NEUROMUSCULAR AND PSYCHOLOGICAL CHARACTERISTICS IN SUBJECTS WITH WORK-RELATED FOREARM PAIN[1]

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ABSTRACT **Weigert BJ, Rodriquez AA, Radwin RG, Sherman J: Neuromuscular and psychological characteristics in subjects with work-related forearm pain.** ***Am J Phys Med Rehabil*** **1999;78:545–551**

There are scant data available on the neuromuscular and psychological characteristics of patients with cumulative trauma disorders. We compared 16 subjects with work-related forearm and hand pain in the dominant upper limb with 9 age-matched control subjects. Pain subjects were divided into two groups based on nerve conduction studies: eight subjects were in the study group for median neuropathy at the wrist (MN, median transcarpal latency >2.3 ms), and eight were in the study group for electrodiagnostically negative pain (EN). Average pain, forearm muscle tenderness, grip strength, pinch strength, and wrist flexor and extensor strength were measured. The Health Status Questionnaire and the Beck Depression Inventory were used to measure health perception and depressive symptoms, respectively. Work satisfaction was determined by a newly devised scale. Statistical analysis was by analysis of variance and planned comparison analysis. The MN and EN groups did not significantly differ on any of the measures except median transcarpal latency. Both pain groups had significantly ($P < 0.05$) greater average pain, greater extensor muscle tenderness, higher Beck Depression Inventory scores, higher pain rating, and poorer physical functioning on the Health Status Questionnaire than did the normal control group. Grip strength and wrist extension force were diminished in both cumulative trauma groups compared with control subjects; however, only grip strength in the MN group and wrist extension force in the EN group differed significantly ($P < 0.05$) from control subjects. Only the EN group had significantly less work satisfaction than did the control group. Overall, both pain groups differed from control subjects and shared similar characteristics, with the exception of median neuropathy.

KEY WORDS: Carpal Tunnel Syndrome, Forelimb, Upper Limb, Repetition Strain Injury, Cumulative Trauma Disorders, Overuse Syndromes, Myofascial Pain Syndromes

Objectives: Upon completion of this article, the reader should be able to (1) discuss some of the limitations of the available literature in characterizing patients with work-related forearm pain; (2) identify physical and psychological characteristics of patients with work-related forearm pain which distinguish patients from control subjects; (3) recognize the importance of evaluating and treating patients with median neuropathy at the wrist for soft tissue disorders including myofascial pain, which may occur simultaneously. **Level:** Comprehensive

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Cumulative trauma disorders are becoming an increasingly common diagnosis, accounting for >50% of all occupational illnesses reported in the United States.[1] Numerous occupational risk factors for work-related pain syndromes have been reported in the literature, including high force, high repetition, awkward or sustained postures and positions, vibration, cold, and localized contact stresses.[1] For the upper limb, a variety of diagnoses have been cited as being attributable to cumulative trauma, including nerve entrapment syndromes such as carpal tunnel syndrome (CTS), musculoskeletal disorders such as tendinitis and epicondylitis, and a nonspecific disorder characterized by diffuse or

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focal pain, paresthesias, and forearm muscle tenderness that does not fit the diagnostic criteria for entrapment neuropathy, tendinitis, or epicondylitis.[2–4] Many patients with forearm pain and muscle tenderness do not have tenderness over the lateral or medial epicondyles, and often do not have pain with either passive stretch of the involved musculotendinous unit or resisted motion of the same musculotendinous unit.[5] Some authors apparently have included this group of patients in the category of epicondylitis because of tenderness in the forearm extensor muscle group distal to the lateral epicondyle.[6]

The epidemiological data are clouded by the lack of clear definition of forearm pain disorders. In early studies, patients with hand, wrist, or forearm symptoms were assumed to have CTS, despite the lack of electrodiagnostic confirmation. Kirschberg and colleagues found that of 112 charts of patients with similar, work-related complaints that were reviewed, only 17% met the clinical and electrodiagnostic criteria for CTS.[7]

