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Post-Offer Pre-Placement Screening for Carpal Tunnel Syndrome in Newly Hired Manufacturing Workers

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ABSTRACT

Objective: We determined the predictive validity of a post-offer pre-placement (POPP) screen using nerve conduction velocity studies (NCV) to identify future cases of carpal tunnel syndrome (CTS).
Methods: A cohort of 1648 newly hired manufacturing production workers underwent baseline NCS, and were followed for 5 years.
Results: There was no association between abnormal POPP NCV results and incident CTS. Varying NCV diagnostic cut-offs did not improve predictive validity. Workers in jobs with high hand/wrist exposure showed greater risk of CTS than those in low exposed jobs (Relative Risk 2.82; 95% CI 1.52, 5.22).
Conclusions: POPP screening seems ineffective as a preventive strategy for CTS.

INTRODUCTION

Reducing medical and disability costs, including Workers' Compensation claims, is a high priority for many employers.[1-5] For many employers, the majority of Workers' Compensation claims are related to musculoskeletal disorders (MSD); carpal tunnel syndrome (CTS), has received attention because it has the highest cost per case among work-related upper extremity musculoskeletal disorders.[6]

Some employers use post-offer pre-placement (POPP) medical screening as a strategy to avoid workers' compensation claims for CTS by rejecting prospective employees with abnormal median nerve conduction from placement in jobs requiring forceful hand exertion. There are no data on the number of companies using POPP screening for CTS, but the availability of portable testing devices for nerve conduction studies has created interest in POPP screening, particularly by manufacturing and food processing companies. While several past court cases have supported employers' ability to reject job applicants based on such screening tests (EEOC vs. Woodbridge Corporation, 8th Circuit No. 01-L045, August 24th, 2001; EEOC vs. Rockwell International Corporation, 7th Circuit Nos. 00–1897 & 00–2034, March 8, 2001), the practice remains controversial, and the question is again under scrutiny in a recent case brought by the Equal Employment Opportunity Commission.[7]

While several studies have found that asymptomatic workers with abnormal median nerve conduction are at greater risk for developing future carpal tunnel syndrome than those with normal nerve conduction studies (NCS), [8-11] no studies to date have demonstrated that POPP screening for CTS is a valid or effective prevention practice. The several studies of POPP screening conducted to date found that the predictive value of POPP screening for CTS was poor, and that the practice was not cost-beneficial for employers. Existing studies also demonstrated that the low predictive validity of POPP screening ensured that many workers would be rejected for employment in order to prevent one case of CTS in the workforce; most of these rejected workers would not develop CTS. Franzblau[10] conducted a retrospective cohort study of 2150 newly hired workers who received POPP median nerve conduction but were hired regardless of results. While workers with abnormal electrodiagnostic studies at baseline were 3.3 times more likely to develop CTS, the majority of CTS cases (63%) occurred in workers with normal baseline studies, and cost of screening was greater than the cost of cases potentially avoided. Evanoff and Kymes showed that such screening could only be cost-effective for employers under very specific conditions- low screening costs, high costs for CTS claims, low employee turnover, high baseline rates of abnormalities, and good predictive validity of the POPP screening.[12] Dale and colleagues[13] conducted nerve conduction studies on a prospective cohort of 1100 newly hired workers from several industries and followed workers for at least three years. Most workers (92%) with abnormal screening results did not develop CTS, and the predictive value of screening was poor, even with optimal screening thresholds of nerve conduction values. This study also found that screening was not a cost beneficial practice for employers. Despite these studies, POPP screens continue to be widely promoted by healthcare providers and device manufacturers.[11, 14-21] The purpose of this study was to determine the predictive validity of a POPP screen using nerve conduction velocity studies to detect future cases of CTS among newly-hired workers in a manufacturing facility. We hypothesized that workers with abnormal nerve conduction values at the time of hire would be more likely to develop CTS than workers with normal values. Based on previous literature, we also predicted that this association would be insufficiently predictive to make POPP screening an effective prevention tool.

