examination for CTS would include the entire arm and neck in order to trace the full length of the nerve, especially if they've been recommended for carpal tunnel surgery.

Ergonomic Risk Factors Contributing to Carpal Tunnel Syndrome

There are a number of risk factors related to the development of CTS including awkward postures, force, repetition, and vibration exposure. Continued or sustained exposure to any or all of the risk factors could result in a musculoskeletal injury.

AWKWARD POSTURES

Flexion, extension, radial, and ulnar deviations of the hand (figure 3) are considered awkward postures of the wrist and aid in the development of CTS by stretching and irritating the median nerve [3, 4]. When the hand is placed in a position outside of its neutral position, it causes the tendons to rub against the walls of the carpal tunnel and cause friction. The tendons of the wrist are surrounded by a synovial membrane which secrets synovium, a lubricating fluid. When friction is present, the membrane produces fluid to limit the friction. However, since the wrist only has a certain amount of space the swelling reduces the space of the carpal tunnel, compressing the median nerve.

Awkward postures also reduce the blood flow to tissues. This reduces the clearance of waste products from the joint, which causes discomfort and fatigue of tissues from having to hold tensed muscles in a fixed or awkward position for a long periods of time.

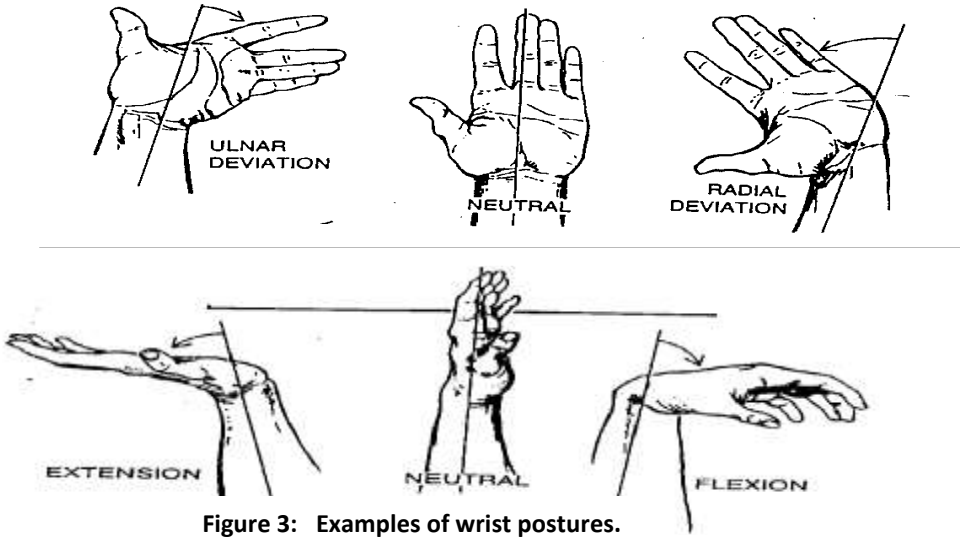

Figure 3: Examples of wrist postures.

Awkward postures such as working with the joints near their end range of motion, uneven loading and static muscle activity are all risk factors in the development of CTS. They increase the biomechanical stress on the muscles and the surrounding joint tissues.

In extreme joint positions, such as with a flexed or extended wrist, the muscles are also not at their optimal working length. Therefore, the muscles are incapable of developing force as efficiently and are more likely to fatigue [5, 6]. Static muscle activity can also increase the risk of developing CTS since static muscle contractions can lead to reduced blood flow and increased compression on the median nerve.

FORCE

Force refers to the amount of physical effort that is required to accomplish a task or motion. Tasks or motions that require application of higher force place higher mechanical loads on muscles, tendons, ligaments, and joints. Tasks involving high forces may cause muscles to tire more quickly. High forces also may lead to irritation, inflammation, strains and tears of muscles, tendons and other tissues.

