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Association between computer use and entrapment neuropathies in the wrist region

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There is general consensus in the literature that computer use is often associated with an increased prevalence of hand and wrist disorders. Symptoms may be associated with specific clinical entities such as peripheral nerve entrapment. Motor and sensory nerve conduction velocity and vibration treshold in the hand of computer users have been evaluated in several studies. In this review the relationship between computer work and entrapment neuropathies of median, ulnar and radial nerves in the wrist region will be examined.

Key words: Neuropathy, computer, wrist, ergonomy.

INTRODUCTION

Intensive computer work can increase the risk of developing musculoskeletal symptoms and disorders in the upper extremities (Pilegaard and Jensen, 2005; Gerr et al., 2002; Tornqvist et al., 2009; Jensen et al., 2002). Computer users with a long daily duration of computer use experienced more musculoskeletal symptoms than those with a short duration of computer use. Computer work in general seemed characterised by repetitive movements, which may be a risk factor for musculoskeletal symptoms (Jensen et al., 2002). Sommerich et al. (1996) quantifed the biomechanics of typing for 25 experienced computer users in three different occupational groups. The average tendon travel, normalized to 1 h of continuous typing, ranged from 30 to 59 m/h for the three groups. Researchers postulate that friction develops as a result of the repetitive sliding of tendons within their sheaths during the performance of highly repetitive activities such as typing. This friction may contribute to disorders of the tendons, their sheaths, or adjacent nerves (Nelson et al., 2000).

The repetitive computer use such as typing the keyboard and drig-drag the mouse overloads neck, shoulder, arm and hand muscles and joints. As they continue to be overworked, cumulative trauma happens. The muscles in the forearm that control the movement of fingers may become irritated and soft tissues become inflamed and swollen. The irritated muscles, swollen tendons and soft tissues can press on the nearby nerves and cause ischemic neurophysiological changes: A progressive reduction in nerve conduction appears, resulting in a transient increase in the sensation, numbness, tingling and then weakness and in advanced cases the outcome is a loss of strength and hand wrist pain such as carpal tunnel syndrome (CTS) (Hagberg, 1996; Ming and Zaproudina, 2003). Association between computer use and distal upper extremity neuropathies has been investigated before. The purpose of this review is to identify factors that play a role in the computer use related neuropathies in the wrist region.

Computer use is often associated with an increased prevalence of hand and wrist disorders (Burgess et al., 2010; Lassen et al., 2004; Gerr et al., 2002). Several cross-sectional studies have indicated the importance of the duration of computer use for the development of symptoms before (Jensen , 2003, Jensen et al., 2002; Karlqvist et al., 2002; Marcus et al., 2002). In the follow-up study by Marcus et al. (2002), the risk of developing hand-arm symptoms increased with hours of keying

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among newly hired computer users with more than 15 h of computer use per week. According to some authors there is moderate evidence, with a dose–response relationship, for a positive association between duration of mouse use and hand/arm symptoms. The risk estimates were generally stronger for the hand/arm region than for the neck/shoulder region, and stronger for mouse use than for keyboard and total computer use (IJmker, 2007). The risk factors associated with the conventional mouse are contact pressure on the palm, a pronated forearm posture, repeated or sustained pinching, wrist extension, or wrist deviation (Conlon and Rempel, 2005). Karlqvist et al. (1994) examined the postures associated with mouse use versus keyboard-only use. They concluded that `strenuous' (i.e. greatly deviated from neutral) wrist and shoulder postures were maintained for a greater percentage of time while using the mouse than using the keyboard. On the other hand, awkward postures identified as risk factors during keyboard use include shoulder elevation, flexion and abduction, neck flexion or extension, wrist extension and ulnar deviation (Tittiranonda et al., 1999). The risk factors were evaluated in a comprehensive review by Punnett and Bergquist (1997). They concluded that the use of a keyboard for more than 4 h per day was directly causative of wrist/hand disorders. A large British national survey found that keyboard usage for more than 4 h per day increased the risk of wrist/hand and shoulder symptoms, but not neck and elbow symptoms (Palmer et al., 2001).

