ORIGINAL ARTICLE

# COMPARISON OF DIAGNOSTIC METHOD OF EVALUATING VIBRATION INDUCED SENSORINEURAL IMPAIRMENT AMONG SHIPYARD'S GRINDERS

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## ABSTRACT

*The objectives of this study are to investigate diagnostic value of two different tests amongst tests highly recommended and used for diagnosis of HAVS of the sensorineural component; Semmes Weinstein Monofilament (SWM) and Purdue Pegboard (PP) tests using vibrotactile perception threshold (VPT) test as standard objective quantitative test. For the method, a total of 176 grinders as vibration exposed respondent of a shipyard's fabrication participated in this study. Questionnaire and vibration exposures data were collected for all respondents where 67 respondents further performed the three quantitative sensorineural testing. The result showed that mean acceleration magnitude of grinding tools used were 4.9 ms-2, exceeding recommendation by European Commission. Both cut-off point methods of mean plus two times standard deviation (mean + 2sd) and z-score (at 75th percentile) show significant difference among healthy and HAVS (p < 0.001). Correlation between SWM with VPT and PP with VPT was weak. However, results suggests progressive pathological damage to sensorineural component of the digits starts with fast-adapting II (FA II) mechanoreceptors indicated with significant correlation primarily at 125 Hz. Analyses of sensitivity and specificity found that monofilament at 0.16g force best discriminate HAVS from healthy. In the other hand, Purdue Pegboard test shows best diagnostic value of indicating HAVS at minimum insert of 16 pin and 14 pin respectively for dominant and non-dominant hand. Both Semmes Weinstein Monofilament and Purdue Pegboard tests has limited diagnostic value to be used as screening tools for early detection of HAVS.*

***Keywords:*** HAVS, VPT, monofilament, Purdue Pegboard, sensitivity, specificity

## INTRODUCTION

During the past decades, investigation into cohorts of longitudinally exposed to occupationally hand transmitted vibration primarily via the hand held power tools, had been evidently causing a series of symptoms, impairment and disorders prominently of the vascular, sensorineural and/or musculoskeletal component known as the hand-arm vibration syndrome – HAVS[1, 2].

Accompanying the term 'HAVS' was the Stockholm Workshop Classification Scales (reference), a scoring system of consensus rating revised from Taylor-Palmear stage classification which is based primarily on subjective symptoms[3, 4], in assessment of two types of disorders – the vascular and sensorineural symptoms[1, 5].

While vibration white finger of the vascular component in HAVS can be visually distinguished, injuries to the peripheral nerve fibre at fingertips involving mechanoreceptors in the distal digits of the sensorineural component in HAVS often is vaguely distinguished from Technically, correlation among these tests as well as their sensitivity and specificity for vibration induced disorder are insufficiently reported[2, 12, 14].

entrapment neuropathies such as carpal tunnel syndrome[6, 7].

Among common presentation of the neurological symptoms of HAVS are such as numbness, tingling, reduced tactile and thermal perception, impaired dexterity as well as grip strength[9, 10]. As such, a wide range of clinical and laboratory tests have evolved to become available over the years to assist the diagnosis objectively[8, 10, 11], supplemented by documentations of detailed medical records, occupational details and social history as well as differential diagnosis through clinical presentation of signs and symptoms[12].

Although ISO committee needs a complete assessing method of manual dexterity due to HAVS, there is lack of evidence in the use of a single tool (i.e VPT). While there are no single objective testing that may be deemed 'gold standard' as to evidently confirm presence of HAVS[2, 13], selection of these tests, using either a single test or in combination particularly for diagnostic value of vibration induced neuropathies was not justified.
This study aim to determine the sensitivity and specificity of Semmes Weinstein Monofilament and Purdue Pegboard as diagnostic method in early detection of HAV induced sensorineural

impairment among workers exposed to hand transmitted vibration.

**METHODS**

This was a cross sectional study conducted among 176 grinders working in construction and fabrication division of a shipyard. The 176 male grinders participated in the preliminary study (first phase) answers a detailed modified questionnaire by Su et al. (2008) in collecting basic information on socio-demographic, occupational history, life-styles and past medical history.

