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ORIGINAL ARTICLE

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# Factors associated with vascular and neurological complications of hand-arm vibration syndrome among tire shop workers in Kelantan, Malaysia

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**Abstract**

**Objective:** Prolonged exposure to hand-arm vibration (HAV) at the workplace is associated with hand-arm vascular syndrome (HAVS). This study aimed to determine the prevalence and the factors associated with the vascular and neurological complications of HAVS among tire shop workers in Kelantan, Malaysia.

**Methods:** A cross-sectional study involving 200 tire shop workers from two districts in Kelantan was conducted. Data were collected at the field using Malay Translated HAVS questionnaire, and hand-arm vibration was measured. Multiple logistic regression analysis was used to determine the associated factors.

**Results:** The prevalence of vascular and neurological complications of HAVS among the tire shop workers was 12.5% (95% CI: 10.16, 14.84) and 37.0% (95% CI: 30.31, 43.69), respectively. From multiple logistic regression analysis, only A(8) of HAV exposure was significantly associated with the development of vascular complications and A(8) of HAV exposure, age. and body mass index were significantly associated with the development of neurological complications of HAVS.

**Conclusion:** This study has identified that HAVS is a significant problem among workers exposed to HAV in a warm environment. A(8) of HAV exposure is significantly associated with the development of both vascular and neurological complications. Therefore, there is a need for better control of vibration exposure in Malaysia.

**KEYWORDS**

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

## 1 | INTRODUCTION

Hand-arm vibration syndrome (HAVS) is a complex disorder of the vascular, neurological, and musculoskeletal systems of the upper limbs associated with prolonged exposure to hand-transmitted vibration.[1] Those at risk of developing HAVS are mainly in the manufacturing, mining, forestry, and construction industries, whereby the work involved the handling of pneumatic and electric vibrating tools.[2] Globally, the prevalence of HAVS is believed to range from 2.5% to more than 80% depending on the duration, magnitude, type of vibration exposed as well as climatic factors.[3]

HAVS is widely studied and known in temperate countries due to the presence of its classical clinical features "vibration white finger."[3] However, HAVS prevalence and characteristics in warm countries such as Malaysia are not well established. The classical presentation of vibration white finger does not occur so commonly and, currently, there is limited literature on HAVS in warm countries.[4] Available limited local evidence in Malaysia among construction workers, grass cutters, foresters, and traffic police riders, found that HAVS is a major occupational health problem for workers exposed to hand transmitted vibration with prevalence ranging between 15% and 30%.[5-8]

Based on the 2010 Malaysia national labor force statistics reports, it is estimated that more than four million workers in Malaysia are in occupation at risk of developing HAVS.[8] There is currently no national legislation in Malaysia to protect workers against occupational HAV exposure, unlike for occupational noise exposure, which is regulated. Meanwhile, a European Directive has set an exposure limit of 5 $ms^{-2}$ and an action value of 2.5 $ms^{-2}$ for hand-transmitted vibration in the workplace for European Union countries.[9] 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.[10]

Symptoms of HAVS include finger blanching for the vascular complication, tingling, and numbness for the neurological complication, pain in the hands, loss of manual dexterity, and weakness of hand muscles for musculoskeletal complications.[11] 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.[4] 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 vasospasm that leads to vibration white finger.[12]Due to rapid industrialization, urbanization, and lack of quality public transportation in most major cities, the number of cars in Malaysia has increased rapidly.[13] Therefore, there is an increase in demand for car maintenances, including tire services. Tire shop workers use an impact wrench to tighten and loosen the nuts on the tire during their daily jobs, which expose them to hand-transmitted vibration. Currently, there is no study done on HAVS on tire shop workers, and the burden of HAVS among them is unknown. The objectives of this study were (a) to determine the prevalence of HAVS, (b) to determine the factors associated with the development of vascular complications of HAVS, and (c) to determine the factors associated with the development of neurological complications of HAVS among tire shop workers in Kelantan, Malaysia.

# 2 | METHODS

## 2.1 | Participants and settings

We conducted a cross-sectional study in Kelantan Malaysia, between March 2018 and July 2018. Kelantan has a tropical climate, with temperature ranging from 21°C to 32°C and intermittent rain throughout the year. The sample size was calculated for all three objectives. For the first objective, the sample size was determined by using a single proportion formula. For the second and third objectives, PS Software version 3.1.6 was used. $\alpha$ 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.

In the first stage, two out of ten districts were selected by simple random sampling. From the municipalities record obtained from the two districts, there were a total of 312 registered tire shops. In the second stage, a simple random sampling was applied: 87 registered tire shop workers were selected, a total of 230 tire shop workers were approached and 200 workers participated with a % participation rate of 87%. We included workers who were at least 18 years of age and had been involved in tire changing using an impact wrench for at least 1 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.

