Carpal Tunnel Syndrome —Identifying the Risk Factors in Forest Industry Operations

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ABSTRACT

Given that the forest industry has diversified from primarily manual extraction and processing of trees to include a wide variety of occupations and job functions, many of which require employees to make repetitive, high force motions of the hands and wrists, suggests that this group of workers may be at risk for developing carpal tunnel syndrome (CTS). To raise awareness, this paper provides an indication of the CTS risks associated with four classes of forestry occupations and gives some avoidance guidelines for the prevention of this disorder.

Keywords: *forestry workers, carpal tunnel syndrome, risk factors.*

INTRODUCTION

Though forestry is one of the world's oldest industries, until recently the extraction and processing of trees was a manual task involving considerable accident potential resulting in a disproportionately high incidence of sudden onset workplace injuries such as amputated fingers and broken legs. It was not until the 1950s that mechanization became an integral part of the industry. This change resulted in a dramatic reduction in the number of traumatic injuries with research and design improvements enabling manufacturers to produce safe machines which could be operated by one person for many hours at a time in relative comfort over a wide spectrum of environmental conditions [25].

Today the forest industry has diversified to include a wide range of occupations and job functions. Unfortunately, however, while the advent of machines reduced the incidence of immediately obvious injuries, these afflictions may have been replaced by repetitive strain injuries (RSI) which can develop over a period of years but which can nonetheless be attributed directly to workplace factors. Though there is a dearth of information regarding incidence rates among forestry workers, given that many forestry job functions require the employee to make repetitive, high force motions of the hands and wrists potentially predisposes them to develop a RSI known as carpal tunnel syndrome (CTS). It is the purpose of this paper to focus on CTS with the intent of exposing some of the forestry workplace tasks which are a high risk for inducing the onset of CTS.

BACKGROUND

a) What is the Carpal Tunnel?

The carpal tunnel is a 2-3 cm long canal [43], formed anteriorly by the transverse superficial carpal ligament and posteriorly by the carpal bones of the hand through which nine finger flexor tendons and the median nerve pass (Figure 1) [26].

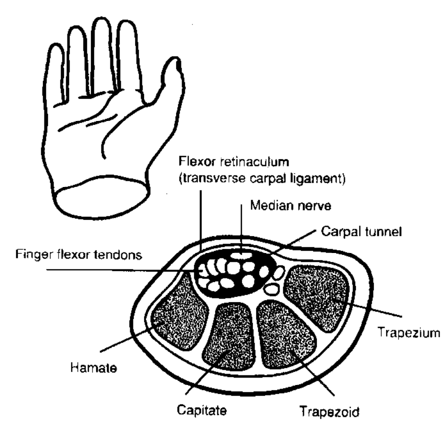

Figure 1. The carpal tunnel and associated structures

b) What is Carpal Tunnel Syndrome?

Carpal tunnel syndrome (CTS) is a repetitive strain injury characterized by numbness and/or burning pain in the hand and wrist as well as the thumb and first three fingers with symptoms becoming most evident at night [5, 17, and 23]. It affects part of the median nerve distribution in the hand, and in extreme cases results in damage which can induce irreversible local muscular weakness and wasting [30]. The syndrome is thought to develop as

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a consequence of median nerve compression in the palm aspect of the wrist between the flexor tendons and the transverse superficial carpal ligament [38]. On a long-term basis, as a result of the space reduction in the tunnel and the concomitant reduction in blood flow [20], maladaptive histological changes begin to occur in the median nerve and the flexor synovium of the wrist with the greatest alterations occurring in locations of maximum compressive stress [1]. Continued pressure on the synovial and connective tissues as well as on the sheath surrounding the nerve stimulate density and thickness increases in these tissues, thus causing further compression of the median nerve as it traverses the carpal tunnel [1]. As with other repetitive strain injuries, the onset of CTS can be very rapid, or the syndrome can take as long as 20 years to develop.

