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Fingertip Loading and Carpal Tunnel Pressure: Differences between a Pinching and a Pressing Task

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Summary: Carpal tunnel syndrome may be caused by repeated or sustained elevated carpal tunnel pressure. This study examined the relationship between carpal tunnel pressure, posture, and fingertip load. In 20 healthy individuals, carpal tunnel pressure was measured with a catheter inserted into the carpal tunnel of the dominant hand and connected to a pressure transducer. With the wrist in a pressure-neutral position, the subjects pressed on a force transducer with the index finger to levels of 0, 5, 10, and 15 N. They then pinched the transducer at the same levels of force. For both fingertip-loading postures, the carpal tunnel pressure increased with increasing fingertip load. Carpal tunnel pressures were significantly greater ($p < 0.015$) for the pinching task (14.2, 29.9, 41.9, and 49.7 mm Hg [1.89, 3.99, 5.59, and 6.63 kPa] for 0, 5, 10, and 15 N force levels, respectively) than for simple finger pressing (7.8, 14.1, 20.0, and 33.8 mm Hg [1.04, 1.88, 2.67, and 4.51 kPa]). This study indicates that although the external load on the finger remained constant between the two tasks, the internal loading, as measured by carpal tunnel pressure, experienced a near 2-fold increase by using a pinch grip. These findings should be given consideration in designing work tasks and tools because relatively low fingertip forces, especially in a pinch grip, elevate carpal tunnel pressures to levels that, if prolonged, may lead to the development or exacerbation of carpal tunnel syndrome.

Epidemiological studies (1,2,7,8,20) have linked forceful and repetitive hand tasks to carpal tunnel syndrome. Carpal tunnel pressure is strongly affected by forearm muscular (22,24), active grasp (9,14), and external forces applied to the fingers (18,19). Sustained elevations in carpal tunnel pressure may initiate a pathophysiological process that causes or aggravates carpal tunnel syndrome (6,17).

The effects of specific tendon loading on median nerve pressure in the carpal tunnel was investigated by Smith et al. (21). In a cadaver model, with use of a balloon transducer (which replaced the median nerve), the pressure was greatest when the wrist was flexed and the flexor tendons to the index and long fingers were loaded. These findings have been confirmed for cadavers by techniques for the measurement of both balloon-transducer and hydrostatic pressure (12). A previous investigation in our laboratory indicated that the response of carpal tunnel pressure was greater to fingertip loading than to wrist posture (18). To our knowledge, the effects of active gripping or pinching on carpal tunnel pressure have not been evaluated in a quantitative manner.

The purpose of this study was to determine the differences in carpal tunnel pressure between a simple fingertip press and an index finger-to-thumb fingertip pinch while controlling both posture and fingertip force.

METHODS

Twenty subjects with no signs, symptoms, or electrodiagnostic evidence of median neuropathy at the wrist participated in this study. There were 10 men and 10 women (mean age: 30 years; range: 22-45 years). Evaluations of muscle strength (thumb opposition, interossei, and grip), thenar atrophy, and sensation to touch in the hand and fingers were made, and testing for Phalen's and Tinel's signs was performed. A neurologist conducted an electrodiagnostic examination of the median nerve by recording from the thenar muscle, measuring antidromic sensory conduction between the wrist and index finger, and recording the orthodromic short-segment between the palm and wrist. If all tests were normal, the subject was included in the study. This study was approved by the Committee of Human Research, University of California at San Francisco, CA, U.S.A.

Carpal tunnel pressure was measured with use of a saline-filled, blunt-tipped, multi-perforated 20-gauge catheter (Burron Medical, Bethlehem, PA, U.S.A.) inserted percutaneously into the carpal tunnel of the dominant hand (right hand in 18 subjects) and connected to a pressure transducer, as previously described (16). On the basis of pilot studies with cadaveric hands and radiographs of the wrists of three subjects, the catheter tip was placed near the center of the carpal tunnel at the level of the hook of the hamate. The pressure transducer was maintained at the same elevation as

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TABLE 1. *Mean applied force in Newtons (±SE) measured by the transducer at each of the target force levels for the press and the pinch tasks*

Task	Target force level 0 N	5 N	10 N	15 N
Press	0.3 ± 0.29	4.7 ± 0.33	8.9 ± 0.64	14.3 ± 0.31
Pinch	0.1 ± 0.15	5.1 ± 0.09	9.9 ± 0.77	14.8 ± 0.21

There were no statistical differences between the two tasks. n = 20.

the carpal tunnel. To minimize the possibility of occlusion, a slight positive flow of physiologic saline at a rate of 0.5 ml/hr was maintained with use of a low-flow continuous flush device. An electronic force transducer (pinch meter; Greenleaf Medical Systems, Palo Alto, CA, U.S.A.) was used to measure fingertip force. Outputs from the pressure transducer and from the force transducer were digitally sampled at 40 Hz and stored on a computer. The protocol for calibration of the pressure transducer has been described previously (23). A linear calibration of the force transducer was performed before each experiment.

