Sensitivity and Specificity of Vibrometry for Detection of Carpal Tunnel Syndrome

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A cross-sectional study was performed to assess the utility of vibrotactile thresholds (VTs) obtained before and after a 10-minute period of wrist flexion as a method for detection of carpal tunnel syndrome (CTS) among adult subjects. Subjects with hand discomfort were recruited from patients referred to a university-based electromyography laboratory. Asymptomatic subjects were recruited from among office and technical staff at a professional school. In addition to electrophysiologic evaluation (EP), all subjects were offered VT measurement of the index and small fingers, bilaterally, before and after a 10-minute period of wrist flexion. A total of 144 subjects were recruited, and three hand-condition groups were established: 57 hands had symptoms and EP results compatible with CTS (Group 1), 58 hands had symptoms compatible with CTS and normal EP results (Group 2), and 123 hands had no symptoms and normal EP results (Group 3). Group 1 was considered the "disease-positive" group, and Groups 2 and 3 were both considered "disease-negative" groups. Analyses were performed separately for dominant and nondominant hands, and results were pooled when appropriate.

Outcomes of interest were the VTs obtained from the index and small fingers before and after 10 minutes of maximal voluntary wrist flexion as well as variables calculated from them. Significant differences in mean VT were observed between the three hand-condition groups for most of the outcomes evaluated. At any given level of specificity, the sensitivity of vibrometry performed after 10 minutes of wrist flexion was approximately two times that obtained before wrist flexion for detection of electrophysiologically confirmed CTS. At specificities of 70 and 80%, the best sensitivity observed among vibrometry outcomes obtained after wrist flexion were 61 and 57%, whereas the best sensitivities observed among vibrometry outcomes obtained before wrist flexion were 35 and 28%.

Carpal tunnel syndrome (CTS) is characterized by dysesthetic hand symptoms such as pain, tingling, and numbness in the distribution of the median nerve as well as by weakness and atrophy of the thenar eminence. It is universally accepted that CTS is the clinical concomitant of compression of the median nerve as it passes through the carpal canal. Median nerve neuritis caused by focal entrapment at the wrist was first described by Marie and Foix in 1913.[1] It is now considered the most common entrapment neuropathy.[2] The lifetime risk of developing symptoms compatible with CTS has been estimated to be as high as 10%,[3] although other risk estimates are considerably lower.[4] In addition, disorders associated with repeated trauma, of which CTS is often considered prototypic, have become the most commonly reported category of occupational illness.[5]

When CTS occurs secondary to occupational ergonomic factors, it is one of a group of conditions sometimes referred to collectively as disorders associated with repeated trauma, cumulative trauma disorders, or repetitive motion injuries.[6–8] Studies attempting to relate occupational ergonomic factors to these disorders have typically relied upon clinical methods to differentiate CTS from other painful conditions of the upper extremity.[9–11] Specifically, a symptom-oriented definition of CTS has been utilized almost exclusively, and misclassification of disease was possible. Cross-sectional studies of CTS in industry have rarely utilized electrodiagnostic evaluation, usually

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because of the cost, sophistication, and time requirements of this method. In one large and frequently cited epidemiologic study of occupational CTS, the investigators stated: "Time and resource constraints precluded use of more elaborate diagnostic tools such as nerve conduction velocity studies" (Ref. 9, p. 347).

Electrodiagnostic studies, in addition to being costly and time consuming, are noxious to some subjects. Many participants in cross-sectional or longitudinal studies of occupational CTS have few or no symptoms and may therefore not be motivated to undergo painful tests for research purposes. A painless diagnostic procedure would be more readily accepted by volunteer participants.

Quantitative, noninvasive, and nonaversive determination of vibrotactile threshold (VT) has been suggested as an appropriate substitute for uncomfortable, time-consuming, and costly electrodiagnostic testing in both epidemiologic studies and clinical practice.[12] If proven useful, this method could also be used for long-term evaluation of treatment in patients suffering from CTS in whom repeated electrodiagnostic study might be tolerated poorly. It would also be well suited to a program of surveillance of workers whose jobs place them at risk for the development of CTS. Used in this manner, periodic testing that would not be acceptable with standard electrodiagnostic techniques could be performed to facilitate medical removal of workers who develop abnormal thresholds before the development of clinically overt disease. Finally, the effects of workplace modification designed to reduce the occurrence of CTS could be evaluated with this method, facilitating prevention of this common disorder.