METHODS

Study Sample

We performed a retrospective cohort study on data provided by an American manufacturing facility, whose production jobs involve hand-intensive assembly line work. Beginning with the opening of the facility, job applicants underwent a post-offer pre-placement (POPP) screening that included a physical examination, functional testing, and nerve conduction velocity study (NCV). Data used in this study were obtained from results of the POPP screening, personnel records including dates of hire and termination, facility medical records, and physical job demands analyses conducted by the employer. Data were available for five calendar years since the opening of this facility. All employee data records were linked by an individual employee identification number assigned by the employer. Workers hired by the company were identified in the dataset, though reasons for not being hired following POPP examination were not available. POPP of potential workers began during the first year the facility was opened, but for the initial 21 months after the start of POPP examinations, all workers who received screening tests were hired regardless of POPP NCV results. This provided the opportunity to follow workers with a range of NCV test results for several years after hire, to assess the predictive value of screening nerve conduction tests in a setting where these tests were performed but were not used in hiring decisions. The Institutional Review Board of Washington University School of Medicine provided the ethical approval for this study.

POPP Screen

All job candidates received several screening tests including a physical examination, nerve conduction velocity studies, and functional screening tests addressing strength, coordination, and repetitive motion relevant to the work activities. The NCV evaluated the motor response of the median nerves across both wrists using the NeuMed Brevio® nerve conduction monitoring system. Testing was performed in a single on-site clinic by several trained physical and occupational therapists, according to the device manufacturer's guidelines. Skin temperature was measured prior to testing; if below 34°C, the candidate's hands were warmed using hot packs; skin temperature was not recorded. Testing with the Brevio device used preconfigured electrodes applied to the skin. Electrodes for median nerve motor latency testing were placed around the thenar eminence, the dorsum of the hand, and the thumb interphalangeal joint. A nerve stimulator was held in place by the tester on the volar wrist, seven centimeters proximal to the electrode on the thenar eminence. Impulses were delivered manually by the tester until a maximum value for the nerve latency and amplitude was observed for four impulses. NCV results available for this analysis included average readings of bilateral median nerve distal motor latencies (DML) and amplitudes. The test procedure used a median nerve DML of 4.5 milliseconds (ms) or greater of one or both hands as the criterion for seeking additional diagnostic nerve conduction testing. The results of all testing were reviewed by an onsite medical provider in making a determination of medical fitness for duty.

Demographic data on workers was obtained from facility medical and personnel records including age, gender, body mass index (BMI), past medical history including diabetes or rheumatoid arthritis, date of hire and date of termination if no longer employed, and the job title into which the candidate was hired. Individual work hours were not available but the employer provided average monthly hours for all production workers for each month, for all years of the study.

Physical Hand/Wrist Exposures estimated by Physical Job Demands

We used the physical job demand scores provided by the employer to estimate physical exposures relevant to carpal tunnel syndrome. Occupational health providers scored the frequency of 35 physical job demands in each work process (scored from 1= rarely, 2=infrequently, 3= occasionally, 4= frequently, 5= constantly). We selected four physical job demands that were most closely related to hand-intensive work: “firm grasping,” “fine hand manipulation,” “wrist flexion/extension/deviation,” and “vibratory hand tools.” We assigned the value for each exposure that we believed best represented workers’ exposures on each production line. If the exposure for any single process occurred “constantly”, the exposure was considered “high” for the line. If exposures in all processes of a line occurred less frequently (not constantly), the exposure for the line was considered “low.” Each worker was assigned the exposure value of their production line for their job title. Exposure assignments were blinded to CTS case or POPP test status of workers.

Definition of CTS outcome

We received a de-identified version of the medical records for all visits to the onsite medical provider. Because the available medical records did not contain standard diagnostic codes for CTS, potential cases of CTS were identified based on information in the medical provider notes, including symptoms typical of CTS in the hand, wrist, or fingers, or a CTS diagnosis by the medical provider. Based on text string searches of three fields in the medical records (diagnosis, body part, and comments fields), workers meeting one of the following criteria were classified as potential CTS cases:

1) The diagnosis or other text fields included one of the following terms: “cts,” “carpal tunnel syndrome,” or “ct syndrome.”
2) The injured body part or diagnosis included one of the following terms: “hand,” “wrist,” OR “finger;” AND, the diagnosis or other text fields in the record included one of the following terms: “nerv,” “numb,” “tingl,” “paresthesia,” “EMG,” “NCV,” “NCT,” “inj,” “surg,” OR “CT.” “CT” was included only if found as a standalone term; all other text strings may have been detected within longer words.