Initially, the forearm and wrist posture associated with the lowest carpal tunnel pressure was determined for each subject. The subsequent tasks started from this posture, which was approximately a neutral position of the wrist with 45° of pronation. The subjects then performed two tasks: pressing a force transducer with the index finger and pinching the transducer between the index finger and thumb. The index finger and wrist postures were kept constant between the two tasks. The metacarpophalangeal joint was maintained at approximately 45° for both the pressing and the pinching tasks. In the pressing task, the subject was instructed to press down on the force transducer with the tip of the index finger to 0, 5, 10, and 15 N levels of force without changing the position of the finger or the hand. During the pinch task, the force transducer was supported by the experimenter to ensure that the subject's exertions were to pinch the transducer and not to support it. The transducer was pinched between the pulps of the index finger and thumb. The thickness of the force transducer created a separation of 20.5 mm between the fingertips. Each load level was maintained for 5 seconds, and the subject relaxed (zero load) between exertion to each level. Visual feedback of the force level from the force transducer was provided to the subject. No other fingers were loaded, and no external objects were in contact with the hand or forearm other than the transducer and the support under the proximal forearm. The data were analyzed by a repeated-measures analysis of variance with specific *post hoc* analyses using the Tukey studentized range test ($p = 0.05$).

RESULTS

Mean pressure at the posture of lowest pressure (resting carpal tunnel pressure) was 5.5 ± 0.9 mm Hg (0.73 ± 0.12 kPa) (±SEM). When the postures of press and pinch (i.e., unloaded) were assumed, the pressure rose to 7.8 ± 1.4 mm Hg (1.04 ± 0.19 kPa) and 14.2 ± 2.2 mm Hg (1.89 ± 0.29 kPa), respectively.

Carpal tunnel pressure increased with fingertip load ($p = 0.0001$) (Fig. 1). The pressures for a pinch grip were about twice as great as those found for finger pressing (Fig. 1). The repeated-measures analysis of variance demonstrated that both force level and mode of loading (i.e., pinch or press) were statistically significant ($p = 0.0001$ and < 0.015, respectively). The interaction of force level and mode was not statistically significant ($p < 0.09$). Follow-up analysis determined that the pressures associated with the 15 N load were significantly greater than those with all other load levels, whereas the pressures at 5 and 10 N loads were significantly greater than those at zero load ($p < 0.05$) (Fig. 1). The actual forces measured by the transducer for the two postures were not statistically dif-

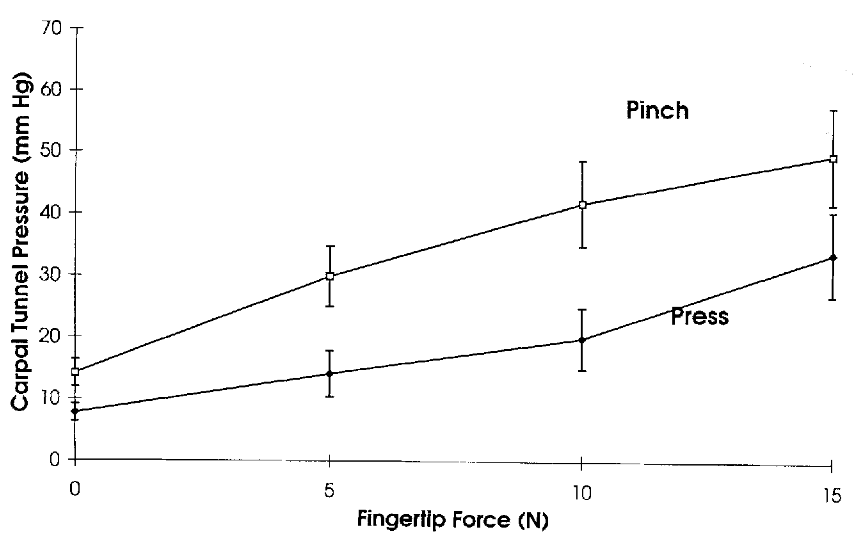

FIG. 1. Mean carpal tunnel pressures (±SE) at 0, 5, 10, and 15 N fingertip loads using a pinch grip (top curve) and a finger press (lower curve). Pressures measured during the pinch grip were approximately twice those measured during the finger press.

ferent and were close to the target forces (Table 1).