A lack of information regarding the relationship of subjective complaints to objective diagnostic data makes clinical diagnosis difficult. Furthermore, the lack of objective findings in patients with cumulative trauma disorders has caused speculation about the contribution of psychologic factors.[8] Age has not been shown to be a significant factor for signs or symptoms or diagnosis of upper limb disorders.[8, 9] Women have been shown to be at increased risk compared with men for upper limb disorders and worker's compensation claims for repetitive strain injuries.[9, 10] There is limited evidence of decreased strength in patients with a diagnosis of repetitive strain injury.[11] Viikari-Juntura et al.[12] studied psychomotor capacity in asymptomatic patients who had one or more episodes of work-related tenosynovitis and found no differences from age-matched controls.

The purpose of our study was to characterize the physical and psychological parameters of subjects with work-related forearm pain and to determine which features distinguish them from a normal population. We also explored whether our measures would distinguish between pain subjects with and without median neuropathy at the wrist (MN). Specifically, we examined these subjects for differences in work status, job satisfaction, location and severity of pain, focal muscle tenderness, strength, and signs of depression or psychological distress.

METHODS

Subjects

Subjects were recruited from among clinic patients in the rehabilitation clinics at the University of Wisconsin, and through an advertisement placed in the newsletter of a nearby long-term care facility. All subjects were volunteers who were not compensated for their participation. To be included in the study, subjects had to have arm or hand pain including, but not limited to, pain below the elbow. The subjects themselves had to attribute their symptoms to work activity. Subjects were excluded who had pain related to acute trauma, rheumatologic disease, malignancy, diabetes, known polyneuropathy, focal neuropathy other than MN, or neuromuscular disease. All subjects with pain were then divided into two groups—the MN group and the electrodiagnostically negative pain (EN) group—based on median nerve transcarpal latency ≥2.3 ms for a distance of 8 cm, measured from the proximal palmar crease between the second and third metacarpal heads across the transcarpal ligament. Although latency of median transcarpal potential was selected as a highly sensitive test for abnormal median conduction across the wrist, amplitude was also recorded. All subjects with normal transcarpal latencies also had normal amplitudes, and all those in the MN group had amplitudes of <50 μV, which is also considered abnormal. There were eight subjects (mean age, 37 yr) in the EN group and eight subjects (mean age, 50 yr) in the MN group. Nine control subjects (mean age, 44 yr) were recruited from hospital staff and were matched for age and gender. Controls had no arm pain below the elbow. Control subjects were not occupationally matched but were involved in similar work activities as the pain subjects, i.e. computer keyboarding or patient care. All subjects were also asked if they participated in any sporting activities or hobbies, and if they played a musical instrument for at least 3 hr/wk. In the MN group, one subject did needlework; in the EN group, one subject crocheted and one played keyboards; and in the control group, one subject sewed and spent time on the computer. The remainder of the subjects answered "no" to this question, with the exception of some control subjects who did aerobic activity.

The demographic data are presented in Table 1. The subjects were predominantly females, which is

TABLE 1
Demographic data

	EN (n = 8)	MN (n = 8)	Controls (n = 9)
Males	2	1	2
Females	6	7	7
Education less than high school	0	2	0
High school graduate	3	3	2
Some college/Associate Degree	4	2	2
College graduate or higher	1	1	5
Consumes >5 alcoholic drinks/wk	1	0	1
Smokes one or more packs per day	1	3	2

EN, electrodiagnostically negative pain; MN, median neuropathy at the wrist.

comparable to our clinic population with these disorders. There was a slightly higher educational level among the control group. The majority of subjects did not smoke or drink more than an average of one alcoholic beverage per day.

Procedures

Subjects were asked to complete a questionnaire that included demographic and occupational information, as well as specific information about their pain, including a visual analog scale (ranging from none to unbearable) and pain diagram, a Beck Depression Inventory, and a Health Status Questionnaire.[13,14] An additional 12-item list of questions, which is related to job satisfaction and was developed for this project, was included (Fig. 1). Negative questions (numbers 3, 7, 11, and 12) were scored in reverse to tabulate a single score for this measure, with a higher score indicating less satisfaction.