Wrist positions and forces employed by computer users have been evaluated in several studies. During typing, wrist and elbow postures are maintained for long periods, creating static loading in the antigravity muscles, namely, the wrist extensors (Keir and Wells, 2002). The average position of the wrist for extension during typing has been reported as between 13° and 33° (Simoneau et al., 1999; Simoneau et al., 2003). The average position of the wrist in ulnar deviation has been reported to be between 11° and 25° (Simoneau et al., 1999; Simoneau et al., 2003). Descriptions of keyboard kinematics have documented that the wrist is often maintained in ulnar deviation (Simoneau et al., 1999; Rose, 1991; Baker, 2007). A hyperextended 5th MCP joint was noted in 50% of the right hands and 68% of the left hands of this sample and a hyperextended 4th MCP joint was noted in 23% of the right hands and 46% of the left hands. This hand position has been noted to cause a muscle contraction that exceeds 25% of the computer users maximum voluntary contraction in the extrinsic extensor muscles (Rose, 1991) putting the finger extensor tendons at risk for musculoskeletal disorders of the upper extremity. Some keyboarders also abduct as well as hyperextend their 5th digits continuously during keyboarding (Pascarelli and Kella, 1993), thereby maintaining tension on the 4th dorsal interosseous and abductor digiti minimi (Baker, 2007). The musculoskeletal system presents the nervous system with a mechanical interface. A static muscle contraction such as those witnessed in keyboard users can cause compression of a nerve in various anatomical sites (Byng, 1997).

Chronic peripheral nerve injury is usually the result of longstanding compression, repeated traction at entrapment sites, or traumatically altered regional anatomy. The result is focal axonal disruption and/or focal segmental demyelination (Elman and McCluskey, 2004). Determining whether there is a link between entrapment neuropathy and computer use is important as a result of the morbidity associated with entrapment neuropathies and the ever increasing use of computers in the workplace and at home (Conlon and Rempel, 2005). The following studies have examined the relationship between computer usage and the development of nerve disorder but the results of these studies are varied: Byng (1997) performed a modified upper limb tension test on 12 patients with repetitive strain injury, 20 asymptomatic keyboard users and 19 asymptomatic non-keyboard users to answer the question of whether asymptomatic "high-risk" groups have any pre-clinical changes to the physiological or mechanical continuity of the nervous system. The upper limb tension test was positive in 100% of the patient group. The results of two asymptomatic control groups showed that the keyboard users had a significantly positive upper limb tension test compared to non-keyboard users. The authors suggested that a subclinical pathological state exits in the keyboard users group. Greening et al. (2003) examined flare responses, sympathetic vasoconstrictor reflexes and vibration threshold over areas of the hand innervated by the median, ulnar and radial nerves in the patients with repetitive strain injury and asymptomatic office workers who intensively used display screen equipment. While patients demonstrate clear indications of changed peripheral nerve function involving small and large sensory and autonomic fibres, office workers who intensively used display screen equipment show early signs of changed sensory nerve function, but no change in autonomic responses. Jepsen (2004) studied a clinical series of computer operators with upper limb complaints in the dominant upper limb. The author identified sensory abnormalities in 19 out of 21 patients. The median nerve territory was most frequently involved.

The median nerve enters the hand above the bones of the wrist by passing beneath the transverse carpal ligament. Compression of the median nerve at the wrist, or CTS, is the most common compressive neuropathy (Elman and McCluskey, 2004). In recent years, with the expanding use of computers, it has been a matter of concern if computer use could be a risk factor for the development of CTS. In a cross-section prospective study Al-Hashem and Khalid (2008) assessed the effect of long-term use of computer mouse devices on the median nerve in healthy frequent computer users. They reported that over one third (35%) of asymptomatic participants and half of the participants who reported right hand discomfort after computer use, but did not meet clinical criteria for CTS (positive phalen's and tinel's signs), showed electrophysiological evidence suggestive of right median nerve entrapment neuropathy at the wrist. They suggested that frequent computer users have a tendency to median nerve entrapment neuropathy at the wrist. A 1-year follow-up study with questionnaires was conducted in Denmark to estimate the prevalence and incidence of possible CTS and to evaluate the contribution of use of mouse devices and keyboards to the risk of possible CTS (Andersen et al., 2003). The interview confirmed that prevalence of tingling/ numbness in the median nerve was 4.8%, of which about one third, corresponding to a prevalence of 1.4%, experienced symptoms at night. Onset of new symptoms in the 1-year follow-up was 5.5%. In the cross-sectional comparisons and in the follow- up analyses, there was an association between use of a mouse device for more than 20 h/wk and risk of possible CTS but no statistically significant association with keyboard use. The authors suggested that computer use does not pose a severe occupational hazard for developing symptoms of CTS. Based on this study, carpal tunnel syndrome risk is low or nonexistent when the keyboard is used for less than 20 h per week. However, a number of cross-sectional epidemiologic studies have found the risk of carpal tunnel syndrome is increased with keyboard use above 20 h per week (Stevens, 2001).