All potential cases thus identified were reviewed and coded independently by two occupational therapists (AMD and BG), using the scoring criteria described in Table 1 for definite CTS, possible CTS, and no CTS. Raters also coded the date of CTS diagnosis and the side(s) affected (right, left, or bilateral). Date was coded as the date when the CTS diagnosis was first assigned by the physician. If the date of diagnosis was not clearly stated in the record, date was assigned based on the CTS outcome scoring criteria as the earliest date of the positive NCV results, referral to hand specialist, or surgery. Cases assigned “possible CTS” were given the earliest date when CTS was suspected as the diagnosis. Date of CTS diagnosis was noted separately for the right and left hands, if the dates differed. If date of determination of the second side was unclear, the same date was assigned for both hands. The raters were blinded to workers’ POPP NCS results, personal, work, and medical information, with the exception of the information provided in the text record of the medical treatment. Discrepancies were resolved by consensus ratings for the CTS outcome, side affected, and the date(s) of diagnosis for each side.

Data analysis

Descriptive statistics were calculated for the demographic characteristics of the cohort, the percentage of workers with abnormal POPP NCV results, and the percentage of workers by physical exposure level (high/low hand-intensive work). For this study, the main outcome measure was a diagnosis of CTS as previously defined. We calculated incidence rates of CTS by person-time during the 5-year study period.

To evaluate the potential predictive value of nerve conduction testing results in hiring decisions, we calculated incidence rates of CTS among production workers using Poisson regression models. The incidence rate accounts for the workers' time at risk that began with the date of hire and ended with either the first date of CTS diagnosis, the earliest termination date if the worker was no longer working for the company, or at the end of the study (end of year 5) if the worker was still working. Workers who were terminated and then rehired at a later date during the study period (n=119) were censored at the first termination date; none of these workers developed CTS during the rehire period. We ran multivariable Poisson regression models predicting the likelihood of CTS and included abnormal POPP NCV results (median DML greater than or equal to 4.5 ms), BMI, age at time of hire, gender, and "high" exposure job in the model. Medical conditions were not included due to their low prevalence. We also examined the effects of work hours to adjust for variation in the number of overtime hours by worker.

Importantly, we explored CTS cases occurring among those workers hired during a period when the NCV test results were not used in hiring decisions, and compared future CTS rates among workers with normal or abnormal POPP NCV at time of hire. We ran sensitivity and specificity analyses by varying the threshold for defining an "abnormal" POPP NCV result, to determine whether the predictive value of the POPP NCV screening would differ with different test thresholds. We calculated the number needed to screen to detect a single case of CTS and the number of workers that would have been denied employment among the number screened. All analyses used SAS version 9.4.[22]

RESULTS

There were 2,975 workers hired during the first 21 months after the facility opened and followed during the 5-year study period. Among these hired workers, 1198 were excluded from analysis since they were hired into non-production jobs such as maintenance and administrative work or because no job information was available. Of the remaining 1777 workers who were hired into production jobs, 1648 had POPP NCV results of at least one hand, and were thus entered into analysis.

Demographic characteristics of the cohort are shown in Table 2. Most workers in the cohort were male (77%), with a mean age of 34.7 years (SD 9.6) at the time of hire, and a mean body mass index (BMI) of 28.7 kg/m^2 (SD 5.8). There were few abnormal findings from the physical examination at baseline among these hired workers (5.3%), though a high proportion (17.3%) had abnormal POPP NCV tests (DML ≥ 4.5 ms).