Although authors have suggested that vibrometry is a useful method for detection of CTS,[13,14] review of the literature demonstrates substantial variability in the observed utility of VTs for detection of carpal tunnel study. This variability may be attributable to differences in subjects selection, equipment used, and threshold-testing procedures. One novel approach required subjects to place their wrists in maximal passive wrist flexion for as long as 16 minutes.[15] Subjects with CTS were observed to experience a strong trend of increasing threshold during flexion, whereas those without CTS were observed to experience no change over the period of flexion.

To evaluate the sensitivity and specificity of VT measurement for detection of CTS, a cross-sectional study was performed using a combination of characteristic symptoms and electrophysiologic findings as the "gold standard" for the diagnosis. Measurement of VT was performed before and after a 10-minute period of wrist flexion.

Methods

Subjects

Symptomatic subjects were recruited from among patients referred to the Emory Clinic Electromyography Laboratory, directed by one of the authors (LCH). Any patient between the ages of 18 and 70 years with symptoms of pain, weakness, numbness, or tingling that involved either hand was eligible for inclusion in the study. Asymptomatic subjects were recruited from among office and technical staff at the Emory University School of Public Health. All subjects provided informed consent approved by the Emory University Human Investigations Committee for participation in the study.

Questionnaire

A standardized questionnaire including demographics (age, gender, height, and weight), occupation, and symptoms of CTS was administered to all participants.

VT Testing

The vibrotactile sensitivity instrument used was the Vibratron-II (Physitemp Inc, formerly Sensortek Inc, Clifton, NJ). It vibrates at a fixed frequency of 120 Hz. The vibration amplitude is manually adjustable from the front of the controller unit. The Vibratron-II is a direct-reading instrument, with the intensity of vibration displayed on the front of the apparatus. The units are a nonlinear function of the microns of displacement of the 1.4-cm–diameter vibrating post. The instrument was calibrated using a Kulite (Kulite Corp, Leonia, NJ) GY-125–10 strain gauge accelerometer, and calibration parameters were used to convert recorded "vibration units" to microns of displacement for all measurements.

A standard psychophysical procedure, the method of limits, was used to determine VTs.[12,16,17] The procedure requires the subject to place his or her finger on the stimulus delivery post that protrudes from the instrument. The stimulus intensity was increased until the subject reported that it was felt, then decreased until it was no longer felt. This ramping up and down was repeated five times (three "descending" trials and two "ascending" trials). Stable, reliable, and time-efficient thresholds can be obtained with this procedure.[16] VTs were measured for the index and little fingers before and after 10 minutes of maximal voluntary wrist flexion.

Electrophysiologic Testing Protocol

Standard electrophysiologic techniques were used. All motor nerve conduction measures were performed according to a standard protocol. Sensory nerve conduction measures were performed with either antidromic or orthodromic stimulation depending upon the preference of the electromyographer. Orthodromic sensory conduction results were recorded as latency in milliseconds from the stimulation artifact to the peak of the evoked response, and antidromic sensory conduction results were recorded as velocity in

TABLE 1
Outcome Variables Used in Analyses

Digit 2	Vibration threshold of the index finger measured before wrist flexion.
Digit 5	Vibration threshold of the small finger measured before wrist flexion.
Diff 2–5	The difference in vibration threshold between the index finger and the small finger measured before wrist flexion (Diff 2–5 = Digit 2 − Digit 5)
Digit 2F	Vibration threshold of the index finger measured after 10 minutes of wrist flexion.
Digit 5F	Vibration threshold of the small finger measured after 10 minutes of wrist flexion.
Diff 2F–5F	The difference in vibration threshold between the index finger and the small finger measured after 10 minutes of wrist flexion (Diff 2F–5F = Digit 2F − Digit 5F)
Delta Diff	The difference between Diff 2F–5F and Diff 2–5 (Delta Diff = Diff 2F–5F − Diff 2–5)

