Use of screening nerve conduction studies for predicting future carpal tunnel syndrome

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Abstract

***Objective*—To determine if an abnormal sensory nerve conduction study consistent with median mononeuropathy in asymptomatic workers was predictive of future complaints of the hand or finger suggestive of carpal tunnel syndrome.**

***Methods*—This was a case-control study of over 700 active workers at five different work sites: four sites involved manufacturing workers and one site represented clerical workers. Patients' reports of symptoms of pain, numbness, tingling, or burning in the hand or finger that lasted more than one week or occurred three or more times after the initial screening were investigated. 77 cases were defined as asymptomatic workers with electrodiagnostic findings of median mononeuropathy in either hand based on a comparison of median and ulnar sensory evoked peak latencies. A difference $\geqslant$ 0·5 ms was defined as abnormal; a normal difference was $\leqslant$ 0·2 ms. Controls were asymptomatic age, and sex matched workers with normal nerve conduction studies in both hands. Follow up questionnaires were completed 17 (SD 6) months later.**

***Results*—The follow up participation rate was 72%. Cases had a 12% risk of developing symptoms during the follow up period compared with 10% in the control group, χ^2 = 0·12, P = 0·73.**

***Conclusions*—Abnormal median sensory nerve conduction studies in asymptomatic workers were not predictive of future hand or fingers complaints and if used for preplacement screening among active workers this should be done with caution.**

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Carpal tunnel syndrome (CTS) is one of several disorders of muscles, tendons, and nerves that afflict people performing hand intensive work, and there has been a tremendous increase in the numbers of reported cases. Several studies indicated that repetition, awkward posture, high force, vibration, and local pressure increase the risk of CTS.[1–9] In an apparent effort to minimise the risk of workers developing CTS and possibly reducing future workers' compensation costs, some industries use preplacement nerve conduction studies to identify workers with impairment of the median nerve.[10–12] The implied hypothesis is that these workers (asymptomatic, electrically abnormal subjects) are at higher risk of developing CTS but are in a presymptomatic state. They are placed in jobs that are considered to be at low risk of CTS, or sometimes they are told that they have a temporary disability (early CTS) and cannot be placed at any available job and need not be accommodated under the guidelines of the Americans with Disabilities Act.[10 11] In our opinion, this administrative practice lacks scientific backing. There is pending litigation over the specific issue of the medical usefulness of preplacement nerve conduction tests for identifying workers at risk of developing CTS.[10]

In previous studies, Franzblau *et al*[13 14] reported that about 25% of active workers had a median mononeuropathy in one or both hands (an abnormal slowing of the median sensory nerve across the wrist, compared with the ulnar sensory nerve) and that this finding was consistent over several industrial sites. About half of such subjects did not report any wrist, hand, or finger symptoms consistent with CTS. Such a high prevalence of median mononeuropathy, often asymptomatic, reduces the potential impact of preplacement electrophysiological screening of workers with the potential of denying employment to those with an abnormal result.

The goal of the present study was to determine if asymptomatic workers with and without a median mononeuropathy develop symptoms consistent with CTS over time.

Methods

This was a case-control study of active workers at five different work sites. Cases were defined as asymptomatic workers with electrodiagnostic findings of a median mononeuropathy in either hand from a comparison of median and ulnar sensory evoked peak latencies. A prolongation $\geqslant$ 0·5 ms of the median sensory evoked response was defined as abnormal. The 0·5 ms cut off is a standard electrodiagnostic criterion for confirming a median mononeuropathy at the wrist.[15 16] Controls were age and sex matched asymptomatic workers from the same site with normal nerve conduction studies in both hands; normal was defined as a median to ulnar sensory peak difference $\leqslant$ 0·2 ms with both the median and

ulnar absolute latencies within the normal range.

Cases were selected from an earlier cross sectional screening that tested the median and ulnar sensory evoked responses of active workers in five different settings within the midwest. The sites included an automobile parts manufacturer, a furniture manufacturer, a spark plug manufacturer, a paper container manufacturer, and clerical staff of an insurance company.[13 14] There was a mean (range) participation rate of 81% (75% to 89%) among eligible workers at the five study sites. Workers were selected to be representative of the range of jobs typically found in contemporary manufacturing and clerical sites. They included exposure to high, medium, and low repetition manufacturing jobs and were rated on a scale 1 to 10 in terms of frequency of hand repetition (0 = idle, 2 = frequent pauses, 4 = slow steady motion, 6 = steady motion, 8 = rapid steady motion, and 10 = rapid steady motion, difficulty keeping up).[17]

The jobs ranged from loading machines and monitoring their operations to highly repetitive hand transfer and assembly operations. Office jobs ranged from incidental use of keyboards to medium use in conjunction with claims processing. Each job category was rated, with the help of a video of the job, on the visual analog scale already mentioned by a group of industrial engineers and hygienists.

