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Computer keyboarding biomechanics and acute changes in median nerve indicative of carpal tunnel syndrome

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ABSTRACT

Background: Carpal tunnel syndrome is a common and costly peripheral neuropathy. Occupations requiring repetitive, forceful motions of the hand and wrist may play a role in the development of carpal tunnel syndrome. Computer keyboarding is one such task, and has been associated with upper-extremity musculoskeletal disorder development. The purpose of this study was to determine whether continuous keyboarding can cause acute changes in the median nerve and whether these changes correlate with wrist biomechanics during keyboarding.
Methods: A convenience sample of 37 healthy individuals performed a 60-minute typing task. Ultrasound images were collected at baseline, after 30 and 60 min of typing, then after 30 min of rest. Kinematic data were collected during the typing task. Variables of interest were median nerve cross-sectional area, flattening ratio, and swelling ratio at the pisiform; subject characteristics (age, gender, BMI, wrist circumference, typing speed) and wrist joint angles.
Findings: Cross-sectional area and swelling ratio increased after 30 and 60 min of typing, and then decreased to baseline after 30 min of rest. Peak ulnar deviation contributed to changes in cross-sectional area after 30 min of typing.
Interpretation: Results from this study confirmed a typing task causes changes in the median nerve, and changes are influenced by level of ulnar deviation. Furthermore, changes in the median nerve are present until cessation of the activity. While it is unclear if these changes lead to long-term symptoms or nerve injury, their existence adds to the evidence of a possible link between carpal tunnel syndrome and keyboarding.

1. Introduction

Carpal tunnel syndrome (CTS) is the most widely reported nerve compression disorder (Werner and Andary, 2002) with symptoms, including numbness, tingling, pain, weakness, and fatigue in the affected hand, present in approximately 5% of the United States general population (Kwon et al., 2008), with as many as 90 per 100,000 requiring surgical intervention (Jerosch-Herold et al., 2014). According to Dartmouth–Hitchcock Medical Center, surgical treatment of carpal tunnel could cost more than $7000 per hand (http://www.dartmouth-hitchcock.org). In addition, the income loss per CTS patient over a period of 6 years was estimated at $45,000–89,000 compared with controls (Foley et al., 2007). CTS symptoms can disturb the ability to perform work-related activities, potentially resulting in work disability (Turner et al., 2007).

The most commonly accepted theory describing pathogenesis of CTS is chronic compression of the median nerve within the carpal tunnel. Upon conducting a systemic review of studies of computer work and carpal tunnel syndrome, Thomsen et al. (2008) concluded that biomechanical factors, such as forceful exertions, repetition, and awkward postures, increase the risk of CTS by increasing carpal tunnel pressure, resulting in median nerve ischemia. Some investigators have suggested that the pathologic changes of the subsynovial connective tissue, including noninflammatory fibrosis and thickening, may also be a cause of carpal tunnel syndrome (Greening et al., 2001).

Common methods for diagnosing CTS are typically limited to physical examinations or nerve conduction. Ultrasound is currently being explored as a cost-effective imaging study due to its non-invasiveness, precision, and accuracy (Beekman and Visser, 2003); a recent meta-analysis found ultrasound to have a high specificity (86.8%) and sensitivity (77.6%) in the diagnosis of CTS (Fowler et al., 2011). Unlike nerve conduction (Werner et al., 1997a,b), ultrasound has the potential to predict future CTS and identify risk factors. Quantitative ultrasound (QUS) techniques have been developed to quantify the immediate effects of an activity on nerve size and shape (Altinok et al., 2004;

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Impink et al., 2010). Using this technique, direct relationships between nerve changes indicative of CTS and a given activity can be established.

Epidemiological evidence suggests occupation plays a role in the development of CTS, with higher risk associated with jobs requiring prolonged repetitive and forceful motions, awkward or static postures, localized mechanical compression, and vibration (Palmer et al., 2007; Punnett, and and Wegman 2004; Roquelaure et al., 1997; Silverstein et al., 1987; van Rijn et al., 2009). While keyboarding is a highly repetitive task requiring small but forceful movements of the fingers, the evidence is conflicting as to whether there is a relationship between computer use and CTS (Gerr et al., 2006). Keyboard users exhibit a variety of preferred postures (Simoneau et al., 1999) that remain stable when typing (Baker et al., 2007) and are dependent on physical characteristics of the workstation (Marklin et al., 1999). Awkward typing postures have been identified as a risk factor for development of CTS symptoms; specifically, greater degrees of ulnar wrist deviation (Hunting et al., 1981) and migration from a neutral flexion/extension position (Simoneau and Marklin, 2001).

In this study we aim to confirm our previous results, which indicated acute increase in size of the median nerve at the inlet of the carpal tunnel after keyboarding (Toosi et al., 2011). This paper involves a larger sample size and investigating changes that occur after a brief resting period, and also incorporate biomechanical variables and subject characteristics, which were chosen based on risk factors identified in the literature (Gelberman et al., 1981; Hunting et al., 1981; Silverstein et al., 1987). It was hypothesized that following 30 and 60 min of typing the median nerve will show increased cross-sectional area (CSA) and flattening ratio (FR) at the pisiform level, and an increased swelling ratio (SR) and that these same variables would then decrease to baseline after 30 min of rest. Increased CSA, FR and SR are associated with CTS (Beekman and Visser, 2003). It was also hypothesized that typing biomechanics (average peak ulnar deviation of the wrist, average peak wrist extension) and subject characteristics (BMI, gender, age, wrist circumference, typing speed) would predict median nerve CSA, SR, and FR after 30 and 60 min of typing.

