WORKER MONITORING TESTS FOR CARPAL TUNNEL SYNDROME: RESULTS FROM AN INDUSTRIAL LONGITUDINAL STUDY

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This paper presents the initial findings from a study using two computer-controlled functional tests for sensory and motor deficits in carpal tunnel syndrome (CTS). The gap detection sensory test quantifies dynamic tactile inspection thresholds for areas of the hand innervated by the median nerve. The rapid pinch and release psychomotor test measures the initiation and control of specific muscles innervated by the median nerve motor branch. The purpose of this ongoing study is to evaluate industrial subjects recruited from varying high risk industrial settings, such as poultry processing, automotive manufacturing, plastics manufacturing, assembly, and newspaper publishing for longitudinal changes in test outcomes. A total of 169 subjects were tested during the first year of this study. All subjects completed a symptom survey, underwent a physical examination of the upper limbs, shoulder and neck, had a nerve conduction study (NCS), and were administered the Wisconsin Test Battery. Both hands of the subjects are examined and categorized by presence of absence of physical exam findings, self-reported symptoms, and nerve conduction study (NCS) results. The data was analyzed for differences between subjects reporting positive or negative symptoms, and positive or negative physical exam and NCS findings. In summary, the psychomotor and sensory test outcomes were related to objective NCS findings but it is interesting to note that symptoms alone were not significantly associated with functional sensory or psychomotor performance. Unlike our previous studies, where CTS patients in the electromyography (EMG) clinic seeking medical assistance were tested, all subjects were from a working population. It is likely that most of the positive exam and NCS subjects in the current study involve CTS symptoms that are less severe than our previous studies using EMG clinic subjects, many whom were preparing for surgery.

INTRODUCTION

Carpal tunnel syndrome (CTS) is one of the most prevailing peripheral entrapment neuropathies (Phalen, 1972) and is a major cause of reported occupational illness in the US (BLS, 1999). Therefore, routine monitoring tests are needed to detect CTS in the context of medical surveillance in the workplace, similar to how hearing tests are used to identify noise-induced hearing problems. When administered periodically to workers performing jobs associated with increased risk for CTS, these tests may detect early subtle changes in function. A variety of surveillance approaches have been used for identifying musculoskeletal disorders in the workplace. These include symptom questionnaires (Waris, Kourinka, Kruppa, Luopajarvi, Virolainen, Pesonen, Nummi, and Kukkonen, 1979), and physical examination (Fine, Silverstein, Armstrong, Anderson, and Sugano, 1986).

Although questionnaires are perhaps the most sensitive indicator, examinations and tests are needed for increasing specificity by providing objective, quantitative measures. A study conducted by Katz, Larson, Fossel, and Liang (1991) observed that the use of symptoms compatible with CTS has a sensitivity of 0.93 but a specificity of 0.25. Non-quantitative clinical tests, such as Phalen's and Tinel's signs are highly variable (Seror, 1988). Use of these tests were shown to have poor sensitivity (50%) among patients with electrophysiologically confirmed CTS compared with subjects with and without hand pain but without electrophysiological evidence of CTS (Gerr, 1994). Additionally, routine physical examination is costly and prohibitive for large workplaces.

Vibrotactile testing has been proposed as a monitoring test for CTS, but these tests were shown to lack sensitivity and specificity. Daily variations in vibrometry have been shown to reduce sensitivity and specificity of the test. Fagius and Wahren (1981) found intra-individual variation ranging from -59 to 58% compared to the first value measured.

Electrodiagnostic methods such as nerve conduction studies (NCS) for predicting future carpal tunnel syndrome in asymptomatic workers were not found to be predictive of future hand and finger complaints (Werner, Franzblau, Albers, Buchele, and Armstrong, 1997). Electrodiagnostic testing in conjunction with physical examinations are currently considered the most accurate diagnostic tests for CTS. The obvious advantage of testing the median nerve directly is the absence of subjective reporting. Increasing electrophysiological deficits have been related to increasing CTS severity (Mackinnon and Dellon, 1988). Electrodiagnostic tests however are costly, time consuming and considered noxious by many.