A physical examination of the upper limbs was performed to evaluate for neurologic deficit and specific clinical entities such as tendinitis. This examination included range of motion of the neck and upper limbs, reflexes, manual muscle testing, palpation, and Tinel's, Phalen's, and Finkelstein's tests.[15] Tendinitis was defined by a triad of tenderness to palpation of the involved tendon, pain with passive stretch, and pain with resisted contraction of the affected musculotendinous unit.

Focal muscle tenderness was rated on a scale developed for this study. The flexor and extensor

1. My co-workers are very supportive of me.

1	2	3	4	5
Totally	Pretty Much	Yes and No	Somewhat	Not at all

2. I get along well with my supervisor.

1	2	3	4	5
Totally	Pretty Much	Yes and No	Somewhat	Not at all

3. I find my work very repetitious.

1	2	3	4	5
Totally	Pretty Much	Yes and No	Somewhat	Not at all

4. My supervisor follows my doctor's recommended work restrictions.

1	2	3	4	5
Totally	Pretty Much	Yes and No	Somewhat	Not at all

5. I like my work.

1	2	3	4	5
Totally	Pretty Much	Yes and No	Somewhat	Not at all

6. I like my work environment.

1	2	3	4	5
Totally	Pretty Much	Yes and No	Somewhat	Not at all

7. My work is boring.

1	2	3	4	5
Totally	Pretty Much	Yes and No	Somewhat	Not at all

8. My work is interesting.

1	2	3	4	5
Totally	Pretty Much	Yes and No	Somewhat	Not at all

9. I am paid adequately for the work I do.

1	2	3	4	5
Totally	Pretty Much	Yes and No	Somewhat	Not at all

10. I have reasonable control over my work rate.

1	2	3	4	5
Totally	Pretty Much	Yes and No	Somewhat	Not at all

11. I view myself as disabled.

1	2	3	4	5
Totally	Pretty Much	Yes and No	Somewhat	Not at all

12. I am unable to work.

1	2	3	4	5
Totally	Pretty Much	Yes and No	Somewhat	Not at all

Figure 1. Job satisfaction questionnaire.

muscle groups were systematically palpated, and each tender area was given a rating from 1 to 3 by the clinician (BW), with 1 representing minimal tenderness, and 3 being marked tenderness. A tenderness score for the forearm flexor and extensor muscle groups was obtained by adding the scores for the various tender points in that muscle group.

Nerve conduction studies were performed on all subjects following the physical examination. Temperature was maintained at >31°C. Radial sensory latency (distance, 10 cm) and amplitude, ulnar motor conduction velocity (distal distance, 6 cm) and amplitude (including comparisons of conduction from the wrist to above and below the elbow), and median and ulnar transcarpal latencies (distance, 8 cm) and amplitudes were recorded. All studies were performed bilaterally. The particular studies were selected to screen for common entrapments and polyneuropathy and to be sensitive for detecting MN without unnecessarily increasing the chance of false positive results. The median transcarpal latency was then used as the distinguishing criterion in establishing the two pain groups, MN and EN.

Grip strength was determined by averaging the results of three trials with a Jamar dynamometer (Jamar, Bolingbrook, IL) set at a middle position. Key pinch strength was also measured by averaging the results of three trials with a dynamometer.

Wrist flexion strength was tested with the subject's forearm resting on a padded table surface with the hand off the surface. A dynamometer (Hoggan Health Industries, Inc., Draper, UT) was positioned over the third metacarpal head with the proximal edge at the distal palmar crease. The subjects then had to maintain neutral position with downward pressure on the dynamometer. Wrist extension strength was tested in a similar manner, in which the subject rested the pronated forearm on a padded table surface and extended at the wrist. The dynamometer was positioned over the dorsum of the third metacarpal head with proximal edge just proximal to the metacarpal head. The subject was then asked to maintain the hand in the extended position against the force applied to the dynamometer. The reliability of these methods for a single examiner was determined by a preliminary study in which 10 subjects were measured with two trials on each of two occasions, 1 wk apart. The average of the two trials from each time was calculated. Pearson product moment correlation coefficients were computed; they were 0.92 for wrist extension and 0.88 for wrist flexion, indicating that the measures were reliable.