Of the 176 grinders, 25 respondents were excluded as they possess characteristic of the exclusion criteria; confounding medical history and age (>45 years old). From the 151 respondents left, 72 respondents were conveniently sub-sampled for further testing of quantitative objective measurement of aesthesiometry using vibrotactometer, Semmes Weinstein Monofilament and Purdue Pegboard tests.

In addition, the frequency weighted acceleration magnitude of tools used was measured using dBMaestro® Human Vibration Meter on 5 types of grinders used by all subjects viz; 4-inch grinder, electrically powered pencil grinder, pneumatic pencil grinder and 7-inch grinder.

**Experimental Condition**

As was specified by ISO 13091-1, the conduct of the objective tests was performed in a quiet room of controlled environmental temperature of 26-29ºC measured with a room thermometer. Subjects are being rested and allowed to acclimatize while at the same time being briefed on tests procedure. Additionally, it was ensured that subjects did not expose at least 3 hour prior to the quantitative objective measurement of aesthesiometry tests to possible confounding factors such as cigarette, alcohol and vibration exposures. Skin temperatures measured at the start of each session using an infrared thermometer were greater than 27ºC.

**Vibrotactile perception threshold test (VPT)**

Fingertip mechanoreceptor-specific vibrotactile threshold is determined using a vibrotactometer, VPT model P8 Pallesthesiometer – EMSON-MAT[17]. Perception threshold of both hands was measured on pulps of index and little finger using the von Bèkèsy algorithm method[16, 17] at 2 frequencies as were mediated by the fast adapting type I population (FAI; 31.5Hz) and fast-adapting type II population (FAII; 125Hz) mechanoreceptors respectively[17, 18].

With arm rested, subjects' fingertips were placed on the VPT probe (vibrator) with force of 0.1N where both the indicator light on the vibrotactometer went off[17]. Concurrently, the other hand holds the response button where subjects were required to depress and hold the button as soon as they felt the slightest vibration on their fingertips and releases immediately when the vibration was no longer felt.

The vibration thresholds were recorded by the software of the vibrotactometer where magnitude of the vibration at the probe increases from standstill until it was felt and when responded by subjects, decreases with depressing of the response button continuously until it was no longer felt. This iterative process creates a sinusoidal pattern until subjects threshold was averaged[17, 19].

**Semmes Weinstein Monofilament**

Semmes Weinstein Monofilament test evaluates the cutaneous sensitivity towards perception of light touch/pressure where touch thresholds of subjects were assessed primarily at the pulp of the similar digits bilaterally as tested using VPT. Using modified test strategy[20], random monofilament test (RMT) was employed using 7 filament with each filament force of 0.04g, 0.07g, 0.16g, 0.4g, 0.6g, and 1.0g respectively where the recorded value were immediate response of first stimulus or two out of three repetition. All subjects were seated and arm rested on a flat surface with palm/fingertips face upwards. After test procedures are explained, the subjects were then blindfolded with a sleep eye mask. Tests performed undertake the similar area or region of tests in the VPT session. Each filament was pressed at 90° angle against the fingertips' skin until the filament starts to bend for 1 – 2 second[21].

**Purdue Pegboard**

The Purdue Pegboard[22] test was chosen as its capability of measuring two types of activity in evaluating manipulative dexterity; gross movement of the fingers, hand and arm as well as fingers dexterity in fine precision insertion task as designed. The first task, involves insertion of pegs into holes using first the dominant hand only, followed by non-dominant hand, then both hand simultaneously, all three in 30 seconds and finally assembling pegs, collar and washer in 60 seconds.

*Quality control and statistical analysis*

Prior to measurement of all equipment is calibrated ac-cording to manufacturer standard protocol, maintained appropriately and tested. Pre-test result of questionnaire reveals α-Cronbach value of 0.7. All data, including measurement of hand-arm vibration frequency weighted acceleration magnitude (analyzed by dBMaestro – 01dB Environment Suite software), vibrotactile perception threshold of respondent as computed by P8 Pallesthesiometer – EMSON-MAT and questionnaire variables were computed and analyzed using Statistical Package for Social Sciences (SPSS Version 14).

