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Effect of Wrist Posture on Carpal Tunnel Pressure while Typing

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Abstract

Long weekly hours of keyboard use may lead to or aggravate carpal tunnel syndrome. The effects of typing on fluid pressure in the carpal tunnel, a possible mediator of carpal tunnel syndrome, are unknown. Twenty healthy subjects participated in a laboratory study to investigate the effects of typing at different wrist postures on carpal tunnel pressure of the right hand. Changes in wrist flexion/extension angle ($p = 0.01$) and radial/ulnar deviation angle ($p = 0.03$) independently altered carpal tunnel pressure; wrist deviations in extension or radial deviation were associated with an increase in pressure. The activity of typing independently elevated carpal tunnel pressure ($p= 0.001$) relative to the static hand held in the same posture. This information can guide the design and use of keyboards and workstations in order to minimize carpal tunnel pressure while typing. The findings may also be useful to clinicians and ergonomists in the management of patients with carpal tunnel syndrome who use a keyboard.

Keywords

carpal tunnel syndrome; keyboard; occupation; overuse; neuropathy

The evidence that keyboard use can cause or aggravate carpal tunnel syndrome is mixed. Two prospective studies of computer users evaluated carpal tunnel syndrome as an endpoint. One, which used nerve conduction measurements, was unable to examine the relationship to keyboard use due to small sample size and related low power, even though there were 632 participants.[1] The second, a study of professional technicians, found no relationship between hours of keyboard use and incidence of carpal tunnel syndrome based on an interview.[2] However, most of the participants in the study reported using a keyboard less than 20 h per week. 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, many employees, such as customer service operators, animators, engineers, and newspaper employees are required to use a computer for more than 20 h per week, and 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.[3–6] A study of medical transcriptionists using nerve conduction to document cases found no relationship with hours of keyboard use, but there was little difference in hours of keyboard use between transcriptionists.[7] A recent study of 180 engineers found a threshold effect for entrapment neuropathies (ulnar and median)

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at the wrist, confirmed by nerve conduction, with increased risk when the computer was used for more than 28 h per week.[8] Finally, a population survey of carpal tunnel syndrome, with cases confirmed by nerve conduction studies, found an association with computer use.[9] Each of these epidemiologic studies has limitations, but the current evidence suggests that there may be an increased risk for carpal tunnel syndrome for those who use a keyboard for more than 20 h per week.

Based on human and animal studies, one mechanism for the development or aggravation of carpal tunnel syndrome may involve the sustained elevation of the fluid pressure inside the carpal tunnel.[10] Patients with carpal tunnel syndrome typically have elevated carpal tunnel pressures in comparison to healthy controls.[11] When carpal tunnel pressures are experimentally elevated to 4 kPa or more, paresthesias and changes in nerve conduction amplitude and velocity occur.[12] Animal studies support the concept of a pressure threshold for nerve injury.[13] Compression pressures as low as 2.7 kPa can decrease blood flow inside the nerve.[14] Pressures of 4 kPa applied to a nerve for just 2 h can cause a persistent increase in the pressure inside the nerve, intraneurial edema, and ultimately nerve demyelination.[15–17] These studies support a pressure threshold for nerve injury at or just below 4 kPa.

Increases in carpal tunnel pressure can be caused by non-neutral hand postures and grip forces. Carpal tunnel pressure is influenced by wrist posture,[11,18–20] forearm posture,[20,21] finger posture,[18] and fingertip force.[22] Specifically, carpal tunnel pressure increases with forearm rotation from 45° of pronation,[20,21] and wrist deviation from neutral, especially in wrist extension.[18]

A common ergonomic recommendation for computer users is to adjust the keyboard or workstation to reduce wrist extension and ulnar deviation. This can be done by changing the height of the keyboard, using a thinner keyboard, a split keyboard, tilting the keyboard so that it is flat or negatively sloped, or using a forearm support. However, it is uncertain how modifying wrist posture during typing will influence carpal tunnel pressure. This study examines the effects of wrist postures and typing on in vivo carpal tunnel pressure. The primary null hypothesis is that wrist angle during typing does not change mean carpal tunnel pressure.

