The Effect of Wearing a Flexible Wrist Splint on Carpal Tunnel Pressure During Repetitive Hand Activity

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We investigated how repetitive hand activity normally affects carpal tunnel pressure and whether a flexible wrist splint can influence this effect. Nineteen healthy subjects were evaluated under four test conditions: at rest with and without a wrist splint (baseline) and while performing a repetitive task with and without a wrist splint. The task involved loading and unloading 1 lb. cans from a box at a rate of 20 cans per minute for period of 5 minutes. Carpal tunnel pressure and wrist angles were continuously monitored by means of a fluid-filled catheter inserted into the carpal canal and a two-channel electrogoniometer mounted on the dorsum of the hand and forearm. Without the splint, carpal tunnel pressure rose from a median baseline level of 8 ± 6 mmHg to 18 ± 13 mmHg during activity. With the splint, carpal tunnel pressure rose from a baseline of 13 ± 5 mmHg to 21 ± 12 mmHg during activity. Median carpal tunnel pressure during activity with the splint was no different from that without the splint. Our data indicate that the median nerve is subjected to increased pressure within the carpal tunnel during repetitive hand activity. Wearing a flexible wrist splint during activity limits the range of wrist motion but has no significant effect on carpal tunnel pressure. (J Hand Surg 1994;19A:106–110.)

Previous investigations have shown that patients with carpal tunnel syndrome have elevated carpal tunnel pressure (CTP).[1–6] Their CTP is higher than normal in the wrist-neutral position.[1,3,4,6] and increases further when the wrist is placed in flexion or extension.[1,2,4,5] It also increases more in response to repetitive passive motion[5] and returns to resting level more slowly after motion ceases.[5] Active motion of the wrist and fingers has a profound effect in patients with carpal tunnel syndrome, increasing CTP even more than passive motion.[2] These studies suggest that CTP may play an important role in the pathophysiology of this nerve compression syndrome.

Occupational tasks that require repetitive hand, finger, and wrist movements are suspected of contributing to median nerve entrapment, and patients are often prescribed a flexible wrist splint to relieve their symptoms. Recently, flexible wrist splints have also been marketed as personal protective equipment for preventing carpal tunnel syndrome in persons who work in high-risk occupations. It is not yet known, though, how repetitive hand motion normally affects CTP and whether a wrist splint can

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influence this effect. The present study was designed to answer these questions and thereby further explain the pathophysiology of carpal tunnel syndrome. We monitored CTP and wrist angles in healthy subjects as they performed a material-handling task, first without and then with a wrist splint.

Materials and Methods

Nineteen volunteers who demonstrated no evidence of carpal tunnel syndrome were selected for study participation. The 9 women and 10 men of this group ranged in age from 23 to 37 years. Each subject completed a standard questionnaire, an interview and clinical examination by a neurologist, and a nerve conduction test to screen for the signs and symptoms of carpal tunnel syndrome and other disorders that could cause a peripheral neuropathy (e.g., diabetes, thyroid disease).

CTP was measured by means of a saline-filled catheter inserted percutaneously into the carpal tunnel, attached at its proximal end to an in-line pressure transducer (model 041-576-504; Cobe, Lakewood, CO). Output from the transducer was amplified and displayed by a monitoring unit (ProPac 104; Protocol Systems, Beaverton, OR). The catheter was a blunt-tipped 20-gauge epidural (Burron Medical, Bethlehem, PA) with three side holes near the distal tip. To minimize the possibility of occlusion, a slight positive flow of physiologic saline was maintained using a low-flow continuous flush device (model 42002-02; Sorenson Intraflow II; Abbott Laboratories, Abbott Park, IL). Ulnar/radial deviation and flexion/extension of the wrist were monitored using a two-channel electrogoniometer (model M110; Penny and Giles, Santa Monica, CA) secured to the dorsal surface of the hand and forearm. Goniometric output was amplified by a Penny and Giles K-100 base unit. Data acquisition was controlled by computer.

A Perifix continuous epidural anesthesia tray (model CE-18TK; Burron Medical) was used in the insertion of the catheter. After anesthetizing the site with xylocaine, an 18-gauge Tuohy-Schliff epidural needle, bevel up and pointed distally, was inserted at a 45° angle about 5 mm proximal to the distal anterior wrist crease, immediately radial to the palmaris longus. After locating the carpal tunnel, the stylet was withdrawn, and the catheter, previously filled with saline, was threaded through the needle hub and into the carpal tunnel. The needle was carefully withdrawn over the entire length of the catheter and discarded. A suture secured to the skin at the site of insertion was then tied to the catheter to hold it in place. The catheter was attached to the transducer using a Luer adapter, and the transducer and catheter were taped to the subject's forearm. All connections were secured in a way that allowed maximum freedom of motion.