Data Analysis

For the physical examination, data for pain location, focal muscle tenderness, and strength measurements were analyzed for the dominant symptomatic hand only. Statistical analyses used the following strategy. First, analysis of variance (ANOVA) was used to compare all group mean differences for each dependent variable. Second, subsequent planned, or a priori, comparisons were conducted for those dependent variables for which the ANOVA yielded statistical significance (<0.05); planned comparisons tested for mean differences between the two groups and between each pain group and the normal control group. The error term of each planned comparison was derived from the overall ANOVA error term of each dependent variable.[16] This statistical approach ensured that, for each dependent variable, type I error remained at $P < 0.05$ and that, because this was an exploratory study, type II error was minimized by using the most powerful comparisons between means.[16] Lastly, because of concerns that our data set consisted of a modestly small sample and that power of detecting a difference might be maximized with a nonparametric statistical approach, parallel nonparametric analyses were also conducted (the Kruskal-Wallis test, the one-way ANOVA by ranks, and the Mann-Whitney *U* test); the pattern of statistically significant results with parametric and nonparametric procedures was the same.[17] We report the results of the more familiar parametric analyses.

RESULTS

Occupational data revealed no statistically significant difference in the number of days of work missed among the three groups. Only two subjects in the EN group and three in the MN group had reduced their hours or were off work completely, and only one subject in the EN group and two in the MN group had been given work restrictions by a physician. Two subjects in the EN group and four in the MN group were receiving or had applied for worker's compensation. None of the subjects were involved in litigation or had consulted an attorney.

Mean job satisfaction using the sum of the 12 questions listed in Figure 1 was 33.25 ± 8.3 for the EN group, 26.63 ± 8.2 for the MN group, and 23.67 ± 5.7 for the control group. This was a significant difference by ANOVA ($P < 0.05$). Planned comparison showed there was no significant difference between the two pain groups. However, compared with the control group, job satisfaction was less for the EN group but not for the MN group.

Subjects were asked to rate their average pain on a scale of 0 to 10. Average pain was 4.4 ± 1.3 for the EN group, 4.4 ± 1.8 for the MN group, and 1.7 ± 1.8 for the control group. There were significant differences between the control group and the two pain groups, but not between the two pain groups. Not surprisingly, both pain groups had significantly greater average pain levels than did the control group.

Subjects were then asked to give the location of their most severe pain. Several subjects listed more than one area, and pain was generally distributed throughout the upper limb for both pain groups (Table 2). It was not possible to distinguish which pain group a subject belonged to based on his or her pain diagram. Some subjects in the EN group had pain diagrams that would be in the expected distribution for MN, and many in the MN group had pain outside of the expected distribution in the hand.

The physical examination findings are listed in Table 3. No subject fit the specific criteria for tendinitis or another specific clinical entity. No subject demonstrated weakness on manual muscle testing.

Focal muscle tenderness scores were significantly different by ANOVA for both the extensor and flexor muscle groups of the dominant hand (Table 4). Planned comparison revealed that the wrist extensor group for both pain groups and the wrist flexor group for the EN group had greater tenderness than did the control group, but the pain groups did not differ from each other.

There were no significant differences in strength (Table 5); however, because of the importance of strength in the treatment of these patients and the trend toward significance for several parameters, exploratory planned comparisons were performed. There were, again, no differences between the two pain groups. For the MN group, only grip strength was significantly less than for the control group. In the EN group, only wrist extension strength reached statistical significance, which was also less than the control group.

On the Beck Depression Inventory, mean score was 10.9 ± 6.4 for the EN group, 9.1 ± 7.9 for the MN group, and 2.6 ± 2.4 for the control group. There was no significant difference between pain groups, but both MN and EN groups had scores that were significantly greater than the control group, and that fall into the mild depression range for this test.

On the HSQ, health perception, social functioning, mental health, and energy/fatigue scales did not significantly differ among the groups. Differences were found in physical function, role limitation-physical, role limitation-emotional, and bodily pain, with all being significantly greater than the control group on planned comparison except the role limitation-emotional scale for the MN group (Table 6).