Over the study period, 42 workers were identified as meeting our case definition of confirmed CTS. Ten additional workers met our definition of possible CTS. The range of follow-up was 0 to 6 years, with a mean of 2.9 years. There were 5239.9 total person-years of observation, with an incidence rate of 8.02 cases per 1000 person-years for confirmed CTS. Job exposure information was available for 1335 of the production workers hired; approximately one-quarter of these workers (23.1%) were hired into "high" hand exposure jobs.

Results of univariate Poisson regression models in Table 3 showed trends toward increased risk of CTS with increased age and increased BMI, although these associations were not statistically significant. Importantly, there was no association between abnormal POPP NCV results and incident CTS (Relative Risk 0.96, 95% CI 0.43, 2.18), indicating that *abnormal screening NCV did not predict future CTS* among these workers, who were hired without regard to results of their POPP screening. Conversely, working in a job with high hand/wrist exposure was associated with an increased risk of CTS compared to working in a low exposure job (Relative Risk 2.82; 95% CI 1.52, 5.22) in univariate analyses. Among workers with high hand/wrist exposure there was a statistically non-significant trend toward a higher risk of CTS among those with an abnormal NCV, though this group accounted for only 5 of the 42 cases of CTS in the cohort. A multivariable model showed no association of incident CTS with abnormal POPP NCV, age, gender, BMI, or high job exposure.

As a test to predict future CTS, distal motor latency of $\geq$ 4.5 ms showed poor sensitivity (17.5) and modest specificity (82.7). The test showed a very poor positive predictive value (0.025), meaning that only 2.5% of workers with abnormal NCV results developed CTS over an average follow up time of 2.9 years. Varying the threshold for defining abnormal nerve conduction test results above or below 4.5ms did not substantially change any of the results (sensitivity, specificity, positive predictive value). Lower thresholds minimally improved sensitivity with a large loss to specificity. Higher thresholds showed loss to sensitivity and minimal gain to specificity. Seventeen percent (17%) of the workers in this relatively healthy population had an abnormal NCV test at the selected threshold of $\geq$4.5 ms. Evaluation of *number needed to screen* showed that 235 workers would need to be screened to detect one future case of CTS. Among these 235 workers, 40 workers would have had abnormal POPP NCV results, and would potentially have been denied employment even though these workers would not have become future cases of CTS.

DISCUSSION

The incidence of CTS among this cohort of newly-hired manufacturing workers was 8.02/1000 person-years. This rate is higher than that found in other recent studies of workers in hand intensive industries that used a more restrictive case definition,[23] but lower than rates that have been reported in other worker groups.[11, 24] Univariate analyses of this cohort showed that future CTS was predicted by exposure to higher hand/wrist exposures at work, consistent with recent studies.[25, 26] Unlike previous studies, workers with prolonged median nerve motor latencies were not at higher risk of future CTS in this cohort. Consistent with past studies, post-offer pre-placement screening was not an effective strategy for identifying future cases of CTS based on nerve conduction screening studies in this sample of newly hired workers; in fact, the rate of future CTS cases was slightly ***lower*** among the workers with abnormal POPP screen results than among those with normal studies. A better predictor of future CTS was job exposure: those in high hand/wrist exposures had nearly a three-fold higher risk for developing CTS than workers in low exposed jobs, regardless of their baseline NCV status. Using different nerve conduction thresholds to define abnormal studies did not improve the predictive power of the POPP screens. In this population, a large number of workers would need to be screened (n=235) in order to detect one worker who would eventually become a case of CTS. Importantly, such screening would also detect 40 potential hires with abnormal NCV results who never became cases, yet may have been denied employment or placed in a less desirable job.

This is the third study to evaluate the predictive value of POPP screening for CTS by following workers over time after the collection of nerve conduction data at time of hire.[10, 13] All three studies collected nerve conduction velocity studies for newly hired workers but used different nerve conduction measurement devices. The two previous studies demonstrated that workers with abnormal NCV values were more likely to become future cases of CTS.[10, 13] Like the current study, these past studies also showed that most workers with abnormal NCS did not develop CTS during the study period, and that the predictive value of POPP NCV for future CTS was very poor in active working populations. All three studies support the conclusion that POPP screening is not an appropriate or effective means to prevent CTS among working populations.