METHODS

Twenty experienced touch typists (mean age 29.8 ±7.5 years) volunteered to participate in the study. Subjects were recruited from staff and students at the University of California at San Francisco. They demonstrated no evidence of carpal tunnel syndrome based on history, physical examination, and nerve conduction testing as previously described.[23] The study was approved by the committee on human research. Carpal tunnel fluid pressure measurement was accomplished via a 20-gauge (0.8 mm) saline-filled catheter (Burron Medical, Inc., Bethlehem, PA) attached at its proximal end to an in-line pressure transducer that was maintained at the same level as the carpal tunnel. The catheter has multiple perforations distributed over a 10 mm length at the end. To minimize the possibility of occlusion, a slight positive flow of saline at a rate of 0.5 mL/h was maintained using a microcapillary infusion technique. The catheter was inserted as previously described[23] and secured at the distal wrist crease with a suture to minimize tip motion within the carpal tunnel. Based on prior pilot studies with cadaver hands and radiographs of the wrist of three subjects, the catheter tip location was at the narrow region of the carpal tunnel at the level of the hook of the hamate. Prior pilot studies had determined that the catheter measured fluid pressure changes and not tendon contact with the catheter tip.

Wrist flexion/extension and radial/ulnar deviation were measured via a two-channel electrogoniometer (model M110; Biometrics Ltd., Ladysmith, VA) mounted on the dorsum of the hand and forearm and calibrated.[23] Carpal tunnel pressure and wrist angles were recorded continuously at 40 Hz on a computer while subjects typed on an adjustable split keyboard (Fig. 1).[24] The keyboard height was adjusted to maintain the wrist at the same height (approximately elbow height) throughout the study. Therefore, across all keyboard configurations, the wrist was at the same height relative to the pressure transducer. Typing speed was not controlled, but subjects were required to touch type. Subjects typed the same text from a magazine article. Subjects were not allowed to rest their hands or wrists on a surface while typing in order to prevent contact pressure at the palm, which can increase carpal tunnel pressure.[15]

Subjects performed nine different touch typing tasks; for each task the split keyboard was adjusted to achieve a desired wrist angle during typing. For five of these conditions, the keyboard was adjusted to achieve wrist flexion/extension angles of 15, 0, −15, −30, or −45° (negative angles denote wrist extension) while holding radial/ulnar deviation constant. For three conditions, the keyboard was adjusted to achieve radial/ulnar deviation angles of 15, 0, and −15° (negative values denote radial deviation) while holding extension/flexion constant. For the final condition, subjects typed with the keyboard adjusted to a conventional configuration by moving the keyboard halves together but maintaining a 7° front-to-back slope of the keycaps. The order of keyboard condition testing was not randomized; based on previous studies, carpal tunnel pressure was not influenced by prior hand tasks. The duration of each typing task was 5 min. Data were recorded during the final 2 min of the typing task, unannounced to the subject. At the end of the task, subjects were asked to hold their hands still in the posture used for typing, and data were recorded for the corresponding static hand posture.

Mean values were calculated for wrist flexion/extension angle, wrist radial/ulnar deviation angle, and carpal tunnel pressure for each task. The flexion/extension and radial/ulnar deviation tasks were analyzed separately to determine the effect of target wrist angle on carpal tunnel pressure using repeated measures ANOVA procedures. Significant findings on the ANOVA were followed-up with the Tukey test to adjust for multiple comparisons ($\alpha = 0.05$). To explore the effect of typing, independent of posture, on carpal tunnel pressure, all wrist configurations (eight), the state condition (typing vs. static), and their interaction term (configuration × state) were included in one RMANOVA model.

RESULTS

Summary measures and plots of the summary data suggest that wrist angle has a strong influence on carpal tunnel pressure during typing (Table 1, *p* Figs. 2 and 3). The effect of wrist flexion/extension angle during typing on carpal tunnel pressure was significant (repeated measures ANOVA, < 0.01). The Tukey follow-up test indicated that the carpal tunnel pressure at the 30° wrist extension configuration was significantly greater than the pressure at the 15° flexion and 0° extension configurations (the superscripts in the table and figures for 15° flexion [c] and 0° extension [c] are different from the superscript for 30° extension [b]). The carpal tunnel pressure at the 45° extension configuration was significantly higher than all other configurations. During these tasks, the mean wrist ulnar deviation was 5.7° (SD = 0.8).