When force is applied repeatedly over a prolonged period to the tendons found in the carpal tunnel, the cumulative forces may cause soft-tissue microtears (small tears found in tendons, ligaments and muscles) and trauma. High muscle force requirements may also cause increased muscle contractions and can lead to muscle fatigue and tendon tension.

It is when fatigue is present and the muscle tension is high that a worker is placed at an increased risk. This is because the muscle becomes weaker and more susceptible to failure. As the tension increases, the muscle tendon becomes elongated and loses the ability to maintain force.

This is much like stretching an elastic band. As we pull on the band with a constant load, it begins to stretch until we reach the point where we have exceeded its capacity to bear the weight of the load. As a result, the band snaps due to its inability to withstand the tension applied to it.

The resulting injury applied to the muscle tendons and the inflammatory response results into the compression and reduction of the blood supply to the median nerve and the development of CTS [7].

Figure 4 demonstrates a normal loading pattern that results when force (stress) is placed upon an object, resulting in strain occurring.

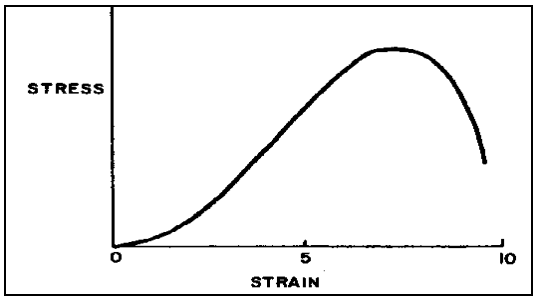

Figure 4: At 5 we begin to enter what is known as the plastic region, where permanent deformation and tearing of muscle fibers and injury begin. At 7, we have entered what is known as the failure point which results in the muscle's tearing away from the joint due to increased tension.

Excessive force should also be minimized in an effort to reduce the risk of developing CTS. Researchers have recommended the force requirements of a job should not require exertion of more than 30 % of a workers maximal muscle force for a prolonged or repetitive period of time[5].

Strong gripping and pressure on the palm can also increase the risk of CTS. This is typically known as a pinch grip. This is when an object is held between the fingers and the thumb. A person engaged in a pinch grip, is only able to generate 25% of a power grasp or gross grip. A "power grasp", refers to a grip using the whole hand where the force is passed through a large number of muscles, unlike the pinch grip which has a high amount of force passing through a small number of muscles increasing the risk of tearing and further injury. To generate a specific force, a pinch grip requires a much greater muscle exertion than a power grip (object in the palm of the hand). Hence, a pinch grip has a greater likelihood of creating injury. This is due to the fact that with a pinch grip, only a few muscles are trying to perform a task requiring a high degree of force or effort opposed to a power grasp.

REPETITION

Repetition is defined as the number of movements in a given period of time. Safe limits of repetition depend on frequency, speed and duration. A highly repetitive movement is considered one in which more that 50% of the shift is spent completing that movement, whereas a low repetitive movement is one in which less then 50% of the shift is spent completing that task.

Operating tools and equipment can force the wrists of the worker to go from ulnar deviation to radial deviation within a short time interval (figure 3). This results in strain being placed upon the muscles. These rapid motions often result in fatigue and increased friction on the tissues located within the carpal tunnel.

These repetitive motions also elevate the pressure inside the carpal tunnel, which may diminish blood flow to the median nerve and cause blocking of the nerve. This is a result of strain being placed on the muscle tendons. If sensory function is impaired (a normal response), the worker may also adopt a more forceful grip, awkward posture, or other compensatory maneuvers increasing the risk of developing CTS [7].

Repetitive actions require rapid muscle contractions which do not favor optimal force production, therefore, faster contracting muscles have to work harder to generate the same amount of force and will need longer recovery times when compared to slower contracting muscles. If a muscle group is not given enough time to recover between repetitions, muscle and joint soreness will escalate and can lead to a cumulative trauma injury [8].

VIBRATION

Vibration has been shown to have a causal relationship on the development of CTS though it is not well understood. Vibration exposure is usually accompanied with exposures to forceful and repetitive motions and awkward postures, and seems to affect the circulatory (blood vessels), nerves, and muscles of the wrist [9, 10, 11].