The costs of POPP screening programs can be quite high depending upon the number of new workers needed for the work force, and the additional number of workers who must be screened to replace potential workers denied employment due to the results of testing.[13] Including the present paper, there are now three longitudinal studies showing that POPP screening for CTS is ineffective and cannot be recommended as an evidence-based practice.

In contrast to the absence of literature supporting POPP screening for CTS, existing literature[25, 27, 28] strongly supports the conclusion that hand-intensive work is an important risk factor for CTS. Rather than conducting ineffective screening, employers wishing to reduce CTS and other upper extremity musculoskeletal disorders among their workers should implement comprehensive ergonomic programs to reduce high risk physical exposures.[29] Recent evidence suggests that the duration of time spent in forceful gripping and pinching is the predominant work-related risk factor for CTS among manufacturing and production workers.[25]

Limitations and Strengths

There are several limitations to this study that may affect the results and conclusions. The POPP NCV study tested the distal motor latency (DML) of each hand rather than using the more sensitive test of the distal sensory latency or median-ulnar distal sensory latency difference that requires testing the ulnar nerve of across the wrist. This study represented an evaluation of nerve conduction velocity testing as applied in current practice at the studied employer, and by other employers our study team is familiar with. Similarly, body temperature of the tested region was not recorded, and may have affected test results. The majority of the CTS cases were identified by the physician's diagnosis and did not require standardized nerve conduction testing. This use of the physician's notes and available text from the medical records to define cases of CTS was a limitation of our study, but also reflects real world clinical practice. An appreciable fraction of workers were missing production line assignment in the available records, and thus could not be assigned job exposures, although there is no reason to believe the missing data were non-random. Those with job title information may have received misclassified exposure levels given our method of exposure assignment, which relied on 5 point exposure scales estimated by the employer, and assigned the same exposures to all workers with the same job title and same production line.

This study had several strengths. We had data on all workers in a newly-opened manufacturing facility and were able to follow the workforce for five years. We had results of the screening (nerve conduction velocity studies and physical examination) and job exposures as well as the medical notes on all workers with hand or wrist complaints that were seen in the on-site medical department. Few studies have both baseline and follow-up data available on a large sample of newly employed workers with five years of follow-up information. Because the employer did not use the NCV results in making hiring decisions, all tested workers could be followed into the workplace, thus creating the opportunity to conduct a "natural experiment" to determine the rates of future CTS cases in relation to baseline testing.

A similar serendipitous event led to a classic paper demonstrating that POPP screening with low back radiographs did not predict low back injuries.[30] A high demand for workers in the forestry products industry caused the employer to hire workers despite “high risk” radiographs that would normally have excluded them from being hired; follow-up showed that these workers subsequently had a lower incidence of back injury than those with “normal” findings. Subsequent studies have confirmed the lack of utility of routine low back radiographs at predicting future work-related back pain. While low-back radiography is thankfully no longer routine in occupational health practice, other types of POPP screening to prevent musculoskeletal disorders are ubiquitous, despite the absence of high quality studies evaluating such assessments as an effective preventive measure.

Conclusion

Consistent with results of previous studies,[10, 13] our study found that POPP screening in the current sample was an ineffective preventive strategy for CTS. There are no published studies supporting the use of POPP screening using NCV to prevent CTS; this is the third study to demonstrate that such screening is a poor use of employers’ health and safety resources. Employers and occupational health providers should apply similar scrutiny to the effectiveness of other common POPP screening practices.[31] As a profession, there is a need for occupational health professionals to re-examine current practices in light of existing evidence, and to seek additional evidence on the utility – or lack of utility – of commonly performed screening that may determine future employment.[31, 32]

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Table 1 Scoring criteria applied to potential cases of CTS

Rating	Criteria
"Definite" CTS	• Hand symptoms with confirmatory findings on diagnostic nerve conduction studies (NCS) • "CTS" diagnosis (mild, moderate, severe CTS) assigned by the physician • Carpal tunnel release surgery was performed
"Possible" CTS	• Symptoms defined as hand numbness AND physician *recommended NCS* but the results were unavailable
No CTS	• If acute/traumatic injury • No NCS ordered • NCS with normal or negative findings • Other diagnosis was given (epicondylitis, trigger finger)