The effect of wrist radial/ulnar angle during typing on carpal tunnel pressure was also significant (RMANOVA, $p < 0.03$). The Tukey follow-up test indicated that the carpal tunnel pressure at the 15° radial deviation configuration was significantly higher than at the other two configurations. The mean wrist extension angle across these tasks was 19.6° (SD = 0.8).

The effect of typing on carpal tunnel pressure was independent of posture because the interaction term of the two factors, wrist angle (eight levels) and state (typing vs. static), in a RMANOVA was not significant ($p > 0.25$). However, both the wrist angle and state were independently significant in the model ($p < 0.001$). Typing was associated with a mean increase in pressure of 0.53 (SD = 0.29) kPa over the static hand posture across all wrist angles.

DISCUSSION

This is the first study to measure carpal tunnel pressure during typing on a keyboard and to evaluate the effects of wrist postures on pressure during typing. The study found that carpal tunnel pressure is influenced by wrist posture during typing and, independently, by the act of typing. The U-shaped relationship of wrist posture to carpal tunnel pressure while typing is similar to that observed in other studies that have measured carpal tunnel pressure at static wrist postures or with simple wrist motions.[11,18,19,23] The pressure is lowest near the neutral wrist posture (0° flexion/extension, 0° ulnar/radial deviation) and increases with increasing deviation from neutral. The finding of a significant difference in pressure only in extension and radial deviation may be due to the small sample size and the limited excursion of wrist posture in the direction of flexion and ulnar deviation. Subjects were unable to type effectively with greater wrist flexion than that tested in this study. The increase in carpal tunnel pressure with wrist extension may be due to flexor muscle incursion into the carpal tunnel space.[25]

Another finding of this study is that the activity of touch typing increases carpal tunnel pressure above the pressure associated with just holding hands suspended over the keyboard at the same wrist posture. The increase associated with typing was 0.53 kPa and was independent of wrist posture. Other studies have found that fingertip loading can increase the carpal tunnel pressure[22]; a static fingertip load of 1 N was associated with a rise in pressure of approximately 0.7 kPa. Typing is associated with peak fingertip forces of approximately 1 N[24]; therefore, the elevated carpal tunnel pressure associated with typing may be due to the fingertip load and not finger motion. A study of carpal tunnel pressure during computer mouse use reported an increase in pressure with button pressing compared to just resting the hand on the mouse.[26] The pressure rise associated with typing is just one of several postural factors (e.g., wrist extension, external palm loading) that can increase carpal tunnel pressure. The concern is that these factors together can contribute to sustained pressures over 4 kPa that may increase the risk for entrapment neuropathy.

The carpal tunnel pressure and wrist postures while typing on a conventional keyboard were not included in the analyses, but were included in Table 1 and Figures 2 and 3 for comparison purposes. The data from the conventional keyboard is consistent with the data from the eight wrist posture configurations. The wrist postures on the conventional keyboard are similar to those observed in studies of computer users in the work-place.[27–29] This finding provides some confidence that the typing task is similar to typing tasks in the workplace. A difference, however, is that in the work-place subjects frequently rest their palms and wrists on a palm rest or the work surface when typing. This would increase carpal tunnel pressure to levels higher than those reported in this study.

The link between awkward wrist postures and hand symptoms or disorders during typing has been mixed. Some epidemiologic studies have found a thick keyboard (e.g., increased wrist extension),[30] ulnar deviation,[31] or non-neutral wrist postures[32] to be associated with hand/arm symptoms and hand/arm disorders among typists. A limitation of these studies is that wrist posture was based on the subject's report of their posture or on a measurement made at a single point in time. These measures may not accurately represent mean wrist posture over time.