The cut-off point defining HAVS were determined using 2 methods; mean plus two times standard deviation (mean+2SD) and z-score method. At mean+2SD, respondent with VPT at or more than 95th percentile were considered as abnormal defining HAVS. In the other hand, cut-off point of z-score method defining HAVS were set at 75th percentile. Independent t-test were used to compare mean VPT between healthy and HAVS while ANOVA with Bonferroni post-hoc test were used to compare mean of different categorical grinding tools. In order to investigate correlation of different tests in this study, Spearman rank correlations were used whilst sensitivities and specificities (Equation 1) were calculated using 2 by 2 contingency tables (Table 1).

**Table 1: Contingency table for calculation of sensitivities and specificities**

| | | VPT | |
|---|---|---|---|
| | | ***Positive*** **(HAVS)** | ***Negative*** **(Healthy)** |
| **Semmes Weinstein Monofilament/ Purdue Pegboard tests** | ***Positive*** | True Positive (TP) | False Positive (FP) |
| | ***Negative*** | False Negative (FN) | True Negative (TN) |

$$\textbf{Specificity} = \frac{\text{True negative (TN)}}{\text{Number of true negative (TN)} + \text{Number of false positive(FP)}}$$

$$\textbf{Sensitiviy} = \frac{\text{True positive (TP)}}{\text{Number of true positive (TP)} + \text{Number of false negative (FN)}}$$

**Equation 1: Calculation formula for sensitivity and specificity**

**Data collection procedures**

Assisted questionnaire was conducted to 176 respondents in two separate session coordinated by the shipyard’s management gathering all grinders. Respondent were later followed up in their fabrication job site during their task in order to obtain measurement on hand-arm vibration frequency weighted acceleration magnitude.

The vibration measurements of tools were conducted for at least 60 second of respective tools used by each worker at the point of time during the follow-up. The result were later extrapolated by calculating the A (8) using the data of estimated duration of tools used/operated daily queried in the questionnaire.

From the total respondent, respondent was then purposively selected to proceed to second phase of data collection; objective testing using VPT test, SWM and Purdue Pegboard aside performing Phalen’s test, height and weight measurement. The data collection procedure flow chart is as shown in Figure 1.

Due to strict time constrain and in addition to avoid interruption to productivity as advised by shipyard’s management, all three tests were conducted simultaneously to three respondents in rotation ensuring conformance to protocol of standard operating procedure by manual as well as ISO 13091-1.

**Ethics**

This research has been approved by the Ethics Committee of the Faculty of Medicine and Health Sciences, Universiti Putra Malaysia.

**RESULT**

**Background of respondents**

The respondents in this study were all male working as grinder in the fabrication sites of the shipyard. The main focus of our study group of 67 respondents’ mean age was 28.9 ± 7.79 years old where the mean service duration was 2.6 years. Result from questionnaire also indicates that 70.1% of them were non-smokers.