2. Methods

2.1. Subjects

A convenience sample of healthy individuals was recruited to participate in the study. Participants were included if they 1) were between 18 and 65 years old, 2) spoke English, 3) were self-report proficient typists (i.e., typing at least 40 words per minute), 4) used a computer keyboard at least 3 h a day, 4 days a week, and 5) typed using at least 8 fingers. Participants were excluded if they 1) had a history of wrist surgery or fracture, 2) self-reported or presented clinical condition that mimics CTS or interferes with its evaluation (e.g. proximal median neuropathy, cervical radiculopathy, or polyneuropathy), 3) self-reported history of CTS signs or symptoms, or 4) had a history of underlying disorders associated with CTS (e.g. diabetes mellitus, rheumatoid arthritis, acromegaly, or hypothyroidism). These criteria were chosen to eliminate potential confounders and reduce error when evaluating CTS symptoms. Participants were asked to refrain from intense physical activity such as sports, exercise, repetitive forceful arm tasks like yard work for 48 h, and vigorous typing, for 12 h prior to participation in this study since intense physical activity may affect the baseline measurements. The study was approved by the appropriate Institutional Review Board and subjects provided written informed consent prior to data collection.

2.2. Study procedure

Participants were tested in the morning to limit the amount of activity performed on the day of testing. Participants completed demographic and hand and wrist pain questionnaires. Bi-lateral wrist circumference and length of finger segments were also measured. Participants were asked to complete two 30-minute typing tasks. Ultrasound images were collected using a Philips HD11 XE ultrasound machine with a 5–12 MHz 50 mm linear array transducer (Philips Medical Systems, Bothell, WA, USA) by a single investigator at four time points: before the first typing task began (baseline), immediately following the first and second typing task, and 30 min after cessation of the second typing task. Bilateral images were taken of the carpal tunnel at the distal radius and pisiform levels using a previously described technique (Impink et al., 2010), with primary emphasis on the median nerve. Keyboard used during the typing tasks was an L100 Dell keyboard (Dell, Inc., Round Rock, TX, USA), which was set in a flat position parallel to the table; set-up was held constant between participants. The keyboarding task was performed using an electronic keyboarding program, Typing Master Pro™ (Typing Master Finland, Inc., Helsinki, Finland), which presents a typing task for the keyboard user on the computer screen. All participants typed the same text at their normal rate and were instructed not to correct errors. Alternate input devices such as a mouse were not used.

Kinematic data were collected using an Optotrack motion capture system (Northern Digital, Inc., Waterloo, Ontario, Canada). Hand, wrist, and finger movements were derived via tracking of active markers positioned on the dorsal surface of the dominant hand (Fig. 1). Sixty seconds of kinematic data were simultaneously collected at 5 and 25 min after typing began in each 30-minute session, using a sampling frequency of 60 Hz, providing total of four measurements. Data were not collected throughout the entire test as individual typing biomechanics remain relatively stable during typing tasks (Baker et al., 2007).

2.3. Data analysis

2.3.1. Ultrasound images

An interactive image analysis program was developed to measure the median nerve at the levels of the distal radius and pisiform using the ultrasound images collected (Impink et al., 2010). Cross-sectional areas of the median nerve were determined by performing a boundary trace at each level, and were used to calculate SR (Eq. (1)), while major (or mediolateral) and minor (or anteroposterior) axes of the nerve were measured to calculate FR (Eq. (2)). CSA, SR and FR have all been found to be reliable measures related to CTS (Beekman and Visser, 2003). One investigator analyzed all images and was blinded to the subject and

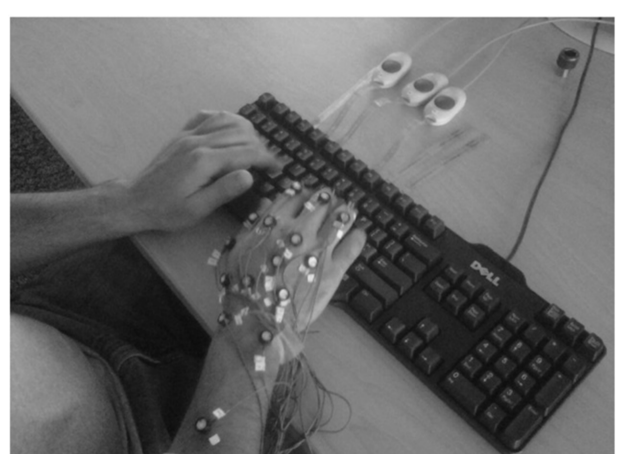

Fig. 1. Active markers affixed to the dorsal aspect of the dominant hand during the typing task.