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by [Haines T](#), [Chong JP](#)

Affiliation: Occupational Health Program, McMaster University, Hamilton, Ontario, Canada.

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Peripheral neurological assessment methods for workers exposed to hand-arm vibration

An appraisal

by Ted Haines, MD, MSc, John P Chong, MD, MSc¹

HAINES T, CHONG JP. Peripheral neurological assessment methods for workers exposed to hand-arm vibration: An appraisal. *Scand J Work Environ Health* 13 (1987) 370–374. Peripheral neurological assessment methods for workers exposed to hand-arm vibration have included vibration perception and esthesiometric threshold testing, electroneurography, handgrip force, and manipulative dexterity. For epidemiologic investigations with the purpose of detecting vibration effects anticipated as moderate to large in size in occupational populations, these methods have demonstrated their usefulness. Concerning their value in the assessment of individual workers, there is little quantitative information, as there have been no studies which have conducted rigorous “gold standard” neurological evaluation with which the results of independently performed diagnostic tests can be compared. However, results from four papers which used depth-sense (or ridge) and two-point discrimination esthesiometry were available for an analysis of the sensitivity of these tests in the detection of Taylor-Pelmeur stages 2 and 3 of the hand-arm vibration syndrome. With specificity set at 90 %, sensitivity ranged from 45 to 96 % for depth-sense esthesiometry and from 19 to 75 % for two-point discrimination. In addition, likelihood ratios were determined, as a measure of the capacity of the tests to alter pretest probability of disease. Because of their direct clinical interpretation and application, the use of likelihood ratios is suggested for future research on diagnostic methods used for vibration-exposed workers.

Key terms: diagnostic tests, likelihood ratios.

For the purposes of this appraisal, we have adopted the perspective that workers do not have occupational disease. Rather, they have a probability of having occupational disease. When estimated before a diagnostic test is done, this probability can be called the “present probability” (13). The rationale for the use of a test is the expectation that it will aid in revising the estimate of the probability of occupational disease. Apart from considerations of feasibility, economy, and the utility of subsequent intervention, a test is worth doing if it can lead to a meaningful change in this estimate — that is, a “posttest probability” meaningfully different from the pretest probability.

The objectives of this appraisal are to outline the literature on the use of peripheral neurological tests for workers exposed to hand-arm vibration and to illustrate how this literature may be applied to estimate quantitatively the capacity of these tests to alter pretest probability. As the measure of this capacity, we have used the likelihood ratio. In the next section, we have defined this term and discussed its use.

The likelihood ratio: A clinical measure of the value of diagnostic tests

The probability that a worker has a particular disorder is uncommonly either exactly zero or exactly one. Rather, the worker has a probability of having the disorder which lies between these two values. On the basis of the history and physical examination, any previous investigations, one's previous clinical experience with similar situations, and the prevalence of the target disorder in the population from which the worker comes, one can estimate the probability that he or she has the disorder. As this probability can be assigned prior to the performance of the diagnostic test of interest, it is the pretest probability. With a positive result from a test known to give valuable diagnostic information, the posttest probability will be higher than the pretest probability; a negative test result will lead to a posttest probability lower than the pretest probability.

Increasingly in medicine (although to only a limited extent in occupational medicine), the likelihood ratio (LR) is being used as a measure of the value of diagnostic tests (13). It expresses the odds that a given level of a diagnostic test result would be expected in a worker with (as opposed to one without) a target disorder. Positive and negative likelihood ratios [LR(+) and LR(–)] can be calculated by the following

¹ Occupational Health Program and Department of Clinical Epidemiology and Biostatistics, McMaster University, Hamilton, Ontario, Canada.

formulas:

$$LR(+) = \frac{\text{sensitivity}}{(1 - \text{specificity})}$$

and

$$LR(-) = \frac{(1 - \text{sensitivity})}{\text{specificity}}$$

The likelihood ratio determines the magnitude of the difference between the posttest and pretest probabilities, as is evident in this formula (derived from Bayes' theorem):

$$\left[\begin{array}{c} \text{The pretest} \\ \text{odds for} \\ \text{the target} \\ \text{disorder} \end{array} \right] \times \left[\begin{array}{c} \text{The likelihood} \\ \text{ratio for the} \\ \text{diagnostic} \\ \text{test result} \end{array} \right] = \left[\begin{array}{c} \text{The posttest} \\ \text{odds for} \\ \text{the target} \\ \text{disorder} \end{array} \right]$$

Thus, with an estimate of the odds, ie, pretest probability/(1 - pretest probability), that a worker has a particular disorder and knowledge of the relevant likelihood ratio, the posttest odds can be readily calculated and converted to the posttest probability.