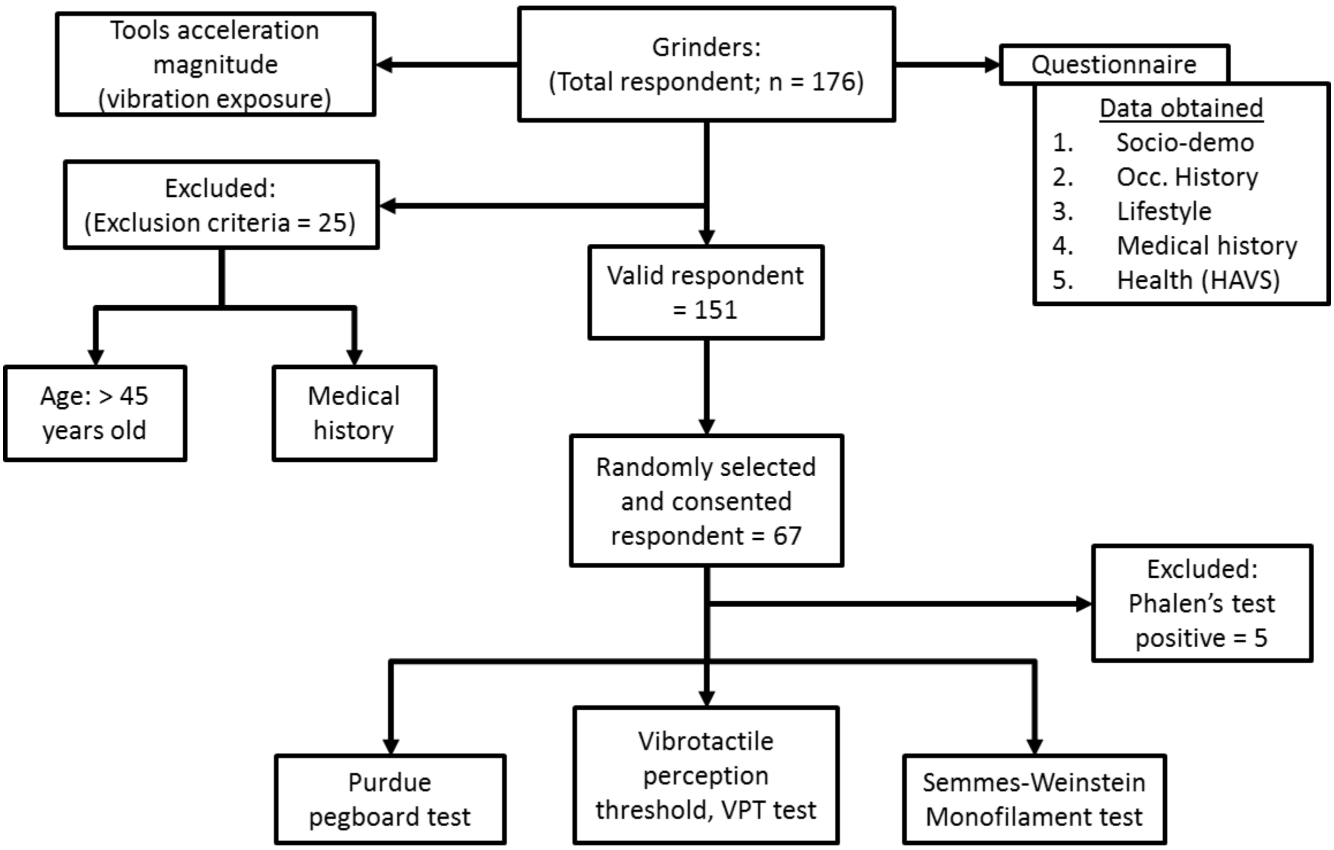


**Figure 1: Data collection flowchart**

**Exposures to hand-arm vibration**

From the result in Table 2, the mean acceleration magnitude for 8 hours, A(8) of grinding tools among the grinders was 4.96 ±1.95 $m/s^2$. Comparing across types of tools, ANOVA shows A(8) of 7-inch grinder were significantly different ($p < 0.0001$) than A(8) of other grinding tools while mean acceleration magnitude of pneumatically driven pencil grinder was also significantly different to electrically driven pencil grinder.

**Vibrotactile perception threshold**

Results in Table 3 shows that z-score at 75th percentile used as cut-off point of VPT defining HAVS were better than the use of mean+2SD. Although both methods show significant difference among healthy and HAVS, z-score method achieve higher significance difference ($p < 0.0001$).

**Association of measures using different tests**

Results in Table 4 shows that significant correlation of VPT vs. monofilament test found was weak for non-dominant index finger and little finger ($r = 0.282$; $r = 0.250$ respectively) both at 125 Hz similarly for VPT vs. Purdue Pegboard test at dominant hand little finger and non-dominant hand little finger ($r = 0.287$; $r = 0.249$ respectively) both also at 125 Hz.

*Sensitivity and specificity in determining diagnostic value of Semmes Weinstein Monofilament and Purdue Pegboard test with VPT*

The best cut-off for defining HAVS using monofilament were at 0.16g force for all finger tested at respective frequencies. In the other hand, result in Table 5 and Table 6 shows cut-off point of Purdue Pegboard defining HAVS were 16 pins and 14 pins for dominant and non-dominant hand respectively.

In comparison of tests, Purdue Pegboard shows better combination of sensitivity and specificity than monofilament of both hands respectively.