Subjects signed a written consent form that was approved by our institution's review board and each subject completed an initial symptoms questionnaire. Age, sex, and medical history were self reported within the questionnaire.

Electrodiagnostic studies of the median and ulnar sensory nerves were conducted bilaterally with the techniques described by Kimura.[15] The tests were performed with antidromic supramaximal stimulation, a distance of 14 cm, and ring recording electrodes placed around digits two and five. A standard distance of 3 cm between electrodes was used. Hand temperature was recorded and the hand was warmed if the mid-palmar temperature was below 32°C. All studies were performed on site by a certified electromyographer and a certified electrodiagnostic technician on a TECA TD 20 machine (TECA, Pleasantville, NY). The peak latency and the amplitude (baseline to peak) were recorded for each sensory nerve.

Follow up data were collected with a posted symptom questionnaire in which the patient self reported symptoms of pain, numbness, tingling, or burning in the hand or fingers that lasted more than one week or occurred three or more times since the initial screening. The posted questionnaire was identical to the initial questionnaire described in previous publications.[13 14] For workers reporting any hand or finger problems, a hand diagram was completed as well as questions pertaining to frequency of complaints, treatment, change in work activity, and functional status. Among cases, the worker had to complain of symptoms in a hand that had originally been found to have a median mononeuropathy to be classified as positive. If the worker did not return the questionnaire, telephone contact was attempted. The minimum time before follow up was 10 months and the maximum 24 months. No electrophysiological testing was performed at follow up.

The statistical analyses were performed with STATA.[18] Student's t tests were used to compare the means of the demographic factors (age, months of follow up, and hand dominance) as well as electrophysiological variables and repetition levels in those workers with a median mononeuropathy and in the controls. Student's t test was also used to compare these factors between responders and non-responders as well as workers with and without follow up symptoms. χ^2 Tests were used to compare the percentage of workers with and without median mononeuropathy who had symptoms in the follow up period. This analysis was repeated with a more stringent definition of median mononeuropathy, a difference of at least 0·8 ms between median and ulnar sensory peak response. Student's t test was performed on the means of the interval data from the cases and controls. The data in the tables was from all responders and no cases where the matched worker did not respond were dropped. A second analysis of only matched pairs was also performed. Logistic regression was performed with presence or absence of symptoms at follow up as the dependent variable and demographic factors (age, sex, months of follow up, and hand dominance) as well as electrophysiological and anthropometric variables and repetition levels as the independent variables. All values are reported as a mean (SD).

Results

The mean (SD) age among all responding workers was 40 (9) years (range 18 to 70); 65% were women. There was no significant difference in age from site to site but the sex ratio did differ. Among the industrial sites, the percentage of female workers averaged 49% (range 36%–74%) whereas the clerical workers were 87% women.

Of all cases and controls surveyed 72% responded to the questionnaire or telephone follow up. The responders did not differ from the non-responders for age, sex, hand dominance, repetition level, or electrophysiological variables. Non-responders tended to have a shorter duration of follow up than responders (15·8 (6·6) v 17·3 (6·5) months, t = 1·3, P = 0·2, respectively). Among responders, the age, sex ratio, degree of right hand dominance, repetition level, and months of follow up did not differ between cases and controls. The body mass index (kg/m^2) was statistically higher among cases than controls (29·9 v 27·8, t = 2·31, P = 0·02, table 1). All responders were entered into the analysis in the accompanying tables.

Only 13 of 108 responders reported any persistent or repeated symptoms of numbness, tingling, burning, or pain in the hand or fin-

Table 1 Demographic factors and electrophysiological variables stratified by responders and non-responders and then by cases and controls (mean (SD))