After system calibration, each subject was instructed to find the position of lowest CTP while keeping the wrist level with the pressure transducer to ensure accuracy of reading. This baseline measurement was taken before and after performing a repetitive task, which consisted of loading and unloading a box containing 1 lb. cans at a rate of 20 cans per minute for a period of 5 minutes. The activity was performed without and then with a flexible wrist splint (cloth-covered rubber with stiffeners and two Velcro closures).

The data were analyzed using the Wilcoxon signed rank test.

Results

Without the splint, CTP rose from a mean baseline level of 8 ± 6 mmHg to 18 ± 13 mmHg during task performance ($p = .0003$). Application of the splint significantly increased the baseline CTP in every subject ($p = .0001$). With the splint, the mean pressure rose significantly during task performance, from 13 ± 5 mmHg to 21 ± 12 mmHg ($p = .0003$) (Table 1, Fig. 1).

During activity, the effect of the splint on CTP was quite variable among the subjects; median CTP was higher in 11 subjects and lower in 8 subjects compared with median CTP without the splint, but the two were not significantly different ($p = 0.6$).

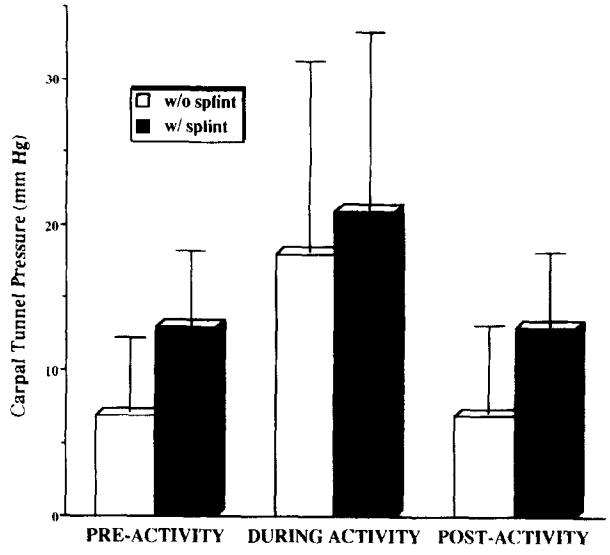

Figure 1. Mean carpal tunnel pressure in 19 healthy subjects before, during, and after 5 minutes of repetitive hand activity performed without and then with a flexible wrist splint. Standard deviations are indicated by bars.

Table 1. Carpal Tunnel Pressure (mmHg) Data for Subjects Performing a Repetitive Material Handling Task With and Without a Wrist Splint

		Preactivity Baseline		*During Activity*			*Postactivity Baseline*			
Case	*Sex*	*w/o Splint*	*w/ Splint*	*w/o Splint*	*w/ Splint*	*ΔCTP†*	*w/o Splint*	*w/ Splint*	*First Minute of Activity**	*Last Minute of Activity**
1	F	17	24	27	23	−4	16	16	30	25
2	M	8	11	9	22	13	3	9	11	11
3	M	4	14	8	19	11	3	14	9	10
4	F	6	9	9	8	−1	NA	8	10	10
5	M	NA	8	9	8	−1	3	5	9	6
6	F	13	NA	48	45	−3	13	16	48	47
7	F	8	12	17	15	−2	6	NA	22	17
8	M	4	5	5	6	1	2	4	7	5
9	M	15	13	24	19	−5	9	15	20	33
10	M	8	13	24	36	12	NA	18	25	24
11	F	14	15	29	25	−4	12	16	24	34
12	F	12	25	32	37	5	10	20	37	32
13	M	0	15	0	8	8	4	16	2	2
14	F	5	12	9	16	7	5	14	8	11
15	F	0	13	9	17	8	0	9	9	11
16	M	1	4	0	3	3	0	5	1	1
17	M	12	19	27	38	11	15	19	26	16
18	F	5	15	27	32	5	5	16	25	29
19	M	18	19	20	17	−3	17	14	19	21
Mean		8	13	18	21	3	7	13	18	18
SD		6	5	13	12	6	6	5	12	13

* Without the wrist splint.
† Change in CTP during activity with the splint compared to without the splint (direction may be negative). NA, data not available.

CTP fluctuated during task performance (Fig. 2), but the median pressure remained fairly constant. The overall median during the first minute of activity was the same as during the last minute (18 mmHg). After task completion, CTP returned to its preactivity level almost immediately; mean recovery time was 14 ± 15 seconds without the splint and 14 ± 11 seconds with the splint.

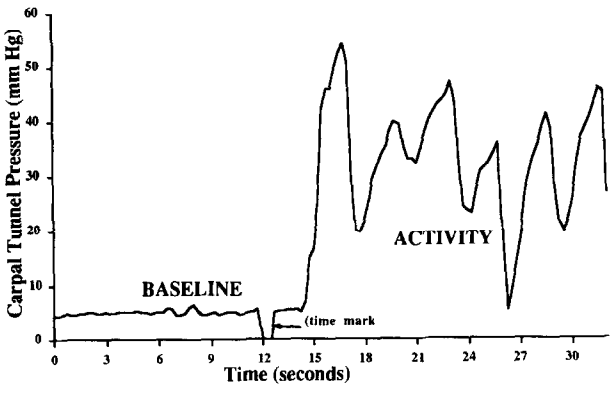

Figure 2. The time course of carpal tunnel pressure in case 18 illustrates the fluctuations during task performance.