meters per second along the nerve segment between stimulating and recording electrodes. All electrophysiologic measures were made with a TECA TD-20 electromyograph (TECA Corp., Pleasantville, NY). Because examinations were performed for clinical indications, some variability in the details of the electrophysiologic examination occurred among symptomatic individuals. In general, sensory and motor studies were performed on the median and ulnar nerves of the affected limb in symptomatic subjects. All subjects had, at least, median motor nerve and median sensory nerve evaluation of the symptomatic hand. In asymptomatic-comparison subjects, the dominant limb was tested.

Standard needle electromyography (EMG) was performed on all symptomatic subjects at the time of initial evaluation. EMG was performed with the muscle at rest and during voluntary contraction. Abnormalities at rest, including fibrillation potentials, positive sharp waves, or complex repetitive discharges, were considered to indicate active denervation. Abnormalities with voluntary effort, including motor unit potentials of increased amplitude or duration or of polyphasic configuration or recruitment with increased interference patterns, were considered to indicate chronic denervation.

An electrophysiologic study was considered positive (ie, consistent with CTS) if any one of the following results was found:

1. Median nerve distal motor latency greater than 4.4 ms at a distance of approximately 7 cm in a subject with normal ulnar nerve function.
2. Median nerve distal motor latency of 1.8 ms or greater than that of the ipsilateral ulnar nerve distal motor latency.
3. Median mixed nerve (sensory and motor) palm-to-wrist latency greater than 2.2 msec.
4. Median sensory nerve conduction velocity from wrist to finger of less than 44 m/s or median sensory nerve latency from finger to wrist of greater than 3.8 msec at a distance of 13 cm.
5. Isolated EMG abnormalities (active or chronic) of the abductor pollicis brevis muscle suggestive of denervation.

Data Analysis

For the purpose of determining the sensitivity and specificity of the VT measures, one CTS-positive group (Group 1) and two CTS-negative groups (Groups 2 and 3) were established. The CTS-positive group consisted of all subjects with hand symptoms and electrophysiologic test results consistent with CTS. Group 2 consisted of all subjects with hand symptoms consistent with CTS (pain, numbness, or tingling in the distribution of the median nerve) and normal electrophysiologic tests, and Group 3 consisted of all asymptomatic subjects who had normal electrophysiologic tests.

VTs of the index and little fingers were measured before and after 10 minutes of maximal voluntary wrist flexion. VT differences between the index and the little finger were calculated for each subject for measurements made both before and after wrist flexion. In addition, the change in the VT difference between Digit 2 and Digit 5 from before and after wrist flexion was calculated. All VTs are presented in units of log microns. A list and description of outcome measures obtained at the time of examination or calculated from those obtained at the time of examination are provided in Table 1. To control for potential confounding, general linear models that included age, height, and body mass index (BMI) as covariates of median nerve VT were used to test for differences in mean threshold scores among the three patient groups. Analyses were performed separately for the dominant and nondominant hands.

For the outcome variables Diff 2–5, Diff 2F–5F, and Delta-Diff, values that correspond to the 70th, 80th, 90th, and 95th percentiles were used to represent test specificities of 70, 80, 90, and 95%, respectively, for that particular outcome. The sensitivity that corresponded to each of these specificities was defined as the proportion of subjects in the disease-positive group (Group 1) who had a value that exceeded the value associated with each of the specificities. These outcome variables were chosen because they were found to be independent of age, height, and BMI, and could therefore be used to provide unbiased estimates of sensitivity and specificity without adjustment for these covariates. Results obtained from both disease-negative groups (Groups 2 and 3) were used to estimate sensitivity and specificity. Re-

TABLE 2
Characteristics of the Study Population Stratified by Carpal Tunnel Group—Dominant Hand