Factors	(+) Median mononeuropathy (responders) n = 49	(−) Median mononeuropathy (responders) n = 59	(+) Median mononeuropathy (non-responders) n = 26	(−) Median mononeuropathy (non-responders) n = 17
Age	41·7 (9·2)	40·1 (9·5)	41·2 (8·6)	39·3 (10·6)
Sex (% male)	33	36	25	29
Right hand dominant (%)	88	86	85	86
Median sensory peak latency (ms)	4·0 (0·7)	3·1 (0·2)	4·0 (0·5)	3·2 (0·2)
Ulnar sensory peak latency (ms)	3·2 (0·3)	3·1 (0·2)	3·2 (0·3)	3·2 (0·2)
Median-ulnar latency difference (ms)	0·8 (0·6)	0·01 (0·1)	0·8 (0·5)	0·01 (0·1)
Body mass index (kg/m²)	29·9 (5·6)	27·8 (3·9)	31·3 (7·5)	27·8 (6·2)
Repetition level	4·5 (2·8)	4·2 (2·6)	3·9 (3·0)	4·0 (2·9)
Months of follow up	17·4 (6·2)	17·1 (6·8)	15·1 (6·3)	15·8 (6·2)

gers during the follow up period. One case reported symptoms in the right hand at follow up. However, this hand had a normal nerve conduction study at baseline (only the left hand was abnormal), and so this subject was not considered to be a positive responder. Even if he was included as a positive responder among the cases, the results and subsequent analysis was not significantly changed. It could be argued that this subject should be counted as a positive response for the controls; this would further strengthen our conclusions. All other cases had symptoms in a hand that was initially found to be abnormal. Table 2 shows the percentage of workers who reported symptoms. Twelve per cent of cases developed symptoms compared with 10% of controls but the difference was not significant, $\chi^2 = 0{\cdot}12$, $P = 0{\cdot}73$. The matched pair analysis gave similar results. None of the workers who reported symptoms stated that they changed their job or work activity because of their new symptoms.

When a subset of cases, who met a more stringent definition of abnormal (a difference of 0·8 ms instead of 0·5 ms), was analysed only two of 27 workers (7%) had symptoms during the follow up period (table 2). There was no significant difference between cases and controls under the new definition ($\chi^2 = 0{\cdot}15$, $P = 0{\cdot}70$).

Table 2 Workers who had hand or finger symptoms in the follow up period stratified by present or absence of a median mononeuropathy (defined by 0·5 and 0·8 ms difference between median and ulnar sensory peak latencies)

Follow up symptoms in hand or fingers	(+) Median mononeuropathy (0·5 ms difference)	(+) Median mononeuropathy (0·8 ms difference)	(−) Median mononeuropathy	Totals
None (n (%))	43 (88)	25 (93)	53 (90)	96 (88)
Present (n (%))	6 (12)	2 (7)†	6 (10)	12 (12)
Totals	49	27	59	108

*$\chi^2 = 0{\cdot}12$, $P = 0{\cdot}73$.
†$\chi^2 = 0{\cdot}15$, $P = 0{\cdot}70$.

Table 3 Logistic regression model with presence of follow up symptoms as the dependent variable and the remaining independent variables after a backward stepwise logistic regression

Independent variables	Odds ratio	SEM	z	P > z	(95% CI)
Rep	1·35	0·19	2·19	0·03	(1·03 to 1·77)
BMI	1·07	0·08	0·94	0·35	(0·92 to 1·24)
MS amp-R	0·94	0·04	−1·42	0·16	(0·87 to 1·02)
MS lat-R	0·27	0·21	−1·61	0·11	(0·05 to 1·32)
MoFU	1·19	0·08	2·49	0·01	(1·04 to 1·36)

BMI = body mass index; Rep = repetition rating; MSamp-R = median sensory amplitude-right; MoFU = months follow up; MS lat-R = median sensory peak latency-right.
Log likelihood = −29·39; N = 104; $\chi^2 = 15{\cdot}6$; probability > $\chi^2 = 0{\cdot}008$; pseudo $R^2 = 0{\cdot}210$.

The point estimate of the difference between cases and controls in terms of percentage of workers who developed symptoms at follow up was 2% (10% *v* 12%). A sample size of over 500 workers per group would be required to have sufficient power ($1-\beta = 0{\cdot}8$, $\alpha = 0{\cdot}05$) to definitively state whether a difference of five percentage points was significant. In our opinion a difference of five percentage points is not sufficient to justify the use of sensory nerve conduction studies as a preplacement examination. If the true point estimate was 10% among controls, then our sample size of 100 would have enough power ($1-\beta = 0{\cdot}8$, $\alpha = 0{\cdot}05$) to detect a difference of 20 percentage points, or a point estimate of 30%, among cases.