DISCUSSION

This is the first study to examine the effects of fingertip loading on carpal tunnel pressure during both pinching and pressing, to our knowledge. At each load level, the fluid pressures in the carpal tunnel were about twice as great during a pinch grip than during a finger press. In addition, relatively low fingertip loads (i.e., 5 N) increased pressure by 15 mm Hg (2 kPa) in a pinch grip. These findings provide a possible explanation for the epidemiological observation that repeated or sustained fingertip loads are associated with the aggravation or development of carpal tunnel syndrome (1,2,4,7,8, 15,20).

The carpal tunnel pressure associated with fingertip loading was previously investigated under different test conditions and with different subjects (18). The earlier study demonstrated that both fingertip load and deviation from a neutral posture of the wrist independently increased carpal tunnel pressure. The pressures associated with fingertip load in the earlier study were higher than the pressures observed in this study, despite the higher fingertip force applied in this study (15 compared with 12 N). The differences may be attributed to differences in forearm posture. In the earlier study, the forearm was fully pronated, whereas in this study the forearm was pronated to approximately 45°. Carpal tunnel pressure at 45° of pronation is lower than at full pronation (18,25). These factors may also explain the apparent linear relationship between pressure and force in this study, although the previous study found the data best described by a second-order polynomial. We have again shown that the level of force exerted at the fingertips has a significant effect on carpal tunnel pressure. Moreover, we have demonstrated that the additional use of the thumb in the pinch grip substantially increases the pressure in the carpal tunnel.

Thumb posture alone cannot account for the higher pressures found during pinching (3), even though it may explain the greater pressure for the pinch posture in the unloaded state. A pinch grip requires the thumb musculature to create the force to oppose that applied by the index finger; this force is not required for the pressing task. Thus, the overall work of the intrinsic muscles of the hand is greater for the pinch grip. Previous studies of cadaveric hands have shown that increased tension in the flexor pollicis longus muscle has little effect on hydrostatic or contact pressure in the carpal tunnel (12,21). Thus, the increase in pressure for the pinching task is likely due to the forces from the thenar muscles that originate from the transverse carpal ligament. The effects of the thenar muscle forces on carpal tunnel shape are to pull the transverse carpal ligament in the palmar, radial direction (11). Although this action would reduce the pressure within the carpal tunnel, the tensed thenar musculature could possibly press on the distal aspect of the flexor retinaculum and elevate pressure, as demonstrated by Cobb et al. (5).

The absolute magnitudes of carpal tunnel pressure in this study deserve discussion, as moderate pressures (30 or more mm Hg) were approached at low levels (5 N) of pinch force. A similar pressure was not attained with less than 15 N of force in the pressing trials. Thirty millimeters of mercury (4 kPa) corresponds to a level of pressure that, if maintained, can alter nerve physiology as seen in isolated animal nerves (10,13). Thus, the mode of exertion of the finger (isolated or with the thumb) must be examined in addition to the force level if the pressure is used as a criterion. This is another example of how similar external loads can lead to very different internal loads.

Contact pressures between the tendons, median nerve, and flexor retinaculum may also play a role in the aggravation or development of carpal tunnel syndrome. Smith and colleagues (21) demonstrated the large effect of these pressures when finger tendon loading was combined with wrist flexion. Keir et al. (12) concluded that the bulb technique (21) was more representative of contact pressure than of true hydrostatic pressure as measured by a multi-perforated catheter (as in the present study) and thus might be indicative of a different mechanism. This discussion is limited to the effects due to hydrostatic pressure as measured by the catheter within the carpal tunnel.

The intent of this study was to maintain finger posture and force levels between the pinch and press tasks. A review of the videotapes of these tasks showed that some subjects slightly altered the posture and nature of fingertip loading (finger pulp compared with fingertip) between tasks. However, the direction of the posture changes were not consistent between subjects and contribute only to increasing the variance in the data.

On the basis of carpal tunnel pressure, pinching presents a greater probability of venous occlusion in the carpal tunnel than does finger pressing. Relatively low levels of fingertip force elevate pressures in the carpal tunnel. These findings have implications for the design of work tasks and tools. Tasks requiring prolonged pinching should be designed to minimize pinch force and should include frequent pauses to prevent sustained, elevated pressures in the carpal tunnel. Further research regarding carpal tunnel pressures during grasping and other daily activities is suggested, as tasks previously deemed innocuous may attain pressure levels of concern.

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