Variable	Total	Group			P
		1	2	3	
N	119	30	30	59	
Age (yrs)					
Mean	42.6	50.1	43.9	38.2	<.001
SD	11.6	11.8	12.6	8.7	
Height (cm)					
Mean	168	166	169	169	NS
SD	9.6	7.4	10.3	10.2	
BMI (kg/m^2)					
Mean	25.3	28.5	26.1	23.3	.003
SD	5.7	5.6	7.1	3.9	
Sex (%)					
Female	71.6	83.3	60.0	69.5	NS

TABLE 3
Characteristics of the Study Population Stratified by Carpal Tunnel Group—Nondominant Hand

Variable	Total	Group			P
		1	2	3	
N	119	27	28	64	
Age (yrs)					
Mean	41.8	49.0	42.1	38.9	<.001
SD	10.9	11.7	10.9	9.1	
Height (cm)					
Mean	168	167	167	169	NS
SD	9.6	11.7	10.3	9.9	
BMI (cm/kg^2)					
Mean	25.3	27.6	27.0	23.5	0.01
SD	5.4	5.0	7.1	3.9	
Sex (%)					
Female	72.3	81.5	71.4	68.6	NS

sults obtained from asymptomatic, electrophysiologically normal subjects (Group 3) were considered "best-case" estimates, and those obtained from symptomatic, electrophysiologically normal subjects (Group 2) were considered "worst-case" estimates.

Predictive value positive (probability of disease when the test is positive) and predictive value negative (probability of absence of disease when the test is negative) were estimated from the observed sensitivities and specificities for a range of prevalences.

Results

Subjects

A total of 144 subjects were recruited. Of those recruited, 119 met criteria for inclusion in one of the three hand-condition groups and were included in the analyses. Demographic characteristics of the study subjects are presented for the total study group (N = 119) and stratified by hand-condition group for the dominant and nondominant hands in Tables 2 and 3. For the dominant hand, 30 subjects met the criteria for Group 1, 30 for Group 2, and 59 for Group 3. For the nondominant hand, 27 subjects met the criteria for Group 1, 28 for Group 2, and 64 for Group 3. A total of 57 hands met criteria for Group 1, 58 for Group 2, and 123 for Group 3. A significant difference was observed between the three hand-condition groups for both mean age and mean BMI for the dominant and nondominant hands. No significant differences were observed between the three groups for height, sex, and percentage of right-handedness.

TABLE 4
Mean Dominant Hand Vibrotactile Threshold Values Before and After Wrist Flexion for All CTS Groups*

Variable	Group			P†
	1	2	3	
N	30	30	59	
Digit 2	.99	.75	−.24	.002
SD	1.09	1.55	.71	
Digit 5	.61	.37	−.40	.009
SD	.88	1.27	.65	
Diff 2–5	.39	.38	.16	NS
SD	.91	.97	.55	
Digit 2F	1.36	.35	−.24	<.001
SD	1.31	1.41	.73	
Digit 5F	.70	.39	−.25	NS
SD	.94	1.31	.73	
Diff 2F–5F	.67	−.04	.01	<.001
SD	1.00	.70	.51	
Delta Diff	.28	−.42	−.16	.005
SD	1.00	1.09	.58	

* Threshold in log microns.
† Statistical significance of group differences from general linear models that include age, height, and BMI as covariates.

Group Mean Threshold Values

Mean dominant-hand VT values before and after wrist flexion for all CTS groups are presented in Table 4. VTs for the index finger (Digit 2) and, surprisingly, the small finger (Digit 5), were significantly different across the hand-condition groups before wrist flexion. Group 2 thresholds for the index and small fingers were intermediate in value between thresholds of Groups 1 and 3. The differences in VT between Digits 2