**Table 2: Acceleration magnitude according to types of tools**

| | N | Mean (s.d) | Minimum | Maximum | F | p |
|---|---|---|---|---|---|---|
| Normal[a] | 112 | 4.83 (1.56) | 1.450 | 9.170 | 10.702 | 0.0001*** |
| Pencil grinder[a] | 13 | 3.71 (1.68) | 1.720 | 7.070 | | |
| Pneumatic pencil grinder[a,b] | 10 | 5.80 (2.08) | 2.140 | 9.470 | | |
| 7 inch grinder[c] | 7 | 8.16 (3.88) | 3.340 | 13.380 | | |
| Total | 142 | 4.96 (1.95) | 1.450 | 13.380 | | |

a, b and c multiple comparison with Bonferonni post-hoc method
*** significant at $p < 0.001$

## DISCUSSION

Although there was no deemed gold standard test for diagnosis of HAVS2, 13, the use of vibrotactile perception threshold test for diagnosis of sensorineural component of HAVS has been well defined in various studies23, 24, 25, 26. Findings in these studies shows reduced sensory perception among vibration exposed workers significantly.

However, in many countries, including of Malaysia, availability of VPT were strictly limited, generally only available in research settings as well as specialist referral centres considering the cost of the device and technical expertise requires for operation, interpretation and maintenance.

Many tests have been used for diagnosing HAVS, however, not much attention and concern has been invested on their sensitivity and specificity in relative to one another. Although it has been pointed out that no single test can reliably diagnose HAVS, it was still important to ensure any of these tests used were clinically valuable.

### Grinding tools acceleration magnitude

In occupational setting where fabrication was carried out, grinding was an exceptional task that subjects to continuous vibration exposures. It has also been shown in few studies27, 28, 29 that vibration acceleration magnitude of the tools operated in shipyards was usually high while some exceeding recommendation by European Directive30 (ED) on vibration standard as is this study.

This study has found that the vibration acceleration magnitude exceeds the action limit of $2.5m/s^2$ and approaches exposure limit of $5.0m/s^2$ as were recommended by ED.

Among different types of grinding tools, 7-inch grinder was significantly higher as compared to other grinding tools. However, it was not the most frequently and continuously used as compared to other grinding tools due to its special heavy duty purposes it serves.

### Vibrotactile perception threshold test

Regardless of method, comparison of VPT among respondents exposed to vibration shows significantly higher VPT among HAVS, as categorized according to cut-off point established. This directly indicates that in the HAVS group, sensorineural impairment was shown among the respondent.

In this study, response of HAVS respondent in determining their VPT shows evidence of reduced tactile sensitivity of mechanoreceptors towards vibrotactile stimuli with significant difference of mean VPT clearly demarcated as compared to healthy respondent explaining the correlation test result.

Weak correlation was found between VPT and monofilament as well as VPT with Purdue Pegboard test. Although the correlation was weak, it was more important that relationship was established between these tests. In addition, one study14 using 10 different tests only found moderate agreement to Stockholm Workshop Classification while study by Poole and Mason (2009) was weak.

Result in **Table 3** shows tendency of correlation were primarily at 125 Hz suggests that progressive pathological damage to sensorineural component of the digits starts with the fast-adapting II mechanoreceptors. Results also indicate that non-dominant hand was also more affected rather than the dominant hand.