The present study provides a physiologic basis to support the findings of two randomized intervention studies of fixed split keyboards.[33,34] Both intervention studies found that the use of a fixed split keyboard reduced hand discomfort and pain when compared to a conventional keyboard. One of the studies was a 6 month trial of patients with carpal tunnel syndrome and tendonitis.[33] In a separate laboratory study, the fixed split keyboard reduced wrist extension, ulnar deviation, and pronation in comparison to a conventional keyboard.[29] These are wrist posture changes that, based on the present study, would be expected to reduce carpal tunnel pressure.

The limitations of the present study should be noted. No attempt was made to control typing speed or accuracy. It is possible that typing rate may affect carpal tunnel pressure but this has yet to be evaluated. The order of testing conditions was not randomized. The duration of each typing task was just 5 min; it is possible that the carpal tunnel pressure would gradually change over the study period. However, in other studies we have noted little pressure change over a 4 h period. Based on those studies we would expect that the pressure measured during a 5 min period would represent the pressure over a 4 h period. The variability between subjects in carpal tunnel pressure was high, as indicated by the error bars in the figures. This variability may have been due to inherent differences in carpal tunnel pressure response to posture and typing or difference in placement of the catheter tip in the carpal tunnel. This study did not evaluate the effects of other factors that are present in workplace that may influence carpal tunnel pressure, such as keyboard height, wrist rests, and psychosocial stressors.

The findings of this study suggest that the keyboard and workstation be adjusted to avoid wrist extension greater than 30° and radial deviation greater than 15° when using a computer for long hours. Wrist extension can be reduced by decreasing the slope of the keyboard, decreasing the keyboard thickness, using a split keyboard, using a forearm support surface, or raising the keyboard height relative to the chair. Ulnar deviation can be reduced by using a split keyboard, but it should be noted that a large keyboard opening angle may lead to radial deviation, which should be avoided. These findings may provide guidelines to keyboard designers and to clinicians for the management of patients with carpal tunnel syndrome who use a keyboard at work or home.

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Figure 1.
Custom adjustable keyboard used in study. Keyboard adjusts in height, separation of the two halves, slope (front to back), opening angle (to alter ulnar/radial deviation), and tenting or gable. In this study there was no tenting.

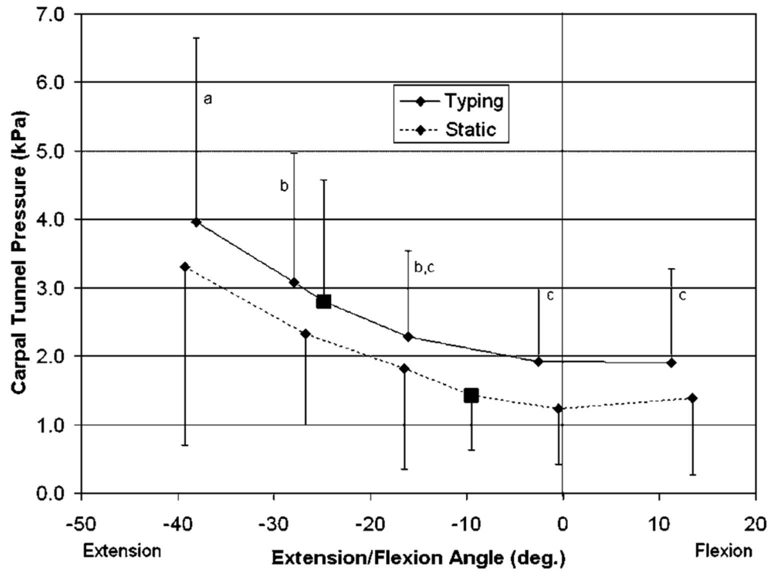

Figure 2.
Mean carpal tunnel pressure versus mean right wrist flexion/extension angle (N = 20). Values represent means ± SD. Typing pressure values with a common superscript letter were not significantly different from each other. Values for the conventional keyboard are labeled as -■- and were not included in the analysis.