## 2.2 | Data collection

### 2.2.1 | Exposure assessment

Data were collected at the respective tire shops. All the workers that fulfilled the sampling criteria were interviewed using a validated Malay Translated Hand-Arm Vibration Syndrome Questionnaire by a single trained health professional.[14] The questionnaire consists of seven parts which included basic demographic information, occupational, social histories, medical histories, detailed information on vibration exposure including duration of usage of vibratory tools, type of tools, frequency and other vibration exposure in leisure times. For smoking status, based on the information given by the subjects, it was classified to current smoker: smoked at least once in the last 30 days and more than 100 sticks of cigarettes in their lifetime; ex-smoker: did not smoke in the past month but reported smoking 100 or more sticks of cigarettes in their lifetime and non-smoker: never smoked or smoked less than 100 cigarettes in their lifetime.[15] Body Mass Index (BMI) were measured from the height and weight given by the subjects during interview.

During the interview, information on HAVS symptoms was also obtained. Hand-arm vibration (HAV) was then measured for all the 200 subjects while they were using air impact wrench during their normal working conditions.

The HAV was measured using a Human Vibration Meter (Larson Davis HVM 100) by a qualified operator conforming to ISO standards 5349-2:2001.[16] A triaxial SEN040F accelerometer was used. The accelerometer was firmly clamped to the tool handle using a metal hose clip and care was taken to ensure that the controls of the hand tool were not impeded by the accelerometer. As the measurement of percussive vibration tools often yields significant drift (direct current 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 shifts.[16] The accelerometer was connected with a 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] Figure 1 shows the settings of the accelerometer and vibration meter for measurement of HAV exposure from an impact wrench. The workers were asked to

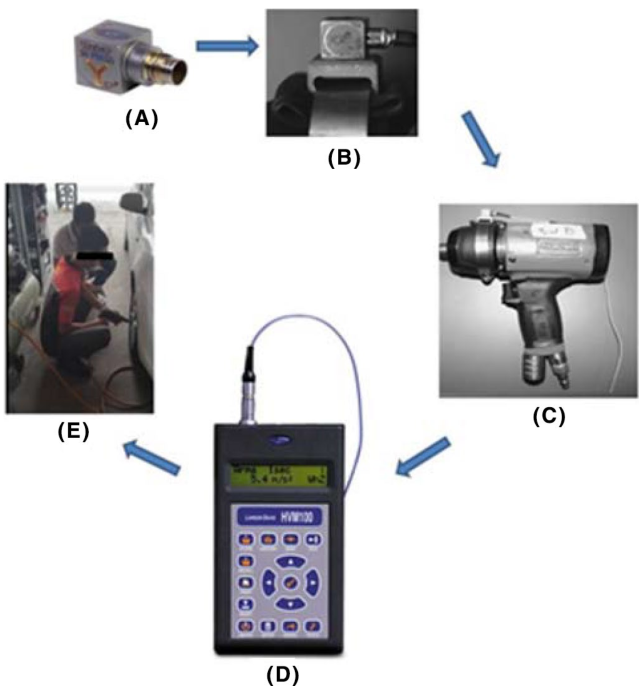


**FIGURE 1** Settings of accelerometer and vibration meter for measurement of hand-arm vibration exposure from an impact wrench. (A) SEN040F triaxial accelerometer. (B) Arrangements of the accelerometer, aluminium mounting block, and metal hose clamp. A layer of rubber was placed under each hose clamp to prevent DC 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

keep tightening and loosening the nuts on the wheel for measurements to be taken for 60 s and repeated three times before calculating the average value confirming to ISO 5349-2:2001 by a trained operator.

Firstly, the vector sum (ahv) of vibration for each worker was calculated by the vibration meter using the formula:

$$a_{hv} = \sqrt{a_{hwx}^2 + a_{hwy}^2 + a_{hwz}^2}$$

Where,

$a_{hv}$ = Vibration total value for the impact wrench (vector sum).

$a_{hwx}$, $a_{hwy}$, $a_{hwz}$ = Frequency weighted-root mean square accelerations in the x-axis, y-axis, and z-axis of vibration, respectively.

There is also minimal correction on the below equation:

$$A(8) = a_{hv}\sqrt{T_i/8}$$

Where ahv is the total vibration value for the impact wrench, and Ti 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 give the value of ahv.

### 2.2.2 | Outcome assessment

Information on HAVS vascular and neurological complications was obtained during the interviewer-guided questionnaire. Workers were asked on the presence of blanching of fingers and fingers coldness for vascular complications and finger tingling and numbness for neurological complications.[14]

## 2.3 | Statistical analysis

The prevalence and 95% confidence interval for vascular complications (finger whiteness, finger coldness) and neurological complications (finger tingling, finger numbness) was calculated.

