ORIGINAL ARTICLE

Prevalence of hand-arm vibration syndrome among tyre shop workers in Kelantan, Malaysia

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Abstract

Background: Prolonged exposure to hand-arm vibration is associated with a disorder of the vascular, neurological, and musculoskeletal systems of the upper limb known as hand-arm vibration syndrome (HAVS). Currently, the evidence of HAVS in tropical environments is limited.

Objectives: To determine the prevalence and severity of HAVS among tyre shop workers in Kelantan, Malaysia.

Methods: A cross-sectional study involving 200 tyre shop workers from two districts in Kelantan was performed. Part one data were collected at the field using questionnaire, and hand-arm vibration was measured. Part two involved a set of hand clinical examinations. The workers were divided into high (≥ 5 m s^{-2}) and low/moderate (< 5 m s^{-2}) exposure group according to their 8-hr time weighted average [$A(8)$] of vibration exposure. The differences between the two exposure group were then compared.

Results: The prevalence of the vascular, neurological, and musculoskeletal symptoms was 12.5% (95% CI 10.16 to 14.84), 37.0% (95% CI 30.31 to 43.69), and 44.5% (95% CI 37.61 to 51.38) respectively. When divided according to their exposure statuses, there was a significant difference in the prevalence of HAVS for all three components of vascular, neurological, and musculoskeletal (22.68% vs 2.91%, 62.89% vs 12.62% and 50.52% and 38.83%) respectively. All the clinical examinations findings also significantly differed between the two groups with the high exposure group having a higher abnormal result.

Conclusion: Exposure to high $A(8)$ of vibration exposure was associated with a higher prevalence of all three component of HAVS. There is a need for better control of vibration exposure in Malaysia.

KEYWORDS
hand-arm vibration, hand-arm vibration syndrome, musculoskeletal diseases, neurological manifestation, occupational health, vascular diseases

1 | INTRODUCTION

Hand-Arm Vibration Syndrome (HAVS) is a disorder of the vascular, neurological, and musculoskeletal systems of the upper limbs associated with prolonged and repeated exposure to hand-arm vibration (HAV).[1] Workers mainly in the manufacturing, mining, forestry, and construction industries are at risk of developing HAVS as their work involves the handling of pneumatic and electric vibrating tools.[2] Available local evidence for construction workers, grass cutters, foresters, and traffic police riders states that HAVS is a major occupational health problem for Malaysian workers, with a prevalence ranging between 15% and 30%.[3-5] Due to rapid industrialization, urbanization, and lack of good quality public transportation in most major cities, the number of cars in Malaysia is increasing rapidly.[6] Therefore, there has been an increase in demand for car maintenance services, including tyre services. Tyre shop workers use an impact wrench to tighten and loosen the nuts on the wheel during their daily work, which exposes them to HAV. However, the burden of HAVS among tyre shop workers in Malaysia has not been studied yet.

Based on the 2010 Malaysia National Labour Force Statistics Report, it is estimated that more than four million workers in Malaysia are exposed to HAV.[7] There is currently no national legislation in Malaysia to protect workers against occupational HAV exposure, unlike for occupational noise exposure, which is regulated. The number of cases reported to the Social Security Organisation, Malaysia (SOCSO) under the item "diseases caused by vibration (disorders of muscles, tendons, bones, joints, peripheral blood vessels, or peripheral nerves)" has increased from just 34 in 2010 to 160 in 2015.[8] Currently, HAVS is the second most common disease caused by a physical agent that is reported to the SOCSO, after noise-induced hearing loss, and the actual number of cases might be higher due to under-reporting and lack of surveillance.[8] Department of Occupational Safety and Health (DOSH) has released Guidelines on Occupational Vibration in 2003 that was aimed at increasing the awareness of employers and employees to the effects of vibration on the human body. Meanwhile, a European Directive has set an exposure limit of 5 m s^{-2} and an action value of 2.5 m s^{-2} for hand-transmitted vibration in the workplace for European Union countries.[9]

Symptoms of HAVS include finger blanching and coldness, paraesthesia, pain in the hands, loss of manual dexterity, and weakness of hand muscles.[10] However, studies have found that clinical features of HAVS in terms of the occurrence of vibration white finger are less common in warm countries than in temperate countries.[11] Therefore, finger coldness is often used as a surrogate for vascular disorders among workers in a warm climate environment, as the surrounding temperature is not cold enough to induce vibration white finger.[12] The objectives of this study were (a) to determine the prevalence of HAVS and (b) to compare the severity of HAVS between high exposure and low-moderate exposure groups among tyre shop workers in Kelantan, Malaysia.