Vibration as the primary cause of CTS is due to the vibration-induced oedematous (swelling) reaction in the median nerve itself and in the tissues surrounding the nerve.

Hand vibration reduces the circulation in the hands and fingers causing blanching (loss of normal colouration). This is a result of the reduction in blood flow and a reduction of the delivery of oxygen and nutrients to the hands and fingers. Severe cases can develop into gangrene in the affected digits. It is believed that blanching occurs due to hypertrophy (enlargement) of the cells resulting in the narrowing of the arteries and therefore reducing the amount of blood that can flow through them at a given time.

Damage to the nervous system has been found to cause median nerve damage. Swelling will also result with the accumulation of scar tissue and compression on the median nerve. This is a result of demyelination (loss of myelin that surrounds the nerve). Myelin protects, electrically insulates each nerve fiber, and increases the speed of transmission of the nerve impulses. Myelin is also non-regenerative, meaning that once it is damaged it cannot be fixed [12]. Demyelination results in a slower and weaker conduction speed in nerve impulses due to lack of insulation. Myelinated nerve fibers have a conduction speed that is 150 times faster than that of unmyelinated fibers [13].

Muscles exposed to vibration exhibit a tonic (stimulating) vibration reflex that leads to increasing voluntary muscle contraction. Vibration has also been shown to produce short-term tactility impairments which can lead to an increase in the amount of force exerted during manipulative tasks [11]. Vibration can also lead to mechanical abrasion of tendon sheaths. It may also directly injure the peripheral nerves, nerve endings, and mechanoreceptors in the hands and fingers, producing symptoms of numbness, tingling, pain, and loss of sensitivity. The sustained awkward postures they are required to maintain to hold and operate the equipment, the controls they are required to operate and the vibrating environments in which they work are major risk factors.

Exposure to hand vibration may also affect the musculoskeletal system. A vibrating tool requires much more energy to hold and operate than a non-vibrating tool. This leads to an increase in muscle activity causing swelling of the muscle tendons and compression on the median nerve. Fatigue will develop faster and cause one to be more susceptible to injury.

TEMPERATURE

Cold temperatures have been linked to the development of CTS by affecting nerves to the skin, blood circulation, manual dexterity, and grip strength.

COMBINATION EFFECT

Many professionals when assessing the extent of CTS tend to focus solely on the repetitiveness of the job, but this should not be the case. There are other factors which are present in the development of CTS including force (the amount and strength associated with using the keypad, and also posture of the wrist and forearm). It is believed that it is the synergistic (combination) actions that result in the development of CTS. An example would be the combination of repetition with a job demanding awkward postures of the wrist and high force when using the keypad.

Non-Work Related Risk Factors

OBESITY

Obesity has been shown to be a possible risk factor in the development of CTS. One study [14] found that for every one unit (6 lbs.) increase of body mass index (BMI) which was defined as the weight (kg)/height squared (m^2) there was an increased risk of eight per cent for developing CTS. One was considered slender if there BMI was less than 18.5; normal for 18.6-25.0; overweight is 25.1-29.9; and obese is greater that 30.0.

Conversely, another study [15] found that CTS patients are twice as likely to be overweight (body mass index [BMI] > 25) than the general population and female patients are twice as likely to be obese (BMI > 30) than the general population.

The American Obesity Association stated that "The odds of an obese patient having CTS were found in one study to be almost four times greater than that of a non-obese patient. Obesity was found in one study to be a stronger risk factor for CTS than workplace activity that requires repetitive and forceful hand use. Seventy percent of persons in a recent CTS study were overweight or obese."

"Workers with a Body Mass Index (BMI) higher than 29 are four times more likely to present with median mononeuropathy than those with a BMI of less than 25."[17]

Based on the above two arguments, there may be some relationship between CTS and obesity. As a result, this association is still controversial.