The splint did not substantially change the average wrist position (4° ± 6° extension and 4° ± 4° ulnar deviation with the splint, compared with 3° ± 13° extension and 7° ± 8° ulnar deviation without the splint) but it did significantly limit wrist motion ($p = .0001$) (Fig. 3).

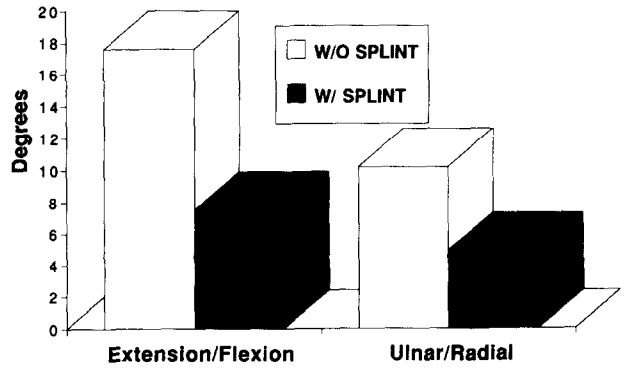

Figure 3. Interquartile ranges of wrist angles in 19 healthy subjects during 5 minutes of repetitive hand activity performed without and then with a flexible wrist splint. There is a significant ($p = .0001$) decrease associated with wearing the splint, indicating a reduction in wrist motion.

Table 2. Resting Carpal Tunnel Pressure in Healthy Subjects: Previous Research

Study	*n*	*Mean Carpal Tunnel Pressure (mmHg)*	*Test Conditions*
Gelberman et al.[1]	12	3	Wrist-neutral position
Gellman et al.[6]	10	8	Paraplegic patients; wrist-neutral position
Luchetti et al.[3]	4	13	Arm in 90° of abduction and supination
Szabo and Gelberman[5]	6	5	Wrist-neutral position
Rojviroj et al.[4]	32	3	Wrist-neutral position
Graham et al.[7]	13	12	—

Discussion

The present data indicate that the median nerve is exposed to elevated fluid pressure within the carpal tunnel during repetitive hand motion. Application of a flexible wrist splint elevates resting CTP, probably because of direct external pressure on the carpal canal, but the splint does not reduce CTP during repetitive activity even though it decreases the range of wrist motion. The possible benefits of a splint on the muscles and tendons of the region remain to be investigated, as does the question of whether CTP is constant during repetitive activity longer than 5 minutes.

The mean baseline CTP agrees with previously reported values (Table 2), and the rapid recovery to baseline after task completion is consistent with the results of other studies on normal subjects.[5,7] Szabo and Chidgey[5] reported immediate postexercise CTP levels that were not significantly higher than baseline, and Graham et al.[7] found that postexercise levels of CTP decreased immediately in 8 of 13 normal limbs.

The pressure increase to which the median nerve is exposed during activity, although of a low level,[7] may be great enough to reduce the flow of blood in the epineurial venules.[8] Theoretically, prolonged disturbances of venule microcirculation could produce retrograde effects on the capillary circulation, resulting in anoxic injury to endothelial cells, subsequent increase in vascular permeability, and endoneurial edema.[9,10] Because there are no lymphatics within the median nerve through which this fluid can drain, endoneurial edema may ultimately affect fiber function.[11]

The pathophysiology of carpal tunnel syndrome is probably related to the duration as well as the magnitude of the pressure increase within the carpal tunnel. During activity, CTP fluctuates. The median nerve is exposed to a higher pressure on the average, but there are intervals during which the pressure is below the average. We assume that blood flow in the epineurial vessels depends directly on the level and duration of the low CTP intervals. Presumably, if there are long enough intervals during which the pressure is below 30 mmHg, the flow of blood will be sufficient to prevent vascular leakage. Thus, edema of the epineurium and other tissues may be avoided even though the average CTP is elevated. Any factors (e.g., anatomic) that prevent the rapid decrease of CTP whenever the wrist is relaxed and near neutral will shorten the intervals of low pressure. Consequently, there will be prolonged disturbances of microcirculation that can lead to epineurial edema. Tasks that require the wrist to be in an extreme position for long periods of time maintain CTP at a high level and will produce this effect.

Our laboratory-based study has shown that CTP is elevated during repetitive hand activity and that this pressure elevation is not affected by wearing a flexible wrist splint. Thus, if there is any benefit to using a splint, it most likely relates to other aspects of hand physiology.

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