and 5 before wrist flexion (Diff 2–5), a measure of difference in sensory function between cutaneous sites in the median and ulnar nerve distributions, was not significantly different across the hand-condition groups. Among subjects with CTS (Group 1), both Digit 2 and Digit 5 thresholds increased after the 10-minute period of wrist flexion, although Digit 2 increased somewhat more than Digit 5. Among Group 2 subjects, Digit 2 thresholds decreased, and Digit 5 thresholds were essentially unchanged after 10 minutes of wrist flexion. Among Group 3 subjects, Digit 2 thresholds were essentially unchanged and Digit 5 thresholds were slightly increased after 10 minutes of wrist flexion. The difference in threshold between Digits 2 and 5 after 10 minutes of wrist flexion (Diff 2F–5F) was significantly greater among Group 1 subjects than among Group 2 or Group 3 subjects. The difference in the change in Digit 2 threshold before and after wrist flexion and Digit 5 threshold before and after wrist flexion (Delta Diff) was also significantly different across the three hand-condition groups, with the largest difference observed among Group 1 subjects.

Mean nondominant–hand VT values before and after wrist flexion for all CTS groups are presented in Table 5. The overall pattern of results was similar, but not identical, to that obtained for the dominant hand. Significant differences in index finger threshold (Digit 2) were observed across the three groups, with the highest value observed among Group 1 subjects. Smaller, but still significant, differences in small-finger VT were observed across the three groups, with the highest value observed among Group 1 subjects. The difference in threshold between Digits 2 and 5 before wrist flexion (Diff 2–5) was greatest for Group 1 subjects and essentially 0 among Group 2 and Group 3 subjects. Unlike the results obtained for the dominant hand, these differences in thresholds obtained before wrist flexion (Diff 2–5) were significant across the hand-condition groups. Digit 2 thresholds increased slightly and Digit 5 thresholds decreased slightly among Group 1 subjects after wrist flexion. Small changes in threshold were also observed for the same sites among Group 2 subjects. Essentially no change in thresholds of either finger occurred after wrist flexion among Group 3 subjects. After wrist flexion, thresholds were highest for both fingers among Group 1 subjects, lowest among Group 3 subjects, and intermediate among Group 2 subjects. The difference between Digit 2 threshold and Digit 5 threshold after wrist flexion (Diff 2F–5F) was significantly different across the three carpal tunnel groups. The Diff 2F–5F was greatest among Group 1 subjects and essentially 0 among Group 2 and Group 3 subjects. The results for Delta Diff were essentially the same as those for Diff 2F–5F.

TABLE 5
Mean Nondominant Hand Vibrotactile Threshold Values Before and After Wrist Flexion for All CTS Groups

Variable	Group 1	Group 2	Group 3	P†
N	27	28	64	
Digit 2	.78	.11	−.48	<.001
SD	1.26	.98	.64	
Digit 5	.45	.11	−.45	.02
SD	.86	.99	.68	
Diff 2–5	.32	.00	−.02	.05
SD	1.02	.44	.46	
Digit 2F	1.02	.21	−.46	<.001
SD	1.59	1.05	.69	
Digit 5F	.32	.17	−.39	.05
SD	.90	1.01	.70	
Diff 2F–5F	.69	.03	−.08	<.001
SD	1.23	.45	.44	
Delta Diff	.37	.03	−.05	.002
SD	.86	.40	.37	

* Threshold in log microns.
† Statistical significance of group differences from general linear models that include age, height, and BMI as covariates.

Sensitivity and Specificity

Results from analyses to estimate sensitivities over a range of specificities for the three VT outcomes found to be independent of potentially important covariates are presented for the dominant and nondominant hands combined (Table 6). Sensitivity and specificity results are presented in each table for analyses performed using both Group 2 subjects and Group 3 subjects in comparison with Group 1 subjects. Sensitivity estimates among Group 1 subjects of threshold measures obtained after wrist flexion (ie, Diff 2F–5F and Delta Diff) were substantially better than those obtained before wrist flexion (ie, Diff 2–5). At a specificity of 80%, the sensitivity of these measures ranged from 46 to 61% (Table 6). Specificities for sensitivities greater than 90% were between 20 and 30% (Table 6). The sensitivity obtained with the Diff 2–5 outcome (ie, the difference in VT between the index and small finger *before* wrist flexion) was poor at all specificities for both dominant and nondominant hands. In general, the sensitivity of this measure was about half that of the measures obtained after wrist flexion.