Data analysis was carried out using SPSS version 24.0. The association between the vascular and neurological complications of HAVS with sociodemographic factors, occupational factors, social factors, and vibration factors were analyzed using simple and later multiple logistic regression analyses. For univariable analysis, simple logistic regression analysis was applied to all independent variables to determine if there was an association with vascular and neurological complications. The outcome of the vascular and neurological complications was coded with binary coding "0" for the absence of the disorders and "1" for the presence of the disorders.

Variables with a *P*-value of less than 0.25 from univariable analysis or clinically significant were selected and considered for multiple logistic regression analysis. Multiple logistic regression analysis was then performed to evaluate clinically and statistically significant factors associated with the two complications. Both vascular and neurological complications were analyzed separately, and the results were reported separately. Multicollinearity and interaction were checked for the final model. Fitness of the model was tested using Hosmer-Lemeshow goodness of fit test, classification table, and area under Receiver Operating Characteristics curve in SPSS software.

# 3 | RESULTS

## 3.1 | Characteristics of the workers

A total of 200 workers fulfilled the study criteria and consented for participation. Table 1 presents the basic characteristics of the workers. More than half (52%) of the subjects were exposed to Hand-transmitted vibration exceeding the European recommended threshold limit of 5 $ms^{-2}$.

## 3.2 | Prevalence of hand-arm vibration syndrome

The prevalence of Vascular and Neurological complications of HAVS among the tire shop workers was 12.5% (95% CI:10.16, 14.84) and 37.0% (95% CI:30.31, 43.69) respectively.

## 3.3 | Factors associated with vascular and neurological complications

Tables 2 and 3 present the simple and multiple logistic regression analysis of factors associated with vascular and neurological complications of HAVS among the tire shop workers. For vascular complications, the variables with a p-value less than 0.25 from the simple logistic regression analysis were age, smoking status, employment duration, long term medical illness, history of injury to the neck and upper limb and A(8) of HAV exposure. From multiple logistic regression analysis, only A(8) of HAV exposure ($P$ <.001) was significantly associated with the development of the vascular complications of HAVS after adjusting for other factors. For neurological complications, the variables with a p-value less than 0.25 from the simple logistic regression analysis were age, body mass index (BMI), smoking status, employment duration, long term medical illness, history of injury to the neck, and upper limb and A(8) of HAV exposure. From multiple logistic regression analysis, A(8) of HAV exposure ($P$ < .001), age ($P$ = .002) and BMI ($P$ = .048) were significantly associated with its development.

**TABLE 1** Characteristics of the Tire Shop Workers (n = 200)

| Variable | Mean ± SD | Frequency (%) |
|---|---|---|
| Age (years) | 31.9 ± 11.33 | |
| Education level | | |
| Primary | | 5 (2.5) |
| Secondary | | 153 (76.5) |
| Tertiary | | 42 (21.0) |
| Ethnicity | | |
| Malay | | 177 (88.5) |
| Chinese | | 21 (10.5) |
| Other(s) | | 2 (0.5) |
| Body Mass Index (kg/$m^2$) | 24.7 ± 5.31 | |
| Smoking Status | | |
| Current smoker | | 123 (61.5) |
| Ex-smoker | | 15 (7.5) |
| Non-smoker | | 62 (31.0) |
| For current smoker | | |
| Smoking duration (years) | 10 ± 12.00[a] | |
| Number of cigarettes/days | 10 ± 10.00[a] | |
| Alcohol consumption | | |
| Yes | | 17 (8.5) |
| No | | 183 (91.5) |
| Chemical exposure at the workplace | | |
| Yes | | 41 (20.5) |
| No | | 159 (79.5) |
| Employment duration (months) | 64.0 ± 100.00[a] | |
| Duration using impact wrench (minutes/day) | 70.2 ± 30.41 | |
| Long term medical illness | | |
| Yes | | 18 (9.0) |
| No | | 182 (91.0) |
| Spare time activities that made hands vibrate | | |
| Yes | | 20 (10.0) |
| No | | 180 (90.0) |
| History of injury to the neck and upper limb | | |
| Yes | | 24 (12.0) |
| No | | 176 (88.0) |
| A(8)[b] ($ms^{-2}$) | 6.0 ± 3.55 | |
| Awareness of vibration hazard | | |
| Yes | | 49 (24.5) |
| No | | 141 (70.0) |
| Maybe | | 11 (5.5) |

(Continues)

**TABLE 1** (Continued)

| Variable | Mean ± SD | Frequency (%) |
|---|---|---|
| Awareness of protection device | | |
| Yes | | 12 (9.0) |
| No | | 188 (94.0) |
| Provided with PPE | | |
| Yes | | 22 (11.0) |
| No | | 178 (89.0) |

*Note:* Chi-square analysis was used for categorical data and independent T-Test for numerical data unless stated otherwise

Abbreviations: SD, standard deviation.