Therefore, there is a need for practical tools in an active surveillance program to detect CTS with a high sensitivity and specificity. Such tools could be used to monitor for potential CTS cases, or they may be used to monitor the recovery from surgical, medical or ergonomic interventions. Because of the high incidence of CTS in some industries, it may be beneficial to monitor workers in high risk jobs periodically for early detection of the disorder before it progresses, as is the practice for other hazardous exposures such as acoustic noise.

A computer-controlled test battery for detecting subtle sensory and psychomotor deficits associated with CTS was developed at the University of Wisconsin – Madison (Radwin, Jeng and Gisske, 1993; Jeng, Radwin, and Rodriquez, 1994; Jeng and Radwin, 1995). The performance measures in these tests are based on functional activities performed in occupational tasks, such as repeatedly pressing a key or tactually inspecting a surface for a defect. The sensory test involves detecting a computer-controlled gap on a highly polished surface (Jeng, Radwin, Moore, Roberts, Garrity, Oswald, 1997; Radwin, et. al., 1993). The psychomotor task is a rapid pinch and release task utilizing specific muscles of the hand innervated by the median nerve, including the index finger and thumb (Jeng et. al., 1997; Jeng, et. al., 1994). Previous studies demonstrated that the Wisconsin Test Battery could differentiate well-defined CTS cases from confirmed normal subjects (Jeng, Radwin and Fryback, 1997). The purpose of this ongoing longitudinal study is to evaluate the Wisconsin Test Battery with industrial subjects that have been recruited from varying high risk industrial settings, such as poultry processing, automotive manufacturing, plastics manufacturing, general assembly, and newspaper publishing.

METHODS

The study is conducted in the midwestern United States at five different industrial study sites. The subjects are tested annually for four years. To date, 169 subjects, (338 hands) have been tested, which includes 56 males and 113 females. A breakdown of the types of companies and the number of subjects tested is shown in Table 1. The mean age is 38.82 years (SD=9.36) and the range is 18-60 years.

Table 1
Test Site and Subject Distribution

Company	Industry	Number of Subjects Male	Female	Total
A	Plastics Manufacturer	8	12	20
B	Window Coverings Manufacturer	14	45	59
C	Turkey Processing Plant	7	26	33
D	Publishing and Printing	2	17	19
E	Automobile Assembly Plant	25	13	38
TOTAL		56	113	169

Subjects were recruited from departments and divisions that were identified by their employer as being high risk for carpal tunnel syndrome. This was confirmed by identifying the prevalence of CTS and the presence of risk factors for CTS (i.e. repetitive motion, extreme wrist postures, forceful exertions, etc.). All subjects were volunteers from the selected areas and participated with informed consent. Volunteers were paid their regular hourly salary for participating and the majority of volunteers were tested during their regular shift time.

All subjects completed a symptom survey, which contained questions about symptoms in the upper extremities, the type of work performed and past medical history (e.g. diabetes, arthritis, thyroid disease, ruptured cervical disk, and renal failure). Information was gathered relating to specific symptoms in the hand such as numbness, tingling or pain, and frequency, duration and magnitude of the symptoms. Each subject also completed a self-reported hand diagram. All subjects also underwent a physical examination of the upper limbs, shoulder and neck, which included general range of motion and strength assessment and provocative tests (ie. Phalen's and Tinel's tests) for the median nerve. Positive response to Tinel's and Phalen's sign required pain or paresthesia in at least one digit innervated by the median nerve.

Nerve conduction studies (NCS) were also completed on both hands of the subjects. Testing consisted of median and ulnar transcarpal studies, median and ulnar motor studies and antidromic median digital sensory studies of the index finger.

Subjects were administered the Wisconsin Test battery, which consisted of a functional sensory and a psychomotor test. An automated aesthesiometer measured tactile sensitivity while the index finger freely probed a tiny gap on an otherwise smooth surface. Gap detection sensory thresholds estimated the minimum gap width needed for detecting a gap on a smooth surface. Subjects were allowed five seconds to probe the metal plate prior to determining the presence of absence of a gap. Gap size was changed using a micropositioner and digital encoder, which was controlled by a microcomputer. As the gap size was changed, subjects responded verbally if they could detect a gap using the converging staircase method of limits paradigm. Contact force was controlled at 50 g. An auditory signal masked the noise of the motor so that subjects were not aware if movement of the plates had occurred. Both hands of all subjects were tested.