2 | METHODS

We conducted a cross-sectional study in Kelantan, Malaysia, between March 2018 and July 2018. Kelantan has a tropical climate, with temperatures ranging from 21°C to 32°C, and has intermittent rain throughout the year. The sample size was calculated for both objectives. For the first objective, sample size was determined by using a single proportion formula. For the second objective, PS Software version 3.1.6 was used. α was set at 0.05 and power at 80%. The sample size was increased by 10% for dropout rate giving the required sample size of 200 workers for this study.

Two-stage simple random sampling was applied. In the first stage, two out of ten districts were selected by simple random sampling. In the second stage, a simple random sampling procedure was applied to select 200 workers from 87 registered tyre shops from the two municipalities. We included workers who were at least 18 years of age and had been involved in tyre changing using an impact wrench for at least one year. Workers with a history of injury or surgery with residual complications involving muscles, vessels, nerves, and bony structures of the hands, forearms, and arms were excluded.

2.1 | Data collection

Data collection was conducted in two phases. In phase one, all subjects were interviewed using a validated Malay Translated Hand-Arm Vibration Syndrome Questionnaire.[13] This questionnaire consists of seven parts, which include basic demographic information, occupational history, social history, medical history, detailed information on vibration exposure including duration of usage of vibratory tools, type of tools, frequency, and other vibration exposure during leisure time. During the interview, information on HAVS symptoms was obtained. Following the interview, HAV was measured in all 200 subjects while they were using an air impact wrench during their normal working conditions.

The HAV was measured using a Larson Davis HVM100-Human Vibration Meter (Larson Davis, USA) by a qualified operator conforming to ISO standards 5349-2:2001.[14] A triaxial SEN040F accelerometer was used. Figure 1 shows the settings of the accelerometer and vibration meter for measurement of HAV exposure from impact wrench. The accelerometer was firmly clamped to the tool using a metal hose clip and care was taken to ensure that the accelerometer did not impede the controls of the hand tool. As
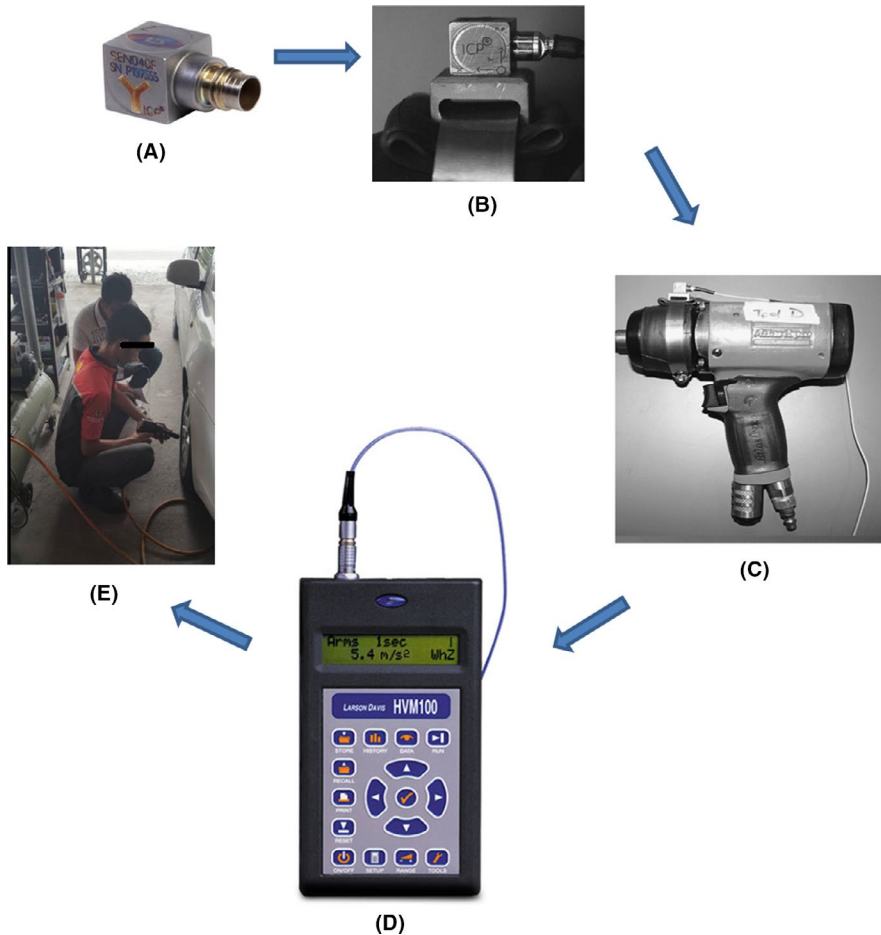
FIGURE 1 Settings of accelerometer and vibration meter for measurement of hand-arm vibration exposure from an impact wrench. (A) SEN040F triaxial accelerometer. (B) Arrangements of the accelerometer, aluminium mounting block and metal hose clamp. A layer of rubber was placed under each hose clamp to prevent direct current shifting (C) placement of the mounting block and accelerometer on the impact wrench as advised by ISO 5349-2:2001 (D) accelerometer was connected to HVM 100 which carried out signal processing and calculations and displayed the results on the LCD screen. (E) Measurement of hand-arm vibration on the field