Contrasting results have been reported in the literature regarding association between computer use and median nerve entrapment. Greening and Lynn (1998) reported significantly raised vibration threshold within the territory of the median nerve in a group of office workers using computer keyboard equipment and concluded that the results indicated a change in the function of large sensory fibres. A study by Murata et al. (1996) found reduced sensory nerve conduction velocity in the median nerve across the carpal tunnel among computer operators compared with healthy controls, indicating that a subclinical CTS was associated with computer use. In contrast to these findings Sanden et al. (2005) found no difference in vibration thresholds between female computer users and nonusers. They found no signs of early neural deficits of large sensory fibres in subjects who intensively use computer keyboard equipment. This is in accordance with the results of Stevens et al. (2001) , who found no association between computer use and manifest CTS defined by symptoms and abnormally low nerve conduction velocities over the carpal tunnel. Atroshi et al. (2007) investigated the relationship between the frequency of keyboard use at work and the prevalence of CTS among a random general population sample of working-age persons. They showed a significant association between intensive keyboard use at work and a lower risk of CTS. In a prospective study of musculoskeletal health among computer users (n=632), CTS was found less common than most other upper extremity disorders (0.9 cases/100 person-years) (Gerr et al., 2002). However the authors observed that symptoms in the distribution of the median nerve were more common than confirmed cases of CTS (6.9/100 person-years). In a systematic review by Thomsen et al. (2008) it was observed that measurements of carpal tunnel pressure under conditions commonly observed among computer users showed modest increases generally believed to be below potential harmful levels. Finally, in a review by Palmer et al. (2007) it was concluded that the evidence did not point at any important association between keyboard and computer work and CTS.

Wrist position has been shown to affect the pressure in the carpal tunnel (Weiss et al., 1995; Simoneau et al., 1999). The most important factor in the CTS pathogenesis for keyboard and mouse users is the carpal tunnel pressure (CTP). CTS patients have elevated CTP compared to healthy population (Keir et al., 1998). Weiss et al. (1995) determined that the lowest carpal tunnel pressure of about 8 mm Hg was found when the wrist was deviated approximately 2° ulnarly and 2° in extension. In this same study, the carpal tunnel pressure increased to approximately 20 and 50 mm Hg when the wrist was deviated 10° and 20° ulnarly, respectively. Based on the work reported by Dahlin and Lundborg (1990), pressures even as low as 20 mm Hg could substantially reduce axonal transport in the neuron, and a pressure of 30 mm Hg would result in marked detrimental morphological changes. Finally, the critical threshold for capillary integrity has been measured to be 30–40 mm Hg (Werner et al., 1997). Both ulnar deviation and extension of the wrist increase CTP (Weiss et al., 1995; Werner et al., 1997). Keir et al. (1999) suggested that two factors may account for the elevated CTP during computer mouse use: (1) wrist extension and (2) the fingertip force applied to depress the button and to grip the sides of the Mouse. With wrist extension angles greater than 15 degrees, pressure in the carpal tunnel could result in more pressure against the median nerve, and this could contribute to the development or perpetuation of carpal tunnel syndrome (Simoneau et al., 2003). Liu et al. (2003) investigated the risk factors for CTS among computer workers by typical symptoms. They showed that the incidence of CTS in the computer workers was 16.7% (15 of 90 hands) and computer workers who kept their wrists extended by more than 20° were at greater risk of developing CTS. During typing the hand and wrist adopt awkward postures that increase CTP exceeding the upper safe limit. Werner et al. (1997) noted that wrist extension stretches flexor tendons and median nerve, exerting pressure on their dorsal face. They showed that compression on the median nerve and tendon flexors between the volar carpal ligament and the volar glide of the proximal row of carpal bones during wrist extension occurs also due to the carpal bones movement against the radial head. Also, the presence of the distal ends of the finger flexors in the carpal tunnel leads to elevated CTP. The flexion of the fingers will lead to an increase in the CTP (Keir et al., 1998). Finger flexion is very important for CTP, and this importance is raised by typing force that may be four to five times greater than the force required to activate the key (Feuerstein et al., 1997). Flexion of the wrist requires the flexor digitorum tendons to be pushed against the palmar side of the carpal tunnel, causing pressure on both the tendons and the flexor retinaculum. Because the median nerve is located between the flexor retinaculum and the flexor tendons, the pressure exerted on it will rise (Fagarasanu and Kumar, 2003).