c) Associated Diseases/Conditions

Carpal tunnel syndrome is associated with many conditions such as diabetes mellitus, endocrine and thyroid disorders, pregnancy, chronic dialysis, inflammatory arthritis of the wrist, obesity, and alcohol use [5, 24, and 41]. The common thread which links each of these ailments to CTS is that they all act to increase the internal tunnel pressure and concomitantly reduce the cross-sectional area of the carpal tunnel [27 and 28]. Interestingly, many investigations have observed that women develop CTS more frequently than do men, suggesting that the smaller carpal tunnel possessed by women may contribute to the development of the disorder [10]. However, in a study where subjects were matched by gender, Winn and Habes observed that gender had no effect on the occurrence of CTS, and in fact found that individuals diagnosed with CTS had larger carpal canal areas than controls. The authors suggested that the risk factor for CTS may be the residual volume of the carpal canal after accounting for the nerves, tissues, and blood vessels passing through it rather than the cross-sectional area of the canal [42].

d) Diagnosis

Diagnosis of CTS is typically accomplished through the patient's self-reported history as well as a wide variety of tests and symptoms, some of which include: Phalen's test, Tinel's sign, vibrometer test (perception threshold for vibration), positive response to a tourniquet test, wasting abductor pollicis brevis and / or thenar muscles, swelling proximal to the carpal tunnel, and sensory conduction velocity testing through electroneurography techniques [10, 28, 34, and 23]. Though a slowing of the sensory conduction velocity of the median nerve is considered to provide the most reliable indication of CTS [17], a diagnosis is most reliably made upon the basis of electroneurographic results coupled with some of the other aforementioned symptoms and test outcomes.

e) Treatment

Treatment of this disorder typically follows a progression in the degree of invasiveness. Initially the patient is asked to refrain from activities which caused or aggravated the condition. Depending upon the severity of the condition, patients may wear a splint on the affected wrist which prevents flexion and extension until the symptoms abate. If these tactics are unsuccessful, the next treatment involves the injection of a small amount of a steroid solution into the carpal tunnel. As a last resort, surgery is performed during which the superficial transverse carpal ligament is sectioned in order to increase the volume of the tunnel [26]. This surgical procedure is typically successful, with the exception that handgrip weakness persists in approximately 30% of cases [6].

THE WORK PLACE

a) Causes and Risk Factors

Baker and Ehrenburg [5] suggest that up to 47% of all CTS cases might be attributable to workplace factors. Carpal tunnel syndrome has been observed in garment workers, butchers, grocery checkers, electronics assembly workers, typists, musicians, packers, housekeepers, cooks, carpenters, rock drillers, and journalists [5, 9, 20, and 23] . In the work place, tasks involving the hands and wrists which require combinations of high repetition and force, awkward wrist postures, large impact forces on the palm and exposure to vibration cause CTS [5, 28, and 31]. When the wrist is flexed, finger motion generates friction by rubbing the tendons against one another, ultimately causing swelling of the tendon sheaths, and reducing the space within the carpal tunnel [20]. Tasks which involve forceful grasping and pinching cause the tendons to stretch, compressing the structures within the tunnel, thereby causing tearing and inflammation as well as friction damage to the tendon sheaths [31]. Though the literature is equivocal in suggesting that flexion is more damaging than extension wrist motion, researchers have observed during tendon loading (such as in a pinch) that the pressure is higher on the median nerve when the wrist is flexed than when it is in a neutral or extended position [32]. High mechanical stresses and/or impact forces on the palm tend to place direct pressure on the median nerve causing CTS. Repetition obviously tends to exacerbate all of the aforementioned alterations.