TABLE 2
Subject selection of primary pain location(s)

	EN	MN	Controls
Pain, bilateral	5	4	0
Neck	1	0	3
Hand	2	2	0
Wrist	3	3	0
Forearm, front	1	3	0
Forearm, back	1	1	0
Upper arm	0	0	0
Shoulder	0	0	1
Elbow	3	0	0

Only one CTS subject had pain isolated to the hand.
EN, electrodiagnostically negative pain; MN, median neuropathy at the wrist.

TABLE 3
Number of subjects with physical examination findings

	EN (n = 8)	MN (n = 8)	Controls (n = 9)
Tenderness at medial epicondyle	5	0	0
Of those, pain with passive stretch of flexors or resisted flexion	2	0	0
Tenderness at lateral epicondyle	7	4	0
Of those, pain with passive stretch of extensors or resisted extension	1	2	0
Positive Phalen's at the wrist	3	4	0
Positive Tinel's at the wrist	1	2	0
Positive Tinel's at the elbow	2	3	0
Positive Finkelstein's	1	0	1
Weakness on manual muscle testing	0	0	0

EN, electrodiagnostically negative pain; MN, median neuropathy at the wrist.

DISCUSSION

Both pain groups differed from the control group, but not from each other, with respect to pain level, focal muscle tenderness, depression, and several parameters of the HSQ. No characteristics, including pain distribution, physical examination findings, or strength were found to differentiate the two pain groups. The lack of distinguishing symptoms and findings may indicate that the EN and MN groups have the same syndrome apart from the median neuropathy. Thus, both groups of pain subjects may have a focal muscle pain syndrome. This may be mistaken clinically for CTS but may be a separate entity that occurs frequently in conjunction with CTS. Given the presence of focal muscle tenderness, absence of findings suggesting tendinitis, and normal conduction studies across entrapment sites, we speculate that the symptoms may result from myofascial trigger points.[3]

Our satisfaction questionnaire demonstrated a difference between the EN group and the control group, but not between the MN group and the control group. Poor job satisfaction is a well known independent risk factor for poor outcome in work-

TABLE 4
Focal muscle tenderness

	EN	MN	Controls	ANOVA
Mean focal tenderness-extensors	8.5 (±5.0)[a]	6.4 (±4.8)[a]	0.78 (±2.0)	$P = 0.002$
Mean focal tenderness-flexors	5.3 (±6.5)[a]	3.0 (±3.0)	0.00	$P = 0.04$

Statistical significance = $P < 0.05$.
The pain groups did not differ from each other on planned comparison.
[a] Significantly less than controls on planned comparison.
EN, electrodiagnostically negative pain; MN, median neuropathy at the wrist; ANOVA, analysis of variance.

TABLE 5
Strength data

	EN	MN	Controls	ANOVA
Mean grip strength	297.0 (±101.2)	278.5 (±107.7)[a]	408.9 (±124.7)	$P = 0.05$
Mean pinch strength	76.4 (±10.3)	84.5 (±22.5)	85.9 (±14.0)	$P = 0.45$
Mean wrist flexor strength	127.6 (±32.8)	126.8 (±27.2)	143.7 (±38.3)	$P = 0.50$
Mean wrist extensor strength	132.8 (±52.6)[a]	156.8 (±3.15)	182.1 (±45.5)	$P = 0.09$

All strength measures are reported in Newtons.
Statistical significance = $P < 0.05$.
The pain groups did not differ from each other on planned comparison.
[a] Significantly less than controls on planned comparison only.
EN, electrodiagnostically negative pain; MN, median neuropathy at the wrist; ANOVA, analysis of variance.