To illustrate the application of likelihood ratios, let us consider three hypothetical workers from a population regularly using hard-rock drills. Worker 1 is 25 years old with no risk factors for neurological or vascular disorders and three years of exposure at approximately 400 h/year. Worker 2 is 40 years old with no risk factors but 12 years of similar exposure; he reports occasional finger tingling at night and whitening of his fingertips when he swims in the summertime. Let us suppose that worker 3 is also 40 years old, has had 15 years of exposure at 1 000 h/year, has no other risk factors, but reports the year-round occurrence of whitening of most fingers upon exposure to cold, along with mild numbness of all fingers most of the time. For purposes of illustration, we can reasonably suppose, prior to carrying out any tests, that the probabilities that workers 1, 2, and 3 have vibration-associated digital sensory loss are 0.1, 0.5, and 0.9, respectively. Let us suppose further that the use of a particular diagnostic test (say, a new form of esthesiometry) is being considered for use among these workers and that the sensitivity and specificity of the test with respect to the presence or absence of digital sensory loss have been determined to be 80 and 60 %, respectively. It can be readily calculated that the LR(+) is 2 and the LR(-) is 0.33. We can now calculate the posttest probabilities associated with positive and negative test results. For worker 1, these are 0.18 and 0.04, respectively. The corresponding values for worker 3 are 0.95 and 0.75. The following question should be posed: if the test is performed, would our recommendations or management change? In the case of worker 1, with either a positive or a negative test result, he would remain at a low probability of having a vibration-associated disorder. With the new information, we would be unlikely to recommend further

investigation or reduction of exposure, beyond general preventive measures applicable to the whole workforce. Similarly, with worker 3, neither a positive nor a negative test result would materially influence our likely recommendation that further investigation be carried out and that exposure be reduced. In the case of worker 2, however, the use of this test, although it has an LR(+) and LR(-) of only modest magnitude, would influence our actions, as the posttest probability associated with a positive result is 0.67 and that associated with a negative result is 0.25. With a positive result, we would likely consider that further investigation and exposure reduction would be warranted; on the other hand, with a negative result, we may prefer to observe and repeat testing after an appropriate interval.

This example illustrates that the absolute size of the difference between posttest and pretest probabilities depends not only on the likelihood ratio, but also on the level of pretest probability.

Literature review

There is an ample body of literature concerning the usefulness of peripheral neurological assessment methods in general medical practice. However, because of the distinctive nature of the pathogenesis of the hand-arm vibration syndrome (2), we have focused attention on research conducted among vibration-exposed populations.

The literature pertaining to the use of peripheral neurological tests in these populations is steadily increasing in volume. Table 1 summarizes the methods that have been employed (and the investigators who have used them) to evaluate the acute and chronic effects of hand-arm vibration. We have excluded maneuvers that are conducted in the course of a clinical examination — the taking of a history and the performance of a physical examination.

This literature can be outlined as follows. The methods listed have been used, for the most part, in investigations of currently employed exposed and unexposed groups. While, in general, they have detected statistically significant differences in neurological status between the exposed and unexposed populations, the overlap in the distribution of the results between the groups has tended to be considerable. Although a few studies include data relating to the use of tests early in the natural history of vibration syndrome, the information available is not sufficient to permit an analysis of their usefulness in the detection of the early stages. The purposes of these investigations have been to study etiology and mechanisms, and little attention has been explicitly directed towards the usefulness of tests with respect to individuals. No studies have assessed the reproducibility or observer variability associated with these assessment methods. While, in much of the literature, there is recognition of the potential influence

Table 1. The literature^a concerning the use of peripheral neurological assessment methods to evaluate acute and chronic effects of hand-arm vibration.