Vibration exposure can also result in CTS. However, not to be confused with CTS, vibration white finger (VWF), Raynaud's Phenomenon, or vibration syndrome can also occur as a result of exposure to vibrating hand tools such as chain saws and jack hammers, causing degenerative alterations in the vascular system of the fingers [37]. Many investigators have observed a disproportionately high incidence of VWF in forestry populations [21 and 29]. However, a large number of these studies have also reported a rather high percentage of peripheral neuropathies [13, 21, and 29]. Given that vibration is being transmitted through to the hand and wrist, it seems reasonable to assume that these studies probably contained individuals with undiagnosed CTS. Though the relationship between the two disorders remains unclear, Loebe and Heidrich's [24] finding that 18-72% of CTS patients suffered from VWF prior to the development of CTS suggests that VWF may in fact be a precursor to CTS.

b) The Forest Workplace

Few investigations have identified CTS as a potential hazard of forestry work [7, 13, 21, 23, and 29]. Nevertheless, tasks requiring high force, repetitive motions utilizing the hands with the wrists in awkward positions are commonplace throughout the forest industry. Moreover, vibration exposure occurs during the performance of some forestry duties. The following sections provide an indication of the CTS risks associated with four classes of forest occupations.

i) Chain Sawyers

The studies contained in Table 1 demonstrate clearly that there is a risk for developing CTS during chain saw operation. However, the results of these investigations must be interpreted cautiously. According to Stock [36], given that all of the studies are cross-sectional, they are subject to survivor bias in that those who develop a musculoskeletal disease may have left the work force and are therefore not accounted for in the survey, thus tending to underestimate the effect. This makes it difficult to establish the temporal relationship between exposure and outcome.

Table 1. Studies of CTS from Chain Saw Use by Forestry Workers

Study	Country	Study group	Controls	Exclusions	Chain saw vibration exposure of study group	Confounders accounted for	Outcome
Färkkilä et al., 1988	Finland	79 chain sawyers (40.3±9.7 yrs) (sawyers with 500 hrs/yr)	none	diabetics and those with a positive glucose tolerance test	16600±4700 hrs	alcohol intake and age	25.3% CTS
Koskimies et al.,1990	Finland	125 chain sawyers (43.6±8.3 yrs)	none	Raynaud's Phenomenon, diabetes, positive urine glucose tolerance test	16000±4400 hrs	alcohol intake and vibration white finger	20.0% CTS (9.6% with bilateral CTS)
Bovenzi and Zadini, 1991	Italy	65 chain sawyers (44.7±13.7 yrs)	31 hospital maintenance workers (44.0±8.0 yrs)	none	11.3±9.3 yrs or 9196±11023 hrs	age and ponderal index ($wgt^{1/3}/hgt$)	controls—3.2% CTS forestry workers—38.4% CTS

Given the prevalence of CTS amongst chain sawyers, it is obvious that vibration exposure can play a role in the development of this disorder. Though it is difficult to separate out the effects of force, repetition and wrist posture from the influence of vibration, it is known that grip force exerted on a handle increases when the handle is vibrated [8]. Moreover, as grip force increases so does the transmitted vibration to the hand [15]. An increase in grip force from 8 to 14 N results in a two dB increase in the vibration level at the wrist [15]. It is thought that vibration stimulates muscle contraction (tonic vibration reflex) which results in decreased tactility and an increase in the required holding force [2]. Koskimies et al. [23] suggested that vibration-induced neuropathies may arise from a reduction in blood flow to the nerve fibres of the fingers which results from damage to the myelin sheath through swelling inside the nerve. Alternatively, vibration-induced nerve damage can occur as a result of carpal tunnel entrapment which occurs as a consequence of swelling of the connective tissue inside and outside of the nerve [14 and 23].

ii) Tree Planters

A forestry occupation which is probably at the highest risk level for the development of CTS is tree planting. Generally, planters are hired for a period of weeks (four to ten is common), and are paid on a piece rate basis, consequently they continue to work at very high rate, even when they are fatigued or injured. Planters often travel over 2 km while carrying 17 kg to plant an average of 1245 seedlings/day [18]. During tree planting, the horizontal alignment of the D-handle grip forces the planter to hold the wrist parallel to the ground-subjecting the wrist to repeated (up to 212 times/hour), elevated wrist extension forces [33]. Moreover, Smith [33] observed that grip strength was optimal at a grip diameter of 40-65 mm whereas most planting tools have a 29-36 mm grip diameter. It is known that as wrist posture deviates from neutral, grasp strength is adversely affected (11).