the measurement of percussive vibration tools often yields significant drift (DC shifts) and overloading in the accelerometer output, a thin layer of rubber was placed underneath the accelerometer mounting blocks and hose clamps. This provided mechanical filtering for overloading and direct current (DC) shifts.[15] The accelerometer was connected with CBL158, a four-pin cable to the human vibration meter. The signal cables were taped to the impact wrench as near as the mounted accelerometer as possible. This was done to reduce any unnecessary cable movement as this can interfere with the signal due to a phenomenon known as "triboelectric effect".[16] The workers were asked to keep tightening and loosening the nuts on the wheel for measurements to be taken for 60 seconds and repeated three times before calculating the average value.

In the second phase of data collection, all subjects were invited to Hospital USM in Kelantan, Malaysia. There was a minimum interval of 12 hours from last exposure to HAV and the commencement of the clinical examinations. Three specific hand function assessments were carried out: the Purdue Pegboard Test (Lafayette, USA) for hand dexterity examination, Semmes-Weinstein Monofilament test (Stoelting, USA) for finger sensation measurement, and Two-Point Discrimination Disk test (McKesson, USA)

for tactile discrimination measurement. For the Purdue Pegboard test, the discrimination threshold for an abnormal finding was one standard deviation below the normative population mean for male maintenance and service employee data (15.49 for right hand, 15.25 for left hand, 12.31 for both hands, 43.04 for right+left+both, and 38.71 for assembly).[17] The Semmes-Weinstein Monofilament test was recorded as abnormal if the subject's threshold response was 3.61 mm and above.[18] For the two-point discrimination test, any value at and above 6 mm was recorded as abnormal.[18]

2.2 | Data analysis

The prevalence and 95% confidence interval for finger whiteness, coldness, tingling, numbness, musculoskeletal problems of upper limbs, musculoskeletal problem of the neck, and hand grip weakness was calculated. The $A(8)$ of HAV exposure of each subject were then calculated based on the following equation [14]:

$$A(8) = a_{hv}\sqrt{Ti/8}, \tag{1}$$

where a_{hv} is the total vibration value for the impact wrench and T_i is the daily duration of exposure to vibration in hours. The

frequency-weighted root mean square accelerations in the x axis, y axis, and z axis gives the value of a_{hv}.

Tyre shop workers were then divided into two groups according to vibration exposure limit as set by European Directive 2002/44/EC of 5 m s^{-2}: high exposure group and low-moderate exposure group.[13] Subjects with $A(8)$ of HAV exposure of 5 m s^{-2} or more were categorized into high exposure group, while those with $A(8)$ of less than 5 m s^{-2} were categorized as low-moderate exposure. Data analysis was carried out using SPSS version 24.0. The differences between the two groups were compared using univariate analysis to determine if the differences seen are statistically significant. The univariate analysis used was Independent T-Test and Mann-Whitey U test for numerical data according to their normality distribution and Pearson Chi-Square analysis for categorical data. The significance level for all statistical tests was set at 0.05 unless otherwise stated.