TABLE 6
Health status questionnaire mean scores (SD)

Scale	EN ($n = 8$)	MN ($n = 8$)	Control ($n = 9$)
Health perception	78.4 (11.5)	64.0 (29.8)	87.4 (14.4)
Physical function	97.2 (5.7)[a]	83.1 (9.2)[a]	74.4 (17.4)
Role limitation, physical	40.6 (39.9)[a]	65.6 (37.6)[a]	100 (0)
Role limitation, emotional	58.4 (42.8)[a]	70.9 (37.6)	100 (0)
Social functioning	86.1 (19.3)	78.3 (23.8)	94.6 (12.5)
Mental health	64.5 (20.2)	73.5 (15.4)	78.2 (13.9)
Bodily pain	55.0 (18.1)[a]	61.9 (17.0)[a]	85.1 (13.0)
Energy/fatigue	48.1 (21.2)	47.5 (22.0)	62.8 (15.4)

Statistical significance = $P < 0.05$.
The pain groups did not differ from each other on planned comparison.
[a] Significantly less than controls on planned comparison only.
EN, electrodiagnostically negative pain; MN, median neuropathy at the wrist.

related back pain. Our finding may indicate that poor job satisfaction may be a risk factor for poor outcome or ongoing symptoms in these patients as well. However, both pain groups had higher scores on the Beck Depression Inventory than did the control group, which supports the widely acknowledged association between pain and depression—although without prospective data, no conclusion can be reached about cause and effect. The absence of distinguishing psychological factors between the two pain groups provides no support for the theory that the EN group has a primarily psychological disorder.[18] Although possible, it is unlikely that our EN subjects might have a median neuropathy not identified by the transcarpal latencies. The use of transcarpal latencies is a highly sensitive test for determining the presence of segmental demyelinization in the median nerve at the carpal tunnel; thus, for the purpose of this study, transcarpal latencies represent the best measure of median neuropathy at the wrist.[19] Further conduction tests to identify mild CTS would most likely increase the percentage of false positive tests.[20]

This exploratory study has several potential clinical applications. Although no significant weakness was found among pain subjects, our pain subjects tended to be weaker than controls. Our subjects also would be expected to be stronger than a population who do not use their arms 8 hr/day for work. In fact, the real issue may be that they are weak relative to the demands of their jobs. It is also possible that, since all of our subjects were working, our study was biased to include subjects with relatively mild involvement and subsequently less marked weakness. Additional subjects would also likely increase the power of the study in determining weakness. In fact, for the two strength measures closest to statistical significance in Table 5, grip strength and wrist extensor strength, we conducted power analyses according to the recommendations of Neter et al.[21] To yield power equal to 0.80, a level proposed for general use with $\alpha = 0.05$, our sample size would have to be approximately 56.[22] Thus, because of the smaller sample size used here, our study lacked the power to detect differences among our groups. The likelihood that increasing the sample size would yield statistical differences in strength encourages strengthening as a continued focus of rehabilitation of patients with upper limb cumulative trauma disorder. However, prospective studies of workers will be needed to determine whether weakness relative to appropriate controls in the presence of repetitive forearm activities is predictive of the kind of forearm pain syndrome we observed in our subjects. With our present level of understanding, it seems prudent that strengthening should remain a focus of the rehabilitation of these patients.

With respect to the patients with MN, the relationship to forearm pain syndrome may be similar to that proposed for the mechanism of low ambient temperature and the use of gloves as risk factors for CTS.[2] The decrease in sensation caused by these two entities has been postulated to contribute to muscle overwork because subjects will increase the amount of hand force they use to give themselves an increased margin of error in completing a task. Possibly, the sensory loss associated with median neuropathy could also then contribute to the use of greater force, or altered muscle usage patterns, which, in turn, may be associated with the development of this myofascial pain-like forearm pain syndrome.[23] A deeper understanding of the pathophysiology of pain associated with focal muscle tenderness is needed.

Perhaps the most important implication of these findings is that the focus for rehabilitation of patients with median entrapment neuropathy at the wrist should be on the function of the whole forearm as a unit, not just on the muscles affected by the median neuropathy.

This pilot study has several limitations. All subjects would ideally have come from a single occupation so that ergonomic job demands would be similar among the groups. In addition, a larger sample size might have improved power sufficiently to demonstrate whether a difference in strength is present between pain subjects and controls.

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