Results obtained from analyses in which Group 2 subjects were used to estimate VT values corresponding to a range of specificities were similar to those obtained with Group 3.

Predictive Value

Positive predictive value and negative predictive value for two sets of observed sensitivity and specificity values were estimated for disease prevalences of 10%, 20%, and 30% (Table 7). Negative predictive values were generally high, and positive predictive values were, at best, modest in magnitude.

Discussion and Conclusions

A cross-sectional study was performed to assess the utility of VT measurement for detection of CTS. Of special interest was the possible improvement in sensitivity (at a constant specificity) that might follow a 10-minute period of wrist flexion. Significant differences were ob-

TABLE 6
Sensitivity and Specificity for Selected Vibrotactile Threshold Outcomes—Dominant and Nondominant Hands Combined

	Specificity							
	5	10	20	30	70	80	90	95
Group 2 vs Group 1 Sensitivity								
Diff 2–5	85.5	85.5	83.6	72.7	31.6	21.1	15.8	12.3
Diff 2F–5F	98.1	96.2	90.4	86.5	61.1	61.1	37.0	25.9
Delta Diff	98.1	98.1	92.3	86.5	55.6	51.9	42.6	35.2
Group 3 vs Group 1 Sensitivity								
Diff 2–5	96.4	90.9	83.6	80.0	35.1	28.1	19.3	14.0
Diff 2F–5F	98.1	96.1	92.3	86.5	61.1	57.4	44.4	33.3
Delta Diff	98.1	98.1	92.3	90.4	59.2	46.3	37.0	29.6

TABLE 7
Predictive Value Positive and Predictive Value Negative, in Percentages, for Diff 2F–5F

	Prevalence	Positive PV	Negative PV
Specificity 80%; Sensitivity 61%	10.0	25.3	94.9
	20.0	43.3	89.1
	30.0	56.7	82.7
Specificity 30%; Sensitivity 90%	10.0	12.5	96.4
	20.0	24.3	92.3
	30.0	35.5	87.5

served in VT outcomes between subjects with symptoms consistent with CTS and EP confirmation of CTS and both subjects with symptoms consistent with CTS and normal EP and subjects without symptoms consistent with CTS and normal EP results. Sensitivities observed for the VT outcomes obtained before the 10-minute wrist flexion period were poor. Those obtained after the 10-minute wrist flexion period were typically two times or more greater than those obtained before flexion but were still modest in actual value.

Estimates in the published literature of the sensitivity and specificity of VT measurement for detection of CTS are quite variable. Using multiple-frequency VT measurements without wrist flexion, Lundborg et al[18] found an abnormal result in 77% of patients considered to have CTS on clinical grounds and in 83% of patients with EP confirmed CTS. However, 54% of subjects with hand symptoms and normal EP results had an abnormal measure of VT, suggesting that the high sensitivities may have been achieved by selecting criteria for VT abnormality associated with poor test specificity.

Using methods similar to those of the current study, Borg and Lindblom[15] found that VT of the index and long fingers increased monotonically as a function of time over a 16-minute period among 100% of 12 hands with electrophysiologically proven CTS. Two of 12 hands with no electrophysiological evidence of CTS also showed an increase. In addition, significant differences in mean VT were observed between the two groups after 5 minutes of wrist flexion. In another study of quantitative sensory outcomes among subjects with CTS,[19] VTs obtained from hands categorized as having CTS were greater than thresholds obtained from the contralateral, asymptomatic hand. Inadequate information was provided to calculate sensitivity and specificity of the outcome.

A study of multifrequency vibrometry results by Jetzer[20] used only symptoms and clinical examination results to characterize CTS. Statistical methods were not adequately described in the study to allow estimation of sensitivity and specificity.

Using the same vibrometer and a different protocol for measuring VTs as used in the current study, Grant et al[21] found a significant difference in mean index finger VT among subjects with electrophysiologically proven CTS when compared with those who were asymptomatic. Results were not presented in a manner that allowed estimation of sensitivity and specificity.