2.3 | Ethics

Written informed consent was obtained from each subject before the commencement of both phases of data collection. Each subject was also provided with a standardized and approved information sheet that explained the details of the study. Ethical approval was obtained from the Human Research Ethics Committee (JEPeM), Universiti Sains Malaysia with JEPeM Code: USM/JEPeM/17110582.

3 | RESULTS

3.1 | Characteristics of the workers

A total of 200 tyre shop workers fulfilled the study criteria and consented for participation. Mean (SD) age of the study participant was 31.9 (11.33) years old. Education wise, 76.5% had secondary education, and 21.0% had tertiary education, and the remainder had primary level education. Nearly all the workers were from Malay ethnicity (88.5%). The previous injury to the upper limb and neck area without residual complications was reported by 24 (12%) workers. The most frequent injury was a fracture of radius and/or ulna bone on the nondominant hand. Most of the workers (82.5%) were right-handed. More than half (61.5%) of the workers self-reported as current smokers, 31% self-reported as a non-smokers, and 7.5% self-reported as ex-smokers. The mean (SD) BMI of the workers were 24.7 (5.31) kg/m^2. The median (IQR) of working in tyre shop workers was 48 (86) months with 10% of the workers having spare time activities after work that exposed the hands to HAV more than 1 hour per week. The mean (SD) of the vector sum of vibration magnitude of the impact wrench in this study was 16.6 (6.10) ms^{-2}. Duration of using an impact wrench

in a day had a mean (SD) of 70.2 (34.95) minutes/day. The mean (SD) of $A(8)$ for HAV exposure for the entire study population was 6.0 (3.55) ms^{-2}. About 25% of all the workers were aware that long-term exposure to HAV could have a detrimental effect to their hands and arms, and only 6% were aware of any device that can protect their hands from HAV. Only 11% of the workers were provided gloves by Personal Protective Equipment (PPE). However, only five were provided with certified anti-vibration gloves, while the rest of the workers were provided with regular rubber gloves.

3.2 | Characteristics of the workers according to their hand-arm vibration

Table 1 compares the basic characteristics of the two exposure groups. The mean (SD) $A(8)$ of HAV exposure for the high exposure group compared to low-moderate exposure group were 8.6 m s^{-2} (3.33) vs 3.4 m s^{-2} (0.90).

3.3 | Prevalence of hand-arm vibration syndrome and clinical examination findings

If we considered the presence of all three vibration components including the classical vibration white finger, neurological, and musculoskeletal components, the prevalence of HAVS in our study was 0%. If we considered the presence of all three components including finger coldness as surrogates for the vascular component, the prevalence of HAVS was 6% among the tyre shop workers exposed to HAV. The component of HAVS with the lowest prevalence was the vascular component, followed by the neurological component. The musculoskeletal component of HAVS had the highest prevalence among the tyre shop workers. The Prevalence of Vascular, Neurological, and Musculoskeletal component of HAVS among the tyre shop workers was 12.5% (95% CI: 10.16, 14.84), 37.0% (95% CI: 30.31, 43.69), and 44.5% (95% CI: 37.61, 51.38) respectively.

For vascular component, initially, five workers self-reported having experienced an episode of finger color change. However, a review of clinical descriptions suggests no possible case of vibration white fingers. The diagnostic criteria were based on the following criteria: (a) positive history of cold provoked episodes of well-demarcated blanching in one or more fingers; (b) the first appearance of finger blanching after the start of occupational exposure to HAV and no other causes of white fingers; (c) experience of finger blanching attacks in the last 2 years.[1] Therefore, none of the workers in this study had finger color change, compared to 12.5% who reported finger coldness. Finger numbness, a subcomponent of the neurological component was reported by 29.5% of the workers, and 20.0% reported finger tingling. Almost half (44.5%) of the

TABLE 1 Characteristics of the study subjects according to their hand-arm vibration exposure status (n = 200)