Table 2. Demographic characteristics, physical exposures, abnormal nerve conduction studies, and carpal tunnel syndrome outcomes among 1777 production workers

	Hired Production		
	n	**Descriptive**	
Demographics			
Age, mean(SD)	1763	34.7	(9.6)
BMI, mean(SD)	1530	28.7	(5.8)
Male, n(%)	1777	1369	(77.0)
Diabetes, n(%)	1708	42	(2.5)
Rheumatoid arthritis, n(%)	1711	8	(0.5)
Exposures			
High exposures in hand/wrist tasks, n(%)*&	1335	308	(23.1)
Baseline screen results			
CTS screening, positive special tests, n(%)†	1729	92	(5.3)
Baseline NCV >= 4.5 milliseconds, n(%)$	1648	285	(17.3)
CTS outcome			
Confirmed CTS, n(%)#	1777	42	(2.4)
Confirmed Bilateral CTS, n(%)	1777	33	(1.9)
Confirmed CTS and positive special tests†	42	1	(2.4)

BMI body mass index, CTS carpal tunnel syndrome, NCV nerve conduction velocity study (median distal motor latency, highest value between hands), SD standard deviation

*Proportion of subjects in high exposed jobs related to hand/wrist tasks from firm grasping, fine hand manipulation, wrist flexion/extension/deviation, and vibratory hand tools.

& Subjects with no job assignment were excluded from the analyses that included physical exposures (n= 442).

†Positive Phalen's, Reverse Phalen's, Tinel's, wrist compression test OR Semmes Weinstein monofilament testing of 3.61 or higher OR Thenar muscle wasting noted on visual inspection.

$Median motor response on NeuMed Brevio

#Determination of CTS: based on independent coding by two Occupational Therapists. Criteria for CTS included medical report of either positive findings on diagnostic nerve conduction studies, "CTS" diagnosis assigned by physician, carpal tunnel release surgery was performed, or referral to a hand specialist.

Table 3. Relative risk of CTS incidence assessed by univariate analysis of nerve conduction velocity studies, work exposures, and personal factors and multivariable analysis with all factors in a cohort of production workers

	CTS cases	Incidence (Cases per 1000 person-years)	Relative Risk (95% CI)*
Univariate poisson regression (n=1648)	42	8.02	
NCV $\geq$ 4.5 ms (n=285)	7	7.99	0.96 (0.43, 2.18)
NCV < 4.5 ms (n=1363)	33	8.28	
High Hand/Wrist Exposure (n=308)	18	20.24	2.82 (1.52, 5.22)
Low Hand/Wrist Exposure (n=1027)	23	7.18	
Of those with High Hand/Wrist Exposure			
NCV $\geq$ 4.5 ms (n=45)	5	38.70	2.18 (0.77, 6.20)
NCV < 4.5 ms (n=238)	13	17.72	
Of those with Low Hand/Wrist Exposure			
NCV $\geq$ 4.5 ms (n=176)	2	3.55	0.43 (0.10, 1.85)
NCV < 4.5 ms (n=786)	20	8.21	
Male (n=1369)	32	7.80	0.87 (0.43, 1.77)
Female (n=401)	10	8.96	
Age when hired (n=1763)			1.02 (0.99, 1.05)
BMI (n=1530)			1.02 (0.97, 1.07)
Multivariable Poisson regression model (n=1292)			
NCV $\geq$ 4.5 ms			0.66 (0.25,1.72)
High Hand/Wrist exposure			1.48 (0.78, 2.85)
Male			0.80 (0.39, 1.67)
Age when hired			1.02 (0.99, 1.06)
BMI			1.02 (0.96, 1.08)

BMI body mass index, CTS carpal tunnel syndrome, NCV nerve conduction velocity study (of the right median distal motor latency), CI confidence interval POPP Post-offer pre-placement

*Computed from Poisson regression models. Significant findings in bold.