VTs were measured using equipment and methods similar to those used in the current study (without wrist flexion) as part of a large government study of office workers.[22] No significant differences in mean VTs were found between "cases" and "controls" of work-related upper-extremity disorder. In addition, no significant association was observed between VTs and median nerve conduction parameters. Similarly, Merchut et al,[23] using the same device used in the current study with a different threshold estimation procedure, found no significant differences in mean VT of the index finger or in the difference between the index-finger threshold and the small-

finger threshold between subjects with electrophysiologically proven CTS and matched comparison subjects. Finally, Franzblau et al,[24] using equipment and VT estimation procedures identical to the current study, found very poor sensitivity and specificity for VTs of the index finger when performed without wrist flexion.

One methodologic issue that remains problematic in this area of research is the definition of CTS. In the current study, both symptoms and electrophysiologic evidence of disease were required for inclusion in the disease-positive group. Two disease-negative groups were used to minimize the effect that subjects with true CTS and negative EP results might have on estimates of sensitivity and specificity. These subjects apparently had little effect on the estimates, as only small differences in estimates of sensitivity and specificity were observed between the symptomatic and asymptomatic comparison groups. It should be noted, however, that use of a gold standard with less than 100% sensitivity and specificity will bias estimates of sensitivity and specificity of the method under evaluation toward lower values. If EP methods are not perfect for identification of CTS, then the estimates of sensitivity and specificity provided in the current study might be underestimates.

The results of this study allow rational application of vibrometry in epidemiologic studies of groups of individuals at risk of CTS. Large and statistically significant differences of several mean VT outcomes obtained after wrist flexion were observed between hand-condition groups in the current study. Estimates of mean VT after wrist flexion, therefore, appear useful for comparison of groups of individuals at risk of CTS. Measurement of VT may also be useful in surveillance programs to identify high-risk jobs or evaluate the effectiveness of workplace changes intended to reduce ergonomic exposures.

VTs after wrist flexion may also be useful for identifying persons who need not be referred for electrophysiologic study. For example, in a population of 100 individuals with a CTS prevalence of 10%, 27 of 28 individuals who test VT-negative would be expected to be free of CTS. Thus, a substantial proportion may be identified as being CTS-negative without using more costly and sophisticated EP methods. However, only nine of the 72 individuals who were VT-positive would actually have abnormal EP studies consistent with CTS. Thus, VT alone appears to have limited value for confirmation of CTS, for which EP study continues to be the gold standard.

Future research should be directed toward development of VT methods with less variability. Specific approaches may include development of better threshold measurement procedures as well as continuing efforts to identify important covariates. With improvements in the estimation of VT, further gains will be observed in their utility for detection of CTS.

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News Nobody Noticed

By now many of us have now read scores of reviews of *The Bell Curve*, by Charles Murray and the late Richard J. Herrnstein. Most have fiercely criticized the book's thesis, which emphasizes the centrality of IQ in lives and careers, and most have dwelt insistently on race and the 15-point black–white IQ gap. But oddly, we have yet to read a review noticing the racial news built into a table on page 324.

The table describes the employment experience of a large (about 12,500) representative sample of relatively young Americans whose lives and careers—and IQs—are being tracked by the so-called National Longitudinal Survey of Youth. The survey began in the U.S. Department of Education in 1979, when the group was mostly in its teens; today it is mostly in its 30s.

The news is about racial discrimination in America. As we all keep reading, blacks generally earn a lot less than whites, even when you compare workers of similar ages and educational backgrounds. The table confirms this finding. But it points to something else one has never before read: that when you control for age and IQ, the black–white earnings gap just about disappears. Taking nine different job categories together, you find that with age and IQ held constant, blacks earn 98% as much as whites.

The obvious implication is that at least so far as younger workers are concerned, employers no longer engage in irrational discrimination based on race. Instead they discriminate based on IQ—which is rational, given the avalanche of data linking IQ to performance in many different job markets. A fascinating question is: In a world where racial discrimination is (properly) an object of enormous concern, how can it be that we are ignoring powerful evidence of its decline?

From Seligman D. Keeping up. *Fortune,* 1994;130:12, p. 255 (December 12, 1994).