Variable	Low-moderate[a] exposure group (n = 103)	High exposure[b] group (n = 97)	P-value
	Vibration exposure, n (%)		
Age (years)[c]	30.3 (11.36)	33.8 (11.08)	0.029
Education level			
Primary	3 (2.91)	2 (2.06)	0.448
Secondary	75 (72.82)	78 (80.41)	
Tertiary	25 (24.27)	17 (17.53)	
Ethnicity			
Malay	87 (84.47)	90 (92.78)	0.125
Chinese	15 (14.56)	6 (6.19)	
Other(s)	1 (0.97)	1 (1.03)	
Body mass index (kg/m^2)[c]	24.1 (5.05)	25.5 (5.50)	0.058
Smoking status			
Current smoker	52 (50.49)	71 (73.20)	0.001
Ex-smoker	7 (6.80)	8 (8.25)	
Non-smoker	44 (42.72)	18 (18.56)	
For current smoker			
Smoking duration (y)	10 (13.00)[d]	10 (11.00)[d]	0.540[e]
Number of cigarettes/days	12 (10.00)[d]	10 (10.00)[d]	0.615[e]
Alcohol consumption			
Yes	13 (12.62)	4 (4.12)	0.041
No	90 (87.38)	93 (95.88)	
Chemical exposure at the workplace			
Yes	21 (20.39)	20 (20.62)	
No	82 (79.61)	77 (79.38)	0.968
Employment duration (months)	36.0 (69.00)[d]	60.0 (104.00)[d]	0.002[e]
Duration using impact wrench (minutes/day)[c]	34.9 (16.96)	107.7 (62.40)	<0.001
Long term medical illness			
Yes	7 (6.80)	11 (11.34)	0.262
No	96 (93.20)	86 (88.66)	
Spare time activities that made hands vibrate			
Yes	6 (5.83)	14 (14.43)	0.043
No	97 (94.17)	83 (85.57)	
A(8)[f] (ms^{-2})[a]	3.4 (0.90)	8.6 (3.33)	<0.001

Note: Chi-square analysis was used for categorical data and independent *t*-test for numerical data unless stated otherwise
[a]$A(8) < 5$ m/s^2.
[b]$A(8) \geq 5$ m/s^2.
[c]Mean (SD).
[d]Median (IQR).
[e]Mann–Whitney *U* test.
[f]$A(8)$ = 8-hour time weighted average of hand-arm vibration exposure.

workers reported symptoms of the musculoskeletal problem of the upper limb, as compared to 15.5% for the musculoskeletal problem of the neck and 2.5% reported of hand grip weakness. For the clinical examination of the hands,

24.5% (95% CI: 18.54, 30.46) of the workers had abnormal Purdue Pegboard Test (manipulative dexterity), 28.0% (95% CI: 21.78, 34.22) had abnormal Semmes-Weinstein Monofilament Test (light touch sensation), and 18.0% (95%

TABLE 2 Comparison of the prevalence of hand-arm vibration syndrome and clinical examination findings among tyre shop workers with high exposure versus low-moderate exposure to hand-arm vibration (n = 200)

Variable	Vibration exposure, n (%)		
	Low-moderate[a] exposure group (n = 103)	High exposure[b] group (n = 97)	*P*-value
Vascular component	3 (2.91)	22 (22.68)	<.001
Finger color change	0 (0.00)	0 (0.00)	NA[c]
Finger coldness	3 (2.91)	22 (22.68)	<.001
Neurological component	13 (12.62)	61 (62.89)	<.001
Finger tingling	4 (3.88)	36 (37.11)	<.001
Finger numbness	11 (10.68)	48 (49.48)	<.001
Musculoskeletal component	40 (38.83)	49 (50.52)	.017
Musculoskeletal problem of the upper limbs	40 (38.83)	49 (50.52)	.097
Musculoskeletal problem of the neck	12 (11.65)	19 (19.59)	.121
Hand grip weakness	0 (0)	5 (5.15)	.020
Clinical examination			
Abnormal dexterity	14 (13.59)	35 (36.08)	<.001
Abnormal light touch sensation	8 (7.77)	48 (49.48)	<.001
Abnormal two-point discrimination	6 (5.83)	30 (30.93)	<.001

Note: Chi-square analysis was used to compare between the exposure groups.
[a]$A(8) <5$ m/s^2.
[b]$A(8) \geq 5$ m/s^2.
[c]NA = Not applicable.