iii) Nursery Workers

Nursery workers perform a wide variety of job functions, most of which subject the hands and wrists to high repetition and force in often deviated wrist postures. It is not surprising that the injuries reported from this occupation consist primarily of hand and wrist ailments [40]. One nursery task involves the sorting of chilled seedlings (6000-7000 per day) [40] with the subsequent placement of these seedlings into trays (1200 trays/day). Once the seedlings take root, the trays are thinned manually, typically using a pinch grip, in order to remove two of the three seedlings in each pot. In tree improvement operations, workers use a great deal of wrist motion during pruning.

iv) Mobile Forest Machine Operators

While little research evidence exists to link the use of joystick controlled forest machines to CTS incidence, given that operators perform multiple repetitions of finger and wrist motions for up to ten hours per day, suggests that CTS risk factors should be quantified during the operation of these vehicles. In his ergonomic evaluation of feller-buncher cabs and controls, Golsse [19] observed that a skilled operator moved the right hand joystick a total of 2250 times in one hour in felling 200 trees. While the number of wrist motions was not quantified over the entire shift, the author estimated that more than 20,000 joystick motions requiring an average force application of 19.4 N would have been performed. These results coupled with the lack of legislation and guidelines in North America regarding joystick controls suggests that this concern warrants further investigation.

CTS AVOIDANCE GUIDELINES

While not encompassing all of the risk factors associated with CTS, Silverstein et al. [31] provided an excellent basis for the determination of high force and repetition. These authors categorized high force to be the lifting (with one hand) of 4 kg or more, and high repetitiveness to be tasks using the hands with a cycle time of less than 30 seconds or having a sequence of steps repeating themselves more than 50% of the cycle.

Given the risk factors of occupationally induced CTS, the development of industry guidelines should focus upon repetitiveness, forcefulness, wrist posture, vibration levels, and mechanical stress on the palms. Until guidelines are established, forestry managers should be cognizant of job tasks which appear to include any of the aforementioned risk factors. Attempts should then be made to modify the job elements using a wide variety of strategies.

Based upon the outcome of previous work measurement analyses as well as recommendations provided by experts, protection and safety suggestions appear warranted. Though gloves help to damp out vibration, spread the grip to a larger area, and keep hands warm, they also reduce tactile sensitivity and manual dexterity therefore causing workers to utilize more force in holding and manipulating tools and parts [31]. Moreover, if gloves are too tight, especially at the crease of the wrist, pressure may be applied against the median nerve [22 and 31]. Therefore, when performing tasks which require high force, workers should use properly fitting gloves, the palms of which should be covered by polymer dots to increase the coefficient of friction and concomitantly reduce the force requirements [12]. In addition, compression and trauma to a small area of the palm can be avoided by keeping the contact surface between the tool and the hand relatively large [3]. Alternatively, palm pads may be utilized to help forces be distributed evenly [31]. To reduce the deleterious effects of both force and repetition, Tichauer [39] suggested modifying the job and/or the tool such that the task could be performed with either hand thus reducing exposure. Generally, exposure can be reduced by design through the introduction of automation, mechanization, job enlargement, and job rotation.

a) Chain Sawyers

Chain saw vibration concerns appear to have been met by most manufacturers through successful attempts at damping out the vibration. Additionally, chain saw weights have been decreased, reducing the force of these devices against the hands as well as the transmitted vibration [35]. Petterson [25] reported that the numbers of vibration-related ailments reported in Sweden have drastically reduced, which can in no small part be attributed to improved vibration damping. Though the papers cited in Table 1 would suggest that vibration-related chainsaw ailments are still a problem, it may be that the sawyers in these studies used old machines. It may also be that the subjects had suffered wrist damage prior to the advent of vibration damped chain saws. In any case, given that the technology exists, forest managers should endorse and enforce the use of chain saws which meet international guidelines (ISO 6532, 1982) for vibration damping.