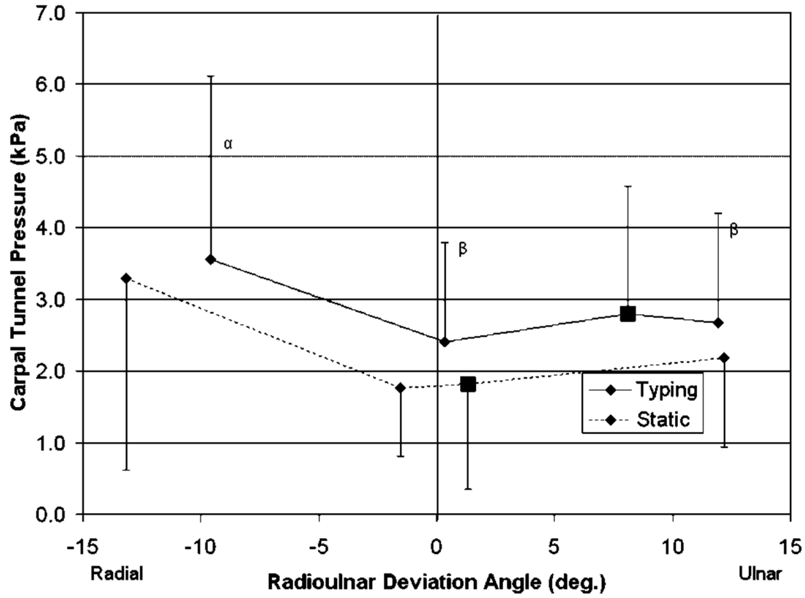

Figure 3.
Mean carpal tunnel pressure versus mean right wrist radial/ulnar deviation angle (N = 20). Values represent means ± SD. Typing pressure values with a common superscript letter were not significantly different from each other. Values for the conventional keyboard are labeled as -■- and were not included in the analysis.

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Table 1

Target Wrist Postures, Actual Wrist Postures, and Associated Carpal Tunnel Pressures (Mean ± SD) of the Right Hand

	Actual Wrist Postures					
	Flexion/Extension Angle (°)		Radial/Ulnar Deviation Angle (°)		Carpal Tunnel Pressure (kPa)	
Target Wrist Posture	Typing	Static	Typing	Static	Typing	Static
15° Flexion	11.2 (±4.5)	13.5 (±8.4)	5.0 (±8.5)	1.4 (±6.1)	1.9^{c} (±1.4)	1.4 (±1.1)
0° Flexion	−2.6 (±3.6)	−0.5 (±5.9)	5.0 (±6.9)	2.0 (±6.7)	1.9^{c} (±1.1)	1.2 (±0.8)
15° Extension	−16.1 (±2.7)	−9.5 (±7.9)	5.7 (±6.3)	2.5 (±6.2)	$2.3^{b,c}$ (±1.3)	1.4 (±0.8)
30° Extension	−27.9 (±3.9)	−26.8 (±7.7)	6.9 (±5.8)	3.5 (±5.3)	3.1^{b} (±1.9)	2.3 (±1.3)
45° Extension	−38.1 (±9.8)	−39.3 (±10.8)	6.1 (±6.8)	3.5 (±6.4)	4.0^{a} (±2.7)	3.3 (±2.6)
15° Radial	−20.5 (±11.2)	−20.0 (±11.7)	−9.6 (±3.6)	−13.2 (±4.3)	3.6^{α} (±2.6)	3.3 (±2.7)
0° Radial	−19.1 (±10.3)	−20.8 (±6.6)	0.3 (±4.4)	−1.6 (±4.3)	2.4^{β} (±01.4)	1.8 (±0.9)
15° Ulnar	−19.2 (±10.3)	−20.2 (±12.3)	11.9 (±4.7)	12.2 (±4.3)	2.7^{β} (±1.5)	2.2 (±1.2)
Conventional keyboard	−24.8 (±6.8)	−16.5 (±11.4)	8.1 (±6.0)	1.3 (±6.7)	2.8 (±1.8)	1.8 (±1.5)

Positive wrist angles are assigned to flexion and ulnar deviation while negative wrist angles are assigned to extension and radial deviation. Carpal tunnel pressures during typing with a common superscript letter (a, b, c for flexion/extension configurations, α and β for the radial/ulnar deviation configurations) were not significantly different from each other based on a Tukey follow-up test ($n = 20$).