The rapid pinch and release test measured psychomotor performance in terms of speed and force control. An aluminum strain gauge dynamometer was pinched using the index finger and thumb. A pulp pinch strength test was first administered for determining maximum voluntary contraction (MVC). The subject was instructed to exert an MVC for five seconds and average strength data from the second to fourth seconds was determined. The objective of the pinch and release psychomotor test was to pinch the dynamometer above an upper force level (F_{upper}) and then release below a lower force level (F_{lower}) as quickly as possible. Subjects performed the test using alternate hands and completed two conditions of F_{upper} (10 and 20 %MVC) for each hand, F_{lower} was fixed at 4 %MVC.

The gap detection sensory test was administered first, followed by the rapid pinch and release psychomotor test. Subjects were allowed to feel the gap closed and the gap open at a fixed interval prior to testing. Both hands of all subjects were tested. Rapid pinch practice sets were completed prior to data collection. In half the subjects, F_{upper}=20% was collected first; the other half, F_{upper}=10% was collected first. Alternate hands were tested to allow for recovery time.

The data was analyzed for observable differences between subjects who reported symptoms on the survey, NCS findings, and physical exam findings according to specified criteria. Positive symptom criteria was defined as symptoms reported at least monthly with an intensity of at least mild and symptom location in the median nerve distribution and carpal tunnel area. For physical exam findings to be considered positive one of the following criteria was required to be positive; Tinel's, Phalen's or tenderness over the flexor wrist compartment. Similar criteria have been developed for + NCS outcomes. The judgement of +NCS was not dependent on all NCS parameters being positive. Hands showing positive results in some NCS parameters and negative results in others were judged +NCS. The NCS parameters are listed in Table 2.

Table 2
Criteria Used to Classify Subjects as Positive NCS

Parameter	Criteria
Median Transcarpal Sensory Latency	>2.3 msec
Median Sensory Latency	>3.6 msec
Transcarpal Difference	>0.5 msec
Median Conduction Velocity	<48 m/s

Analysis of variance was used for evaluating statistical significance of the functional performance variables, gap detection threshold, pinch rates, and change in pinch rate when stratified by symptoms, nerve conduction studies and physical exam findings. Each hand was treated as individual in all statistical analysis. Age was used as a covariate and was statistically significant for some of the functional test variables. One hand from a subject classified in the control group was excluded from the data analysis secondary to physical exam findings and reported symptoms consistent with the diagnosis of cervical radiculopathy.

RESULTS

No statistically significant differences were observed for the gap detection thresholds or for F_{upper}=20% MVC pinch rate among subjects categorized by NCS, symptoms or physical exam alone. Subjects having +NCS had a F_{upper} =10% MVC pinch rate for the pinch rate of 4.62 pinches/s while the subjects having –NCS findings had a F_{upper}=10% MVC pinch rate of 5.50 pinches/sec ($F(1,223)=6.84, p=.01$). Significant differences in (F_{upper}=10% MVC) pinch rate were also observed for subjects categorized by physical exam criteria ($F(1,233)=5.545, p<.05$).

The average change in pinch rate between F_{upper} =20% MVC and F_{upper}=10% MVC for the +NCS group was -0.0031 pinches/sec/MVC. In contrast, the change for similar conditions for the -NCS group was -0.1390 pinches/sec/MVC. This difference was statistically significant ($F(1,187)=4.953, p<.05$). The groups classified by either symptom or physical exam criteria did not demonstrate significant findings.

Subjects were next classified based on combined physical exam and NCS results (Table 3). Statistically significant differences were observed between the +NCS/+PE group and -NCS/-PE group for the F_{upper}=10% MVC pinch rate.