b) Tree Planters

To reduce the probability of tree planters becoming fatigued and thereby increasing their risk for developing CTS, based upon research by Smith [33], it is suggested that the following work procedures be implemented: hourly rest pauses of 5-10 minutes, maximum tree bag weights of 10-15 kg, and a standard eight-hour shift. It is also suggested that planting tools which optimize grip strength (grip diameter of 40-65 mm) should be utilized. Moreover, while the ground breaking force remains the same, the reduction in tool weight achieved through the use of aluminum bladed and plastic handled shovels reduces the force required during recovery motions and carrying thus decreasing cumulative loading on the hands and wrists [33]. Feldman et al. [16] recommended that jobs and tool handles be designed so that tasks could be accomplished with straight wrists. This also requires that the tools be properly balanced so that the centre of gravity of the tool is aligned with the centre of the grasping hand, minimizing the tendency of the tool to slip. In accordance with the research of Smith [33] it is recommended that the mandated use of specific planting tools be dropped. A selection of safer planting instruments should be available to workers, such as straight handled shovels which help to maintain a straight wrist posture. The Pottiputki (Figure 2) should also be available. The Pottiputki planting tool was designed to reduce injuries while improving productivity. However, depending upon soil conditions, since the wrist tends to be ulnarly deviated and extended while the operator breaks the ground with the Pottiputki's jaws suggests that the tool's use on particularly hard ground may predispose the worker to develop CTS and other hand/wrist injuries.

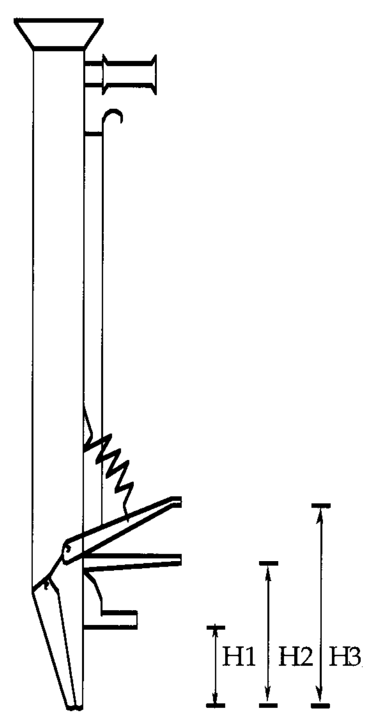

Figure 2. The Pottiputki—H1 = Step height above the ground, H2 = Step height above the ground (jaws), H3 = Step height when jaws are open.

c) Nursery Workers

Work stations such as those utilized by nursery workers sorting, planting and thinning seedlings should be adjustable so that the elbows aren't elevated above mid-torso height and the shoulders are neither flexed nor abducted more than 60 degrees [4]. Similarly, the research of Armstrong et al. [4] indicates that tools should be designed to utilize a power grip (fingers wrapped around the tool) rather than a pinch grip (load located at the end of the fingers). Workers involved in pruning operations must be encouraged to use tools which take advantage of the strongest joint positions, such as using pliers instead of forceps for tasks where a high clasping force is required [3].

d) Mobile Forest Machine Operators

Given that there is very little data to support the potential CTS risks associated with joy stick controlled machine operation, future research which focuses on quantifying the force, repetition, and wrist postures coupled with modelling information to predict internal wrist forces is required prior to making recommendations regarding such aspects as shift lengths and job rotation.

CONCLUSIONS

Undoubtedly, monitoring of RSI's and in particular CTS incidence in forestry occupations is necessary to determine the extent of the problem. Additionally, further research is required using work measurement techniques to investigate various forestry job characteristics in terms of known CTS risk factors. In addition to work environment and machine/tool modification, from an employer's perspective, given the high cost of workers' compensation claims resulting from the incidence of CTS, it may be warranted to consider the implementation of employee screening for CTS as well as other repetitive strain conditions. While it is inappropriate to discriminate against individuals based upon risk factors revealed in medical exams and histories, it may be appropriate to consider placing the employee in a job which minimizes their potential for developing CTS. In any case, employees should be made aware of CTS risk factors and management should strive to provide a safe workplace through planning and the development of guidelines for risk avoidance.

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