	Acute effects	Chronic effects
Vibration perception threshold testing	Bjerker et al, 1980 Lidström et al, 1974, 1977, 1982 Nishiyama & Watanabe, 1981 Pyykkö et al, 1982 Verberk et al, 1985	Lidström et al, 1974, 1977, 1982 Taylor et al, 1974 Pelmeur et al, 1975 Rafalski et al, 1977 Pyykkö et al, 1982 Starck et al, 1983 Harada & Matsumoto, 1984 Lundström, 1985 Färkkilä et al, 1985
Esthesiometric threshold testing — depth sense and two-point discrimination	Verberk et al, 1985 Haines et al, 1986	Taylor et al, 1974, 1977, 1984 Pelmeur et al, 1974, 1975 Chatterjee et al, 1978 Corlett et al, 1981 Carlson et al, 1984
Pressure esthesiometric threshold testing	Hochreiter et al, 1983	None
“Light touch and pinprick” esthesiometry	None	Marshall et al, 1954
Thermoesthesiometry	None	Hirosawa, 1983
Electroneurography	None	Seppäläinen, 1970, 1972 Lukáš, 1970, 1982 Abbruzzese et al, 1977 Alaranta & Seppäläinen, 1977 Chatterjee et al, 1982 Pelnar et al, 1982 Juntunen et al, 1983
Hand steadiness	Simon, 1969	
Handgrip force	None	Färkkilä et al, 1978, 1979, 1985 Harada & Matsumoto, 1984
Manipulative dexterity	None	Banister & Smith, 1972

^a Complete references are available from the authors.

Table 2. Esthesiometric threshold testing of vibration-exposed workers: Sensitivity, specificity, and positive [LR(+)] and negative [LR(–)] likelihood ratios for the detection of the hand-arm vibration syndrome.

Study	Sensitivity (%)	Specificity (%)	LR(+)	LR(–)
Pelmeur et al (11) (Thetford population)				
Ridge test	45	90	4.5	0.61
Two-point discrimination	19	90	1.9	0.90
Chatterjee et al (5)				
Ridge test	90	90	9.0	0.11
Two-point discrimination	76	88	6.3	0.27
Corlett (8)				
Corlett ridge test	96	90	9.6	0.044
Carlson et al (4)				
Depth-sense perception	77	91	8.6	0.25
Two-point discrimination	37	89	3.4	0.71

of vibration on sensory receptors and nerves, no studies have used specific strategies to delineate the definitive or “gold standard” state of neurological disease (9, 13) on the basis of careful clinical evaluation and the use of appropriate adjunct investigations. In numerous studies, however, the status of the populations investigated neurologically has been determined with respect to the presence or stage of vibration syndrome; in these, the Taylor-Pelmeur classification (15) has been used for this determination.

On the whole, for epidemiologic investigations with the purpose of detecting vibration effects anticipated to be moderate to large in magnitude, the methods listed in table 1 have demonstrated their usefulness.

In order to illustrate how the literature can be applied in a quantitative evaluation of the usefulness of peripheral neurological tests in individuals, we have selected publications to examine in more detail, on the basis of the following criteria: (i) independent determination of target variable status, (ii) appropriate selection of affected and unaffected groups, (iii) sample size greater than or equal to 10 per group, and (iv) sufficient information presented to permit determination of the cut-off value associated with 90 % specificity.

The lack of literature delineating “gold standard” neurological status does not prevent our carrying out this illustrative evaluation, since the studies which have diagnosed vibration syndrome can be used for this purpose. As the Taylor-Pelmeur classification amalgamates the vascular and neurological elements of vibration syndrome, it is a safe assumption that an appraisal of the value of a neurological test in its assessment will underestimate the value of the test in the assessment of peripheral neurological status. [Recently proposed classification systems (1, 10) attempt to dissociate these elements of the syndrome.] In any case, such an evaluation, based on these studies, is of intrinsic interest, as neurological tests have been considered potentially useful in the diagnosis of the syn-

drome itself (14). Because the results of these studies have been presented the most consistently for stages 2 and 3 of the Taylor-Pelmeur classification, the following analysis is restricted to these stages.

Next we would like to elaborate briefly on the application of and rationale for the aforementioned selection criteria. Although the independence of the assessment of the hand-arm vibration syndrome from the use of the diagnostic test in question was not explicitly stated in the studies selected, one can be confident that this criterion was met, because the staging of the syndrome is generally based on an analysis of a separately performed history and physical examination. For present purposes we accepted unaffected vibration-exposed workers or nonvibration-exposed workers from a socioeconomically similar industry as comparison populations. Groups of students or academic or laboratory personnel were not considered acceptable, as inherent population differences could confound the evaluation of these tests. The criterion of a sample size of at least 10 subjects in each of the unaffected and affected groups was intended to confer a minimum level of stability to the estimates of sensitivity and likelihood ratios. As a basis for comparison across different studies, we considered it useful to set specificity at a particular level (90 %) and determine what the sensitivity and likelihood ratios would be in association with this level of specificity. In order for this criterion to be met, in general, there was a need for information concerning the distribution of the results of the diagnostic test in the affected and unaffected groups.