CI: 11.78, 24.22) had abnormal Two-Point Discrimination Disks Test (tactile discrimination).

3.4 | Comparison of the prevalence of hand-arm vibration syndrome and clinical examination findings between the two exposure groups

Table 2 shows the comparison of prevalence of HAVS and clinical examination findings among the workers according to their HAV exposure status. There were no cases of vibration white finger recorded for both the exposure group. There was a significant difference in the prevalence of all three components of HAVS and the three clinical examinations between the two exposure groups. About 12 (12.4%) of the high exposure group and 4 (3.88%) of the low-moderate exposure group were suspected of having CTS.

For musculoskeletal component, there was no significant difference in the subcomponent of the musculoskeletal problem of the upper limb and neck. Only hand grip weakness had a significant difference between the two exposure groups. However, the prevalence of workers reporting this was very low with only 5.15% in the high exposure group and none

in the low-moderate exposure group. The most frequently reported upper limb and neck symptoms were pain and stiffness.

4 | DISCUSSION

Vascular component of HAVS is classically associated with blanching of fingers or occurrence of vibration white fingers.[4] None of this study population developed blanching of fingers which only occurred when exposed to cold conditions. Studies have shown, that clinical features of HAVS in terms of occurrence of vibration white fingers in warm countries are very low than those of the temperate countries.[4] A systematic review of studies conducted in temperate countries reported prevalence rates of finger blanching of vascular components to be between 15% and 71% as compared to tropical countries where the prevalence of finger blanching reported tends to be less than 5%.[19]

It seems that blanching of fingers is mostly precipitated by cold temperature. Therefore, finger coldness is often used as a surrogate for vascular disorders among workers in a warm climate environment as the temperature is not cold enough to induce vibration white fingers.[12] Taking into consideration

both blanching of fingers and finger coldness as symptoms of the HAVS vascular component, its prevalence in this study population was 12.5%. This finding is congruent with a systematic review of vibration white finger in tropical countries, where the prevalence of vascular component was found to be between 10% and 30%.[19]

About one-third (37.0%) of the subjects of this study had symptoms of the neurological component of HAVS. This is higher than the reported 25% prevalence of neurological component among car mechanics in Sweden.[20] However, the Swedish study only considered numbness as a neurological complication of HAVS. In our study, we also included tingling in addition to numbness as a complication of the neurological component. Furthermore, the Swedish study used a different set of questionnaires which could have contributed to the differences seen in the prevalence of neurological complication of HAVS. A systematic review of HAVS among warm countries reported that both tingling and numbness are commonly considered as a complication of neurological component of HAVS with the prevalence of neurological component incorporating both symptoms ranging between 18% and 68%.[11] However, 8% of the workers also complained of tingling and/or numbness on the median nerve worsening at night and are suspected to have CTS. The relationship between HAV and CTS remains uncertain. Studies have shown that exposure to HAV increases the risk of CTS.[21,22] However, since the usage of vibratory tools requires highly repetitive movement in the hand, wrist, and forearm, it is not clear if HAV contributes to this additional risk.[22]

Of all the three components of HAVS, the musculoskeletal component is less well defined and less studied. The association between vibration exposure and musculoskeletal outcomes, despite having been reported, is still unclear due to the strong confounding effect of other ergonomic stressors related to manual work.[23] About half of the workers complained of having symptoms of a musculoskeletal component of HAVS complications. Compared to a study among auto repair mechanics in Klang Valley, this is lower as the study reported the prevalence of more than 80% musculoskeletal disorder.[24] However, the Klang Valley study used a general Standardised Nordic Questionnaire and included nine different parts of the body including lower limb, back, and thigh, while in this study only musculoskeletal problems of the upper limb and neck were included. Upper limb and neck are the major areas where musculoskeletal effects from exposure to HAV are most likely to occur.[25] A study among construction workers in Malaysia exposed to HAV reported prevalence of musculoskeletal component of HAVS as being suffered by almost half of the workers.[18] The study used the same Malay Translated HAVS questionnaire as in our study and only incorporated musculoskeletal component involving the upper limb and neck.