**Table 3: Comparison of mean VPT values for the healthy and HAVS group as defined by two different methods**

| VPT | | | Mean + 2SD | | | | | | Z-score (75th percentile cut-off point) | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Mean (± SD) | | | | t | p | Mean (± SD) | | | | t | p |
| | | | N | Healthy | HAVS | N | | | N | Healthy | HAVS | N | | |
| Dominant hand | 31.5Hz | Index | 63 | 109.7 (7.21) | 133.5 (3.62) | 4 | -6.532 | 0.001*** | 50 | - 0.4111 (0.5976) | 1.3644 (0.7540) | 17 | -9.89 | 0.0001*** |
| | | Little | 64 | 117.2 (10.96) | 147.4 (2.76) | 3 | -4.720 | 0.001*** | 49 | - 0.4663 (0.6318) | 1.2672 (0.6533) | 18 | -9.87 | 0.0001*** |
| | 125Hz | Index | 64 | 110.4 (7.06) | 130.8 (0.85) | 3 | -20.153 | 0.001*** | 50 | - 0.4519 (0.6589) | 1.3291 (0.5295) | 17 | -10.08 | 0.0001*** |
| | | Little | | 118.5 (11.58) † | | | | NA | 50 | - 0.4332 (0.7352) | 1.2751 (0.3836) | 17 | -12.07 | 0.0001*** |
| Non-dominant hand | 31.5Hz | Index | 66 | 109.0 (7.99) | 135.2 (0) | 1 | -3.253 | 0.002** | 50 | - 0.4609 (0.6222) | 1.3555 (0.5687) | 17 | -10.62 | 0.0001*** |
| | | Little | 64 | 117.2 (10.96) | 147.4 (2.76) | 3 | -4.720 | 0.001*** | 50 | -0.4593 (0.6251) | 1.3509 (0.5746) | 17 | -10.52 | 0.0001*** |
| | 125Hz | Index | 64 | 108.9 (8.04) | 129.4 (2.34) | 3 | -4.377 | 0.001*** | 50 | - 0.4515 (0.6553) | 1.3280 (0.5447) | 17 | -10.06 | 0.0001*** |
| | | Little | 65 | 114.5 (9.57) | 138.1 (2.62) | 2 | -3.456 | 0.001*** | 50 | - 0.4238 (0.7271) | 1.2464 (0.5425) | 17 | -8.67 | 0.0001*** |

† no respondent has threshold values higher than cut-off

** significant at $p < 0.01$

*** significant at $p < 0.001$

N = 67

**Table 4: Correlation of VPT to Monofilament and Purdue Pegboard**

| VPT | Frequency | Monofilament | | Purdue Pegboard dominant | | Purdue Pegboard non-dominant | |
|---|---|---|---|---|---|---|---|
| | | r | p | r | p | r | p |
| **Dominant index finger** | 31.5 | -0.038 | 0.760 | -0.186 | 0.132 | - | - |
| | 125 | 0.225 | 0.067 | -0.190 | 0.124 | | |
| **Dominant little finger** | 31.5 | 0.080 | 0.518 | -0.226 | 0.066 | - | - |
| | 125 | 0.197 | 0.110 | -0.287* | 0.019* | | |
| **Non-dominant index finger** | 31.5 | 0.233 | 0.058 | - | - | -0.105 | 0.397 |
| | 125 | 0.282* | 0.021* | | | -0.249* | 0.042* |
| **Non-dominant little finger** | 31.5 | 0.205 | 0.096 | - | - | -0.218 | 0.076 |
| | 125 | 0.250* | 0.041* | | | -0.221 | 0.072 |

* Correlation is significant at the 0.05 level (2-tailed).

**Table 5: Sensitivity and specificity of monofilament and Purdue Pegboard according to abnormality as defined by the vibrotactile perception threshold (z-score at 75th percentile) test for dominant hand**