Five papers listed in table 1 met these criteria: Pelmeur et al (11), Chatterjee et al (5), Corlett (8), Carlson et al (4), and Chatterjee et al (6). The first four of these relate to esthesiometric threshold testing, and the last one is concerned with electroneurography. We elected, therefore, to focus the analysis on the first four of these publications. The reader should refer to these for details concerning the nature of vibration exposure, sample size, nature of the reference groups, and measurement methods.

In a study of workers using chipping hammers and grinders, Carlson et al (4) utilized depth perception and two-point discrimination esthesiometry. The instruments used were modifications (3) of esthesiometers originally developed by Renfrew (12). The results for the index, middle, and ring fingers from both hands were presented in the form of histograms, which made it simple to determine the approximate esthesiometric value among the referents, which corresponded to 90 % specificity. We applied this value to the distributions for stage 2 and 3 subjects to determine the sensitivities and thus the LR values. The results of this analysis are shown in table 2.

The instruments designed by Renfrew were used in the studies of Chatterjee et al (5) and Pelmeur et al (11).

Chatterjee et al (5) studied drill-using fluorspar miners. By the criteria for abnormality given in the text, the results of the reference group indicated that the specificities of ridge and two-point discrimination esthesiometry were 90 and 88 %, respectively (meeting the fourth criterion for inclusion of this paper in the present analysis). The sensitivities and LR values are shown in table 2 for the index fingers of both hands.

Of the numerous vibration-exposed groups studied by Pelmeur et al (11), the results for the Thetford population (chain-saw operators) were selected for analysis in this paper because they contained the greatest number of stage 2 and 3 subjects. The results were presented as means and standard deviations of the ridge test and two-point discrimination results for the left index, left middle, right index, and right middle fingers. For each test, the value associated with 90 % specificity was determined by calculating, for all fingers combined, the point 1.28 standard normal deviates above the mean value of the reference group (7). We used this point in the distributions for the stage 2 and 3 group to determine the sensitivities and LR values. The results are shown in table 2.

Corlett (8) used a new esthesiometer, based on the principle of the ridge test, to study vibration-exposed workers, consisting mainly of grinders. Results consisting of means and standard deviations were presented for the left index, left middle, right index, and right middle fingers. The procedures to determine the specificity, sensitivity, and LR values, outlined for the data of Pelmeur et al (11), were applied to the results of Corlett's investigation. The results are shown in table 2. (Our application of these procedures required assumptions concerning the normality of distributions and the homogeneity of variance, which could not be analyzed fully because of lack of detail in the published data. However, even moderate violations of these assumptions would not substantially alter the findings shown.)

The sensitivities, LR(+) and LR(-), show considerable differences in magnitude in the four studies and for the two types of esthesiometry. The sensitivities range from 45 to 96 % for depth-sense esthesiometry and from 19 to 76 % for two-point discrimination. Some of these differences may be attributable to differences in type of reference subject used, in the specific digits included in the results, in the number of replications performed per digit, and in the mix of stage 2 and 3 subjects. However, this analysis shows the the depth-sense (or ridge) esthesiometer performed consistently better than the two-point discrimination esthesiometer. The likelihood ratios associated with the depth-sense esthesiometer are sufficiently different from 1.0 that its use would usually result in meaningful differences between posttest and pretest probabilities, even with rather low or high pretest probabilities.

In summary the peripheral neurological assessment methods listed in table 1 have generally been used successfully in epidemiologic studies to detect vibration-

associated effects in populations of workers. Because of the lack of research relating the use of diagnostic tests to "gold standard" neurological status, little is known concerning the usefulness of these methods in the assessment of individuals. The limited relevant literature on vibration syndrome was used in this appraisal to illustrate how LR values may be estimated, as a measure of the capacity of a test to alter pretest probability. Because of their direct clinical interpretation and application, the use of LR values is suggested for future research on diagnostic methods for vibration-exposed workers.

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