In our study, there was a significant difference in finger coldness prevalence between the two groups. Almost 23% of the high exposure group reported experiencing finger coldness as compared to only about 3% of the low-moderate group ($P < .001$). This finding is consistent with a study among construction workers exposed to HAV in Malaysia, where 18% of the high exposure group reported finger coldness as compared to only about 2% in the low-moderate exposure group.[18] However, the study divided the workers according to the American Conference of Governmental Industrial Hygienist (ACGIH) recommended HAV exposure limit value of 4 ms^{-2}, which is lower than the European Directive value of 5 ms^{-2} used in our study. Apart from that, finger coldness is a vague and subjective symptom and does not causes identifiable well demarcated color changes of the finger. Currently, there is no objective method to classify finger coldness. It is also not part of the severity staging for vascular symptoms of HAVS according to Stockholm Workshop Scales.

As high as 62.89% of the high exposure group complained of suffering from the neurological component of HAVS as compared to only 12.62% in the low-moderate group ($P < .001$). Both subcomponents of the neurological component of HAVS, finger tingling, and numbness showed significant differences between the two exposure group. This finding proved that if workers are exposed to $A(8)$ of HAV above the European Directive limit of 5 ms^{-2}, as much as 33.23% and 38.80% more of the workers reported symptoms of finger tingling and numbness compared to workers exposed below the European Directive limit of 5 ms^{-2}. A study done among grasscutters in Southern Region of Malaysia further supported this finding, where about 20% and 30% more of the high exposure group reported finger tingling and numbness compared to the low-moderate group.[3]

However, the grasscutters study divided the workers into high- and low-moderate exposure group according to how they worked as part-time or full-time as grasscutters. Therefore, the exact 8-hour time weighted average of HAV exposure between the two exposure groups was not known. There was no clear $A(8)$ division between the two groups. Our study population also had exposure to vibrating tools for about 11 months longer than the grasscutters. Both of this could have explained for the higher neurological damage seen among the tyre shop workers. The grasscutters also had a better awareness of the danger of HAV to the hand as compared to the tyre shop worker. About half of the grasscutters were aware of the dangers as compared to only a quarter of the tyre shop workers. Better awareness has been shown to enhance safe work behavior and, therefore, reduce the likelihood of developing an occupational disease.[26]

For the musculoskeletal component of HAVS, in overall, there was a significant difference in the prevalence of musculoskeletal complications between the two exposure groups, albeit the differences being only about 12% (50.52% vs 38.83%, $P = .017$). This finding is consistent with a study performed among auto mechanics in Klang Valley.[20] They

reported that workers were exposed to $A(8)$ of HAV above the action level of 2.5 m s^{-2} and were associated with about eight times the odds of developing musculoskeletal disorder compared to workers exposed to $A(8)$ of HAV below the action level. However, this finding was reported at action value suggested by the European Directive which is lower than the exposure limit value used in our study (2.5 m s^{-2} vs 5 m s^{-2}).[14]

Despite the significant differences in the musculoskeletal component between the two exposure groups in our study, the only subcomponent of the musculoskeletal component that significantly differed between the two groups was hand grip weakness. About 5% of the high exposure group complained of hand grip weakness while none of the low-moderate group did. HAV are known to lead to muscle damage that can cause weakness of the hand grip. A study among grasscutters found that the prevalence ratio of the grasscutters in the high exposure group was about 1.5 times more likely to report hand grip weakness than the low-moderate group.[3] A study among workers using rock-crushing equipment in Sweden further strengthened this finding, where it was reported that the rock-crushing workers had significantly lower hand grip by 7% ($P = .009$) than a group control of male policeman not exposed to HAV.[27]

For the clinical examinations carried out on the hands of the workers, there was a significant difference for all the three examinations between the two exposure groups ($P < .001$). As high as 36% of the high exposure group had abnormal Purdue Pegboard test that was used to measure dexterity as compared to only about 14% in the low-moderate group. This finding is validated by a prospective cohort study among workers exposed to HAV which reported that the Purdue Pegboard score was lower as the HAV exposure level increases during the 1-year follow-up.[28] Moreover, the same study also reported that the deterioration of the score over time was associated with worsening of the hand functions in the workers. This finding is further supported by a study among construction workers in Malaysia, where the high exposure group had 1.18 times the prevalence ratio of abnormal dexterity as compared to the low-moderate group.[18] Therefore, Purdue Pegboard test could be used not only to diagnose dexterity in workers exposed to HAV but can also be used for treatment follow-up as a cheap quantitative way to measure hand function improvement of the workers with HAVS.