HYPOTHYROIDISM

Women with mild hypothyroidism (reduced thyroid gland activity) who have mildly elevated serum Thyroid Stimulating Hormone (TSH) levels have fatigue which is the most common complaint, as well as: cold intolerance, dry skin and constipation. Patients with severe hypothyroidism have multisystem abnormalities, including mental dysfunction that may be mistaken for dementia, arthritis, pericardial (excess fluid around the heart) and pleural effusions (excess fluid around the lungs), CTS and other entrapment neuropathies, gastrointestinal complaints, and occasionally seizures. Placebo-controlled double-blind studies have shown that these symptoms improve with thyroxine replacement therapy.

PREGNANCY

Pregnancy often results in fluid accumulation and the swelling of joints. As a result, pregnant women often develop CTS. This often disappears following the completion of the pregnancy.

It should be noted that the development of CTS during pregnancy does not usually occur until the beginning of the third trimester when the mother begins to increase in mass due to the weight of the baby and fluid accumulation at the joints [18].

ALCOHOL AND SMOKING

Alcohol and nicotine have been shown to be a small risk factor in the manifestation of carpal tunnel symptoms. A study[19] of 1464 workers related to tobacco, caffeine, alcohol and carpal tunnel syndrome. This study concluded that greater use of tobacco combined with greater consumption of caffeinated and alcoholic beverages was associated with more median nerve slowing, more specific hand/wrist symptoms, and more clinically diagnosed cases of confirmed CTS. Although these effects explained only a small portion of the total risk for CTS, abuse of these substances may serve as a marker for increased CTS. Therefore, use of alcohol and tobacco can only be a small contributing factor to the development of carpal tunnel syndrome as found in the studies reviewed.

AGE

Many studies suggested that age plays a significant role in the manifestation of carpal tunnel syndrome. Several studies agree that the risk of CTS increases after the age of 30[20, 21, 22, 15]. Since CTS is a "repetitive strain disease, it would be logical to associate it with the aging process"[23]. It was also found to be extremely rare among people below the age of 20 in several studies[23].

DIABETES

One study[24] found that the chance of developing CTS increases the longer the person has lived with diabetes. For example, 85% of patients with Type I diabetes who have been living with the condition for 54 years have a greater chance of developing CTS. Another study[25] found that the rate of CTS in diabetic patients is reported to be 15% - 33.7%. The overall risk of developing CTS as a diabetic is related to age and duration of the diabetes.

OTHER RISK FACTORS

These include synovial inflammatory (rheumatoid arthritis), tumoral processes, previous bone fracture of the wrist, amyloid (protein) deposits in the nerve or surrounding tissue, or edematous swelling associated with pregnancy, being postmenopausal and neuritis (inflammation of a nerve).

Symptoms

Figure 5: Symptoms of carpal tunnel syndrome include numbness in areas of the hand.
Source: Medical Multimedia Group. 2003[1]

Numbness in the area of the median nerve is one of the first symptoms of CTS. This is quickly followed by pain in the same area that may also radiate up the arm to the shoulder. Persons will commonly complain of waking in the middle of the night with pain and a feeling that the whole hand is "asleep". Evidence has shown that the little finger is unaffected. This could be key to your diagnosis; if you awaken with your hand asleep, pinch your little finger to see if it is numb also. Be sure to tell your doctor your findings. Other complaints include numbness while the hand is in a gripping motion, such as driving.

How do doctors identify the condition?

Your doctor will start by obtaining a history of the problem, followed by a physical examination (including Phalen's and Tinel's tests). The description of the symptoms (from the patient) and the physical examination are important in the diagnosis of CTS.

If your symptoms started after a traumatic wrist injury, X-rays may be needed to check for a fractured bone.

Blood work is taken to test for a variety of conditions such as diabetes (random glucose, three month average HgAIC), thyroid (TSH) and a general complete blood count (CBC) to rule out any pre-existing conditions.

Studies of the nerves in the wrist may be requested by your doctor. Several tests are available to see how well the median nerve is functioning, including the nerve conduction velocity (NCV) test. This test measures how fast nerve impulses move through the nerve.

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