Table 3
Functional Performance Variables for Physical Exam and Nerve Conduction Studies

	PE - NCS – Mean SD	N	PE+ NCS – Mean SD	N	PE - NCS+ Mean SD	N	PE + NCS+ Mean SD	N
Gap detect thres-hold (mm)	.17 (.13)	193	.17 (.11)	50	.18 (.12)	30	.26 (.18)	15
20% Pinch Rate	4.75 (1.27)	184	4.29 (1.40)	44	4.55 (1.34)	26	4.51 (0.86)	14
10% Pinch Rate **	5.62 (1.62)	152	4.99 (1.68)	38	4.83 (1.01)	23	4.26 (1.65)	13
Pinch Rate Differ-ence	-.1350 (.2965)	131	-.1558 (.2107)	31	-.0554 (.2261)	18	.1015 (.2316)	9

**p<.01

To be considered +CTS a subject must have a +physical exam and +NCS. In addition, the subject must also report +symptom criteria in at least one hand to be classified in the +CTS group. Both the physical exam and NCS were required to be positive if not the subject was placed in the -CTS group. Results for this classification is shown in Table 4. The average gap detection threshold for the +CTS group was 0.26mm while the -CTS group gap detection threshold was 0.17mm ($F(1,285)=5.37$ $p<.05$). The F_{upper} =10% MVC pinch rate for the +CTS group had a pinch rate of

Table 4
Functional Performance Variables for +CTS and –CTS groups

	-CTS Mean SD	N	+CTS Mean SD	N
Gap detection threshold(mm)*	.17 (.12)	273	.26 (.18)	15
20% Pinch Rate	4.65 (1.31)	254	4.51 (0.86)	14
10% Pinch Rate*	5.42 (1.60)	213	4.26 (1.65)	13
Pinch Rate Difference*	-0.1306 (.2772)	180	0.1015 (.2316)	9

*p<.05

4.26 pinches/s while the –CTS group had a pinch rate of 5.42 pinches/sec ($F(1,223)=4.91, p<.05$). Change in pinch rate also demonstrated significant differences ($F(1,186)=5.29$, $p<.05$).

Sensitivity and specificity information for the Wisconsin test variable change in pinch rate between F_{upper} =20% MVC and F_{upper} =10% MVC demonstrated the best results with a sensitivity of 0.78 and a specificity of 0.70.

DISCUSSION

When subjects were categorized as +CTS or –CTS there was significant performance differences between groups for all of the functional variables of the Wisconsin test battery with the exception of F_{upper}=20% MVC pinch rate. When subjects were categorized based on symptoms alone, performance on the functional variables did not differ between groups. When subjects were categorized based on NCS or physical exam findings, there were some differences between the groups but it varied depending on the functional variable being tested. There were no differences in the gap detection thresholds or F_{upper}=20% MVC pinch rate among subjects categorized using NCS or physical exam alone. For F_{upper}=10% MVC pinch rate and change in pinch rate, subjects categorized using NCS demonstrated differences in performance. Subjects categorized by physical exam findings only demonstrated a difference in performance in F_{upper}=10% MVC pinch rate.

These results indicate that the Wisconsin test variables, F_{upper}=10% MVC pinch rate and change in pinch rate were related to electrophysiological parameters regardless of symptoms. The Wisconsin test variable, F_{upper} =10% MVC pinch rate was related to physical exam findings regardless of symptoms.

Unlike previous studies, where CTS patients in the electromyography (EMG) clinic seeking medical assistance were tested, the +CTS subjects were from a working population. It is likely that most of the +CTS subjects in the current study involve CTS symptoms that are less severe than our previous studies using EMG clinic subjects, many whom were preparing for surgery. This makes it more difficult to categorize subjects as +CTS or –CTS. Physical exam findings and symptoms may not be at a level that indicate that the subjects should be placed in the +CTS category. Additionally, a positive physical exam finding was one of the requirements for a subject to be categorized as +CTS. Previous studies have demonstrated that Phalen's and Tinel's have sensitivities varying from 25 to 75% and specificities from 47 to 90%. Therefore, some subjects may be classified as controls or –CTS because of a negative physical exam but have symptoms and NCS findings indicative of CTS.

CONCLUSION

In summary, the psychomotor and sensory tests were related to objective NCS findings but it is interesting to note that symptoms alone were not significantly associated with functional sensory or psychomotor performance deficits. These findings are for a random industrial population working in jobs considered high risk for CTS.

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