Several studies have demonstrated an increased risk of carpal tunnel syndrome with increasing hours of computer mouse use (Stevens et al., 2001; Andersen et al., 2003). Restriction of transverse movement of the median nerve at the wrist and neural mechanosensitivity in the median nerve trunk and along the cords of the brachial plexus has been demonstrated in patients with whiplash injury and with non-specific arm pain (Greening et al., 2005). Such an occurrence is also possible in computer users where there is prolonged static and awkward postures of the neck and upper limb. Certain postures or positions can place increased pressure directly or, by increasing compression on nerves at different entrapment sites create neural irritation (when the worker moves away from these static postures). This may result in multilevel nerve compression where a distal site of compression can negatively affect the more proximal entrapment site (Novak and Mackinnon, 2002). Low extraneural compression of the median nerve in the carpal tunnel is sufficient to produce edema within the nerve and impair endoneurial microcirculation This compression has been demonstrated to be strongly influenced by repetitive fingertip loading, hand, wrist and forearm postures which may be seen during keyboard activity (Rempel and Diao, 2004; Johnston et al., 2008).

The ulnar nerve enters the hand above the transverse carpal ligament through Guyon’s canal (Elman and McCluskey, 2004). There typically are two cutaneous branches of the ulnar nerve in the forearm, the dorsal branch to the hand and a smaller palmar branch. The main trunk of the ulnar nerve continues to the wrist, where it enters Guyon’s canal This is the narrow space situated between the pisiform and the hook of the hamate in the proximal hypothenar region through which the ulnar nerve and artery pass. Here it divides into a superficial and deep branch (Khoo et al., 1996). Ulnar neuropathy can occur at the wrist just proximal to, within, or distal to Guyon’s canal.The first of these lesions spares the dorsal ulnar cutaneous branch, the second spares all cutaneous branches, and the third spares all but the superficial sensory branch to the fifth digit and ulnar side of the fouth digit (Shea and McClain, 1969). Ulnar nerve compression at Guyon's canal may be associated with an occupational disease in which the nerve is exposed to repeated blunt trauma or high frequency vibration (Palmer, 2011). Guyon's canal syndrome due to occupational overuse has been attributed to prolonged flexion or extension of the wrist and repeated pressure on the hypothenar eminence (Yassi, 1997). It has been reported that approximately 10% of computer users who have work-related symptoms were found to have positive Tinel's sign over the Guyon's canal (Pascarelli and Hsu, 2001). Chan et al. (2008) report a case of Guyon's canal syndrome caused by a ganglion in a computer user. In this case the nerve conduction study revealed that both the abductor digiti minimi and the first dorsal interosseus muscles showed prolonged motor latency and ulnar sensory amplitude across the right wrist to the fifth digit was reduced. Deleu (1992) examined two patients who presented with an isolated ulnar palmar-cutaneous-branch sensory neuropathy resulting from daily use of a mousedirected personal computer. Prior literature provide no more information in that respect.

It has been speculated that the pathologic processes causing CTS might also be expected to affect ulnar nerve at the wrist level (Cassvan et al., 1986; Gozke et al., 2003). Since a close contiguity exists between carpal tunnel and Guyon canal at the wrist level, there may an association between CTS and ulnar nerve compression at the wrist. Jensen et al. (2002) found an elevated vibration threshold in hand areas innervated by the median and ulnar nerves among computer users with pain in the upper limbs compared with a control group of computer users without symptoms and a control group of subjects without symptoms or computer use. They concluded that the findings indicated entrapment of the median and ulnar nerves. Another study found a threshold effect for entrapment neuropathies (ulnar and median) at the wrist, confirmed by nerve conduction, with increased risk when the computer was used for more than 28 h per week (Conlon and Rempel, 2005)

The radial nerve is predisposed to injury and entrapment at several locations along its course, which includes the radial nerve in the spiral groove of the humerus (spiral groove syndrome), the deep branch of the radial nerve at the supinator muscle (posterior interosseous nerve syndrome), and the superficial branch of the radial nerve where it crosses over the first dorsal wrist compartment (Wartenberg’s syndrome). The degree of sensory and motor problems relate to the chronicity and severity of the compression, as well as the location of the entrapment along the course of the radial nerve (Jacobson et al., 2010). Elevated levels of vibrotactile sense in the median and ulnar nerves have been reported in computer users with upper extremity pain (Jensen et al., 2002) and in patients with non-specific arm pain who associated their symptoms to intense computer use (Greening et al., 2003) but not in the radial nerve (Johnston et al., 2008). We could find no studies in the literature suggesting electrodiagnostic abnormalities of radial nerve in computer users so we thought that the radial nerve is not in a vulnerable position as it lies through the wrist during repetitive motions or awkward positions.

In conclusion, several studies showed that long term computer users are at increased risk for entrapment neuropathies in the wrist region.However, most of these studies include no measure of nerve conduction velocity and conclusions of these studies were based on self reported symptoms of entrapment neuropathies without conforming neurophysiological studies. A scientific reseach that elucidates the association between computer use and entrapment neuropathy risks in the wrist region has not been conducted yet.

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