Among responders, those who reported and those who did not report symptoms did not differ for age, sex, hand dominance, body mass index, repetition level, and electrophysiological variables, but there was a trend for duration of follow up and to a lesser extent repetition level. Workers who reported symptoms (n = 12) were followed up for a mean (SD) of 21·5 (4·3) months with a repetition level of 5·6 (2·7) compared with workers without symptoms (n = 96) who were followed up for 16·8 (6·6) months ($t = 2{\cdot}4$, $P = 0{\cdot}02$), and had a repetition level of 4·2 (2·7) ($t = 1{\cdot}8$, $P = 0{\cdot}08$). A logistic regression model of responders that included all demographic, electrophysiological, anthropometric, and ergonomic factors was not significant; these factors did not help to predict who would develop symptoms. When a backward stepwise logistic regression was run, the model was significant but only months of follow up and repetition level were significant factors at the 0·05 level (pseudo $R^2 = 0{\cdot}21$, $P = 0{\cdot}008$ (table 3)). Baseline electrophysiological results were not significant in this model. When controlling for other factors in the model, the estimated relative risk was 1·19 for reporting symptoms for each additional month of follow up and 1·35 for each unit of repetition on the scale of 1–10. For example a subject screened at 18 months was 2·8 times as likely to report symptoms than a worker with 12 months of follow up. A worker in a job with a repetition level of 8 was 4·5 times as likely to report symptoms at follow up than a worker with a job at the repetition level of 3. A stratified analysis of only workers with a high repetition rating (> 6·0) failed to show a relation between an abnormal nerve conduction study and the

development of symptoms during the follow up period ($\chi^2 = 0{\cdot}84$, $P = 0{\cdot}36$).

Discussion

To our knowledge, this is the first prospective study to examine if an abnormal finding of median mononeuropathy during screening of active workers is predictive of whether a worker is more likely to develop symptoms consistent with CTS in the future. We found that nerve conduction studies are not useful for this purpose among asymptomatic workers. Asymptomatic workers with an abnormal median sensory evoked response are no more likely to develop symptoms consistent with CTS than workers with a normal median sensory nerve conduction. Therefore, in our opinion, there is no justification for preplacement nerve conduction studies among active workers because such studies do not predict who is more likely to become symptomatic.

The presence of median mononeuropathy does not define CTS as this is a clinical presentation and in our opinion must include symptoms. This study does not support the concept that an electrophysiological abnormality is a preclinical marker for workers who will go on to develop symptoms consistent with CTS. Even a more stringent definition of a median mononeuropathy, 0·8 ms difference, did not distinguish cases from controls for incidence of symptoms during follow up. The mean follow up was 17 months, which we think was sufficient to allow expression of symptoms if there was a true relation between abnormal median sensory response at baseline and subsequent development of symptoms consistent with CTS. There was a trend that workers who became symptomatic were followed up for a longer time and had a higher repetition rating for their job but there was no difference between cases and controls for duration of follow up or repetition level.

Two possible explanations for the unexpectedly high prevalence of median mononeuropathy in this working population are: that the hospital based normative data is "supernormal" and cannot be applied to the working population; or that workers with slowly progressive problems of the median nerve within the wrist do have a physiological abnormality but do not show the same symptoms of numbness and tingling that is associated with acute CTS.

For the first explanation, nerve conduction tests used for screening active workers may have an unacceptable level for specificity and the cut off for defining abnormality may need to be changed. The fact that a more stringent definition of a median mononeuropathy, a 0·8 ms cut off, did not enhance the predictability of identifying who develops symptoms argues against this explanation. An even higher cut off may be tested, but although this may raise the specificity of the test, it would definitely lower the sensitivity.

The second possibility suggests that a very slowly progressive injury to the median nerve, as a result of cumulative trauma and localised ischaemia, may cause a prolongation of the action potential of the median sensory nerve but may not be related to the sensory symptoms that typify CTS. In an experimental model, the symptoms of CTS have been shown to be secondary to transient conduction block secondary to local ischaemia.[19 20] Perhaps, in a slowly evolving demyelinating process related to repetitive wrist movement, there is no conduction block and related symptoms of CTS. This raises the interesting issue of whether these workers should be treated. Stetson *et al*[21] did report a difference in the nerve conduction studies among asymptomatic industrial workers compared with business executives. A group of industrial workers with a high exposure to hand intensive activity had a smaller median sensory amplitude and longer median sensory latencies than a group of executives with minimal exposure to repetitive hand activity. This implied that work activity placed the median nerve at risk due to repetitive activity and subsequent changes within the carpal canal. Perhaps workers should be treated as a unique population with the development of new norms for this population.

To date, there are no studies which define or characterise the natural history of median nerve function and hand symptoms among active workers. We do not know if a median mononeuropathy in a worker without symptoms is potentially harmful but it does not predict who will become symptomatic. Should the abnormal electrophysiological findings be ignored or is there reason to treat the person? A prospective cohort study would help to define the natural history of workers by changes in their median sensory nerve conduction over time related to symptoms, functional disability, hand activity, and other possible covariates.

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