Almost half of the high exposure group had abnormal light touch sensation on the Semmes-Weinstein Monofilament test as compared to less than 8% in the low-moderate exposure group. A study among construction workers in Malaysia also reported differences between the two groups with the high exposure group having higher abnormal light touch sensation than the low-moderate exposure group (56.8% vs 38.9%).[18] For two-point discrimination disk test, about 31% of the high exposure group had abnormal two-point discrimination disk test. For the low-moderate exposure group, only 6% of them had abnormal two-point discrimination disk test.

Although these findings suggest there is a possible association between the level of HAV exposure and HAVS symptoms, a causal relationship and temporality cannot be established due to the limitation of the study design. A better study design would be a cohort study. However, this would be more costly and long follow-up as median latency for the development of HAVS is believed to be 16 years with the range being between 9 months and 41 years.[29] Since the study population consisted of tyre shop workers in Kota Bharu, Kelantan, the result cannot be generalized to all tyre shop workers in Malaysia. Majority of the workers' population in this study are Malays (87%) which might be different in other states. This study used a validated questionnaire, and most of the information obtained especially on the duration and frequency of vibration exposure required the subject to recall prior information. Thus, the study is liable to recall bias. Recall bias was minimized as far as practical by checking with the shop records the number of tyres changed by the workers in a day, therefore, giving estimates of vibration exposure and by concealing the study hypothesis from the subjects. As the data collection was conducted by one interviewer, interviewer bias was possible. This was limited by using a validated standardized questionnaire. To reduce measurement bias, all vibration measurements were done by a trained technician according to ISO 5349-2:2001. The accelerometer used was calibrated annually.

In this study, there was a significantly higher proportion of workers in the high exposure group with the previous history of injury to the neck and upper limb. Although any workers with residual complications involving muscles, nerves, vessels, and bony structure were excluded, it is still possible that this might have contributed to the differences seen between the two groups in the clinical examination test. The high exposure group also had significantly higher proportion of current and ex-smokers, age, longer duration of employment, and higher duration of exposure to HAV during spare time activities, while the low-moderate exposure group had a higher percentage of workers with alcohol consumption. All these factors could have contributed to the differences between the two-exposure groups in addition to $A(8)$ of HAV exposure.

This study measured the individual HAV exposure of each worker instead of using company declared values or on representative's samples as used by some other previous studies.[4,26-28] Thus, a more accurate and precise exposure level and dose-response association can be established. According to ISO 5349-2:2001, for power tools without damping systems such as impact wrench, the location of the accelerometer is sufficient in a direction parallel to the percussive direction. However, we found that mounting the accelerometer on the tool handle interfered with the worker's grip and handling of the impact wrench. Thus, we mounted the accelerometer on the tool near the

front of the tool housing as shown in Figure 1 as advised by Mcdowell et al.[30] Mcdowell et al.[30] compared the vibration reading from an accelerometer mounted on the tool handle and tool housing for impact wrenches. They reported that the accelerometer location may not be critical for impact wrench exposure assessment, and it may be best to select accelerometer mounting location that allows for minimal interference with the hand-tool interface.[30] The findings from this study suggest, that HAVS is a significant problem even among workers in tropic countries despite lack of vibration white finger presentation. Currently, in Malaysia, there is no legislation for HAV exposure.

5 | CONCLUSION

From this study, it can be concluded that if the $A(8)$ of HAV is kept below 5 m s^{-2} as per European Directives if will have significant effect on the vascular, neurological, and musculoskeletal component of HAVS. Risk assessment of the workplace should be carried out and workers who are exposed to a high level of HAV should be placed under suitable health surveillance. Besides legislation intervention, it is important to raise awareness of the employees, employers, and health professionals on HAVS. In this study, only 25% of the workers were aware that prolonged exposure to vibration can be detrimental to their hands. It is important that such health professionals involved in health surveillance of workers exposed to HAV have the necessary expertise to carry out an adequate clinical assessment and avoid misdiagnosing symptoms of HAVS.

DISCLOSURE

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