| Semmes-Weinstein Monofilament | | Dominant hand | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | Index Finger | | | | Little Finger | | | |
| Lowest force perceived | | VPT31.5 | | VPT125 | | VPT31.5 | | VPT125 | |
| Normal | Abnormal | Sensitivity | Specificity | Sensitivity | Specificity | Sensitivity | Specificity | Sensitivity | Specificity |
| 0.04 | > 0.04 | 100 | 3 | 100 | 3 | 67 | 3 | 0 | 4 |
| ≤ 0.07 | > 0.07 | 75 | 10 | 67 | 9 | 67 | 9 | 0 | 10 |
| ≤ 0.16 | > 0.16 | 75 | 24 | 67 | 23 | 67 | 27 | 0 | 27 |
| ≤ 0.4 | > 0.4 | 0 | 79 | 0 | 80 | 33 | 88 | 0 | 87 |
| ≤ 0.6 | > 0.6 | 0 | 94 | 0 | 94 | 0 | 97 | 0 | 97 |
| ≤ 1.0 | > 1.0 | 0 | 100 | 0 | 100 | 0 | 100 | 0 | 98 |
| **Purdue Pegboard** | | **Dominant hand** | | | | | | | |
| | | **Index Finger** | | | | **Little Finger** | | | |
| **Lowest force perceived** | | **VPT31.5** | | **VPT125** | | **VPT31.5** | | **VPT125** | |
| **Normal** | **Abnormal** | **Sensitivity** | **Specificity** | **Sensitivity** | **Specificity** | **Sensitivity** | **Specificity** | **Sensitivity** | **Specificity** |
| ≤ 18.7 | > 18.7 | 100 | 0 | 100 | 0 | 100 | 0 | 100 | 0 |
| ≤ 17.7 | > 17.7 | 82 | 4 | 88 | 6 | 83 | 4 | 94 | 8 |
| ≤ 17.0 | > 17.0 | 82 | 16 | 76 | 14 | 78 | 14 | 82 | 16 |
| ≤ 16.5 | > 16.5 | 82 | 32 | 76 | 30 | 72 | 29 | 76 | 30 |
| ≤ 16.0 | > 16.0 | 76 | 44 | 65 | 40 | 72 | 43 | 71 | 42 |
| ≤ 15.7 | > 15.7 | 59 | 50 | 59 | 50 | 61 | 51 | 65 | 52 |
| ≤ 15.0 | > 15.0 | 53 | 62 | 59 | 64 | 56 | 63 | 65 | 66 |
| ≤ 14.0 | > 14.0 | 35 | 82 | 29 | 80 | 39 | 84 | 35 | 82 |
| ≤ 13.0 | > 13.0 | 12 | 90 | 6 | 88 | 11 | 90 | 12 | 90 |

**Table 6: Sensitivity and specificity of monofilament and Purdue Pegboard according to abnormality as defined by the vibrotactile perception threshold (z-score at 75th percentile) test for non-dominant hand**

| Semmes-Weinstein Monofilament | | Non-dominant hand | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | Index Finger | | | | Little Finger | | | |
| Lowest force perceived | | VPT31.5 | | VPT125 | | VPT31.5 | | VPT125 | |
| Normal | Abnormal | Sensitivity | Specificity | Sensitivity | Specificity | Sensitivity | Specificity | Sensitivity | Specificity |
| 0.04 | > 0.04 | 88 | 4 | 94 | 6 | 94 | 6 | 94 | 6 |
| ≤ 0.07 | > 0.07 | 82 | 12 | 94 | 16 | 88 | 26 | 94 | 28 |
| ≤ 0.16 | > 0.16 | 71 | 34 | 82 | 38 | 71 | 40 | 76 | 42 |
| ≤ 0.4 | > 0.4 | 18 | 90 | 24 | 92 | 12 | 94 | 6 | 92 |
| ≤ 0.6 | > 0.6 | 6 | 100 | 6 | 100 | 6 | 98 | 6 | 98 |
| ≤ 1.0 | > 1.0 | 0 | 100 | 0 | 100 | 0 | 100 | 0 | 100 |
| **Purdue Pegboard** | | **Non-dominant hand** | | | | | | | |
| | | **Index Finger** | | | | **Little Finger** | | | |
| **Lowest force perceived** | | **VPT31.5** | | **VPT125** | | **VPT31.5** | | **VPT125** | |
| **Normal** | **Abnormal** | **Sensitivity** | **Specificity** | **Sensitivity** | **Specificity** | **Sensitivity** | **Specificity** | **Sensitivity** | **Specificity** |
| ≤ 18.7 | > 18.7 | 100 | 0 | 100 | 0 | 100 | 0 | 100 | 0 |
| ≤ 16.7 | > 16.7 | 88 | 6 | 88 | 6 | 88 | 60 | 82 | 4 |
| ≤ 16.1 | > 16.1 | 76 | 18 | 82 | 20 | 76 | 18 | 76 | 18 |
| ≤ 15.3 | > 15.3 | 76 | 30 | 82 | 32 | 76 | 30 | 71 | 28 |
| ≤ 15.0 | > 15.0 | 71 | 36 | 82 | 40 | 76 | 38 | 71 | 36 |
| ≤ 14.3 | > 14.3 | 71 | 52 | 76 | 54 | 71 | 52 | 59 | 48 |
| ≤ 14.0 | > 14.0 | 65 | 58 | 71 | 60 | 59 | 56 | 53 | 54 |
| ≤ 13.0 | > 14.0 | 53 | 72 | 59 | 72 | 53 | 72 | 35 | 66 |
| ≤ 12.7 | > 12.7 | 41 | 84 | 41 | 84 | 47 | 86 | 29 | 80 |
| ≤ 11.0 | > 11.0 | 18 | 92 | 24 | 94 | 18 | 92 | 24 | 94 |

According to study by McGeoch et al. (1994), sensorineural damage was found to be the greatest for forefinger and little finger examined and was most likely to receive maximum damage. However, Coughlin et al. (2001) in their study during personal observation has noted that right handed respondent tend to hold vibrating tools with their left hand closer to the source of vibration which explain the degree of difference in their results.

**Semmes Weinstein Monofilament**

The result of this study shows that using Semmes Weinstein Monofilament, the inability of detecting monofilament at 0.16g force was best suggestive to vibration induced sensorineural impairment for both dominant and non-dominant hand. Therefore, if a respondent were able to detect the monofilament at force of 0.16g, it indicates that the worker is healthy from HAVS.

In contrast, inability to detect monofilament at force of 0.16g can be interpreted as being possible HAVS while in event of non-responsive towards monofilament of the next higher force of 0.4g indicates high probability of HAVS. Nevertheless, comparison to study Poole and Mason (2009) shows better combination of sensitivity and specificity at monofilament of 0.2g force monofilament.

Despite lower diagnostic value it should be however noted the method used was different besides monofilament of different force used (0.2g vs 0.16g).

Besides that, the use of z-score for establishing cut-off point of VPT seems to improve diagnostic result as were reported in this study similarly in study by Poole and Mason (2009).

Thus, either monofilament of 0.16g or 0.2g force can equally be used to for preliminary screening or diagnosis in combination with another test of HAVS.

**Purdue Pegboard**

The use of Purdue Pegboard shows slight variation of results for different hand. The results indicate that respondent who performed 16 pins and less with their dominant hand are considered HAVS and vice versa while less than 14 pins insert with non-dominant hand indicates possibilities of HAVS, vice versa.

These results shows that the grinders in this study performed better than respondent in study by Rui et al. (2008) which found significantly lower Purdue Pegboard test score among vibration exposed of forestry (dominant hand: 14 pin; non-dominant hand: 13 pins) and stone workers (dominant hand: 13 pins non-dominant hand: 13 pins) compared to control.

There have been numbers of study which investigate the impairment of manipulative dexterity among vibration exposed workers.

While it was not conclusive or significant to affect Purdue Pegboard test result in temporary threshold studies[34, 35], other studies[33, 36, 37] has shown deterioration of manipulative dexterity with study by Necking et al. (2002) emphasizing complexity of motor function loss in vibration-exposed workers.

**Diagnostic value**

The use of monofilament shows best diagnostic value at force of 0.16g detecting HAVS while Purdue Pegboard with minimum pin insert of 16 pins and 14 pins for dominant and non-dominant hand respectively. However, results for both tools used in this study were regardless of limited diagnostic power due to combination of sensitivity and specificity as were shown.

Nevertheless, in situation where both tests are available (Semmes Weinstein Monofilament and Purdue Pegboard) and can be used simultaneously, the combination of results they produced would give greater diagnostic power. This may give a more definitive diagnosis of presence of HAVS.

For examples, if monofilament test indicates that one does not perceive the force at 0.16g and that performance of Purdue Pegboard was 16 pins or less on the dominant hand, it indicates very high probability of sensorineural impairment attributable to HAVS of the neurological disorder in event of evident vibration exposure.

Similarly, for the non-dominant hand, if the respondent did not perceive monofilament at force 0.16g and performed 14 pins or less were indicative also of HAVS.

**Conclusion**

The results of diagnostic value of different tests in this study were inconclusively absolute. Weak correlation was found among tests where further study with of greater numbers of respondents should be conducted. In addition, further study attempt is advised to be designed as case control study involving healthy vibration exposed group and healthy unexposed group.

Nevertheless, it is found in this study that the A(8) estimated from this study exceeds recommended action value of $2.5m/s^2$ similarly in various study requires intervention in fabrication shipyards.

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