[a]Median (IQR).; [b]A(8) = 8 hours' time-weighted average of hand-arm vibration exposure.

## 4 | DISCUSSION

Most of the workers in this study were young male with a mean age of about 32 years. As the day-to-day job of tire shops involved mainly tire changing and maintenance which included handling or lifting heavy tires and equipment, it is not surprising that this industry are mainly dominated by younger age male group. The majority (88.5%) of the workers were Malays as they are the major ethnic group in Kelantan. In Kelantan, Malays compromise of about 95% of the population.[17] The standard deviation for the duration of using wrench per day is relatively high as the duration is spread out over a wider range according to the number of tire changes done by each worker. Although the duration was normally distributed, the busier shops had a much longer duration of

**TABLE 2** Simple and multiple logistic regression analysis of factors associated with vascular complications of HAVS among tire shop workers in Kelantan (n = 200)

| Variable | Wald-Statistics | Crude OR (95% CI) | *P* | Adjusted OR (95% CI) | *P* |
|---|---|---|---|---|---|
| Age (years) | 5.070 | 1.04 (1.01, 1.08) | .018 | | |
| Education level | | | | | |
| Primary & Secondary | | 1.00 | | | |
| Tertiary | 1.479 | 0.48 (0.14, 1.67) | .247 | | |
| Body Mass Index (kg/m$^2$) | 0.709 | 1.03 (0.96,1.12) | .400 | | |
| Smoking Status | | | | | |
| Non-smoker | | 1 | | | |
| Current & ex- smoker | 6.544 | 6.00 (1.37, 26.31) | .018 | | |
| Alcohol consumption | | | | | |
| No | | 1 | | | |
| Yes | 0.700 | 0.41 (0.05, 3.26) | .403 | | |
| Chemical exposure at the workplace | | | | | |
| No | | 1 | | | |
| Yes | 0.214 | 1.26 (0.47, 3.40) | .644 | | |
| Current employment duration (months) | 5.502 | 1.01 (1.00,1.01) | .008 | | |
| Long term medical illness | | | | | |
| No | | 1 | | | |
| Yes | 6.867 | 4.29 (1.44, 12.75) | .009 | | |
| History of injury to the neck and upper limb | | | | | |
| No | | 1 | | | |
| Yes | 6.264 | 3.61 (1.32, 9.89) | .012 | | |
| A(8)[a] vibration exposure (ms$^{-2}$) | 21.184 | 1.30 (1.17, 1.46) | <.001 | 1.28 (1.14,1.44) | <0.001 |

*Note:* Constant −4.941.

Forward LR, Backward LR method applied.

No multicollinearity and no interaction.

Hosmer-Lemeshow test, *P*-value = .336.

Classification table 88% correctly classified.

Area under the receiver operating characteristic (ROC) was 82.4%.

[a]A(8) = 8 hours time-weighted average.

**TABLE 3** Simple and multiple logistic regression analysis of factors associated with neurological complications of HAVS among tire shop workers in Kelantan (n = 200)

| Variable | Wald statistics | Crude OR (95% CI) | *P* | Adjusted OR (95% CI) | *P* |
|---|---|---|---|---|---|
| Age (years) | 17.047 | 1.06 (1.03, 1.09) | <.001 | 1.05 (1.02,1.09) | .002 |
| Education level | | | | | |
| Primary&Secondary | 0.063 | 1.00 | | | |
| Tertiary | 0.197 | 0.92 (0.46, 1.85) | .822 | | |
| Body Mass Index (kg/m$^2$) | 5.982 | 1.07 (1.01,1.13) | .014 | 1.07 (1.01,1.15) | .048 |
| Smoking Status | | | | | |
| Non-smoker | 11.829 | 1 | | | |
| Ex-smoker | 1.484 | 2.09 (0.64, 6.83) | .223 | | |
| Current smoker | 11.771 | 3.29 (1.67, 6.50) | .001 | | |
| Alcohol consumption | | | | | |
| No | | 1 | | | |
| Yes | 1.180 | 0.55 (0.19, 1.62) | .277 | | |
| Chemical exposure at the workplace | | | | | |
| No | | 1 | | | |
| Yes | 0.187 | 0.86 (0.43, 1.73) | .665 | | |
| Current employment duration (months) | 18.492 | 1.01 (1.00,1.01) | <.001 | | |
| Long term medical illness | | | | | |
| No | | 1 | | | |
| Yes | 2.834 | 2.35 (0.87,6.33) | .092 | | |
| History of injury to the neck and upper limb | | | | | |
| No | | 1 | | | |
| Yes | 8.361 | 3.95 (1.56, 10.02) | .004 | | |
| A(8)[a] vibration exposure (ms$^{-2}$) | 42.552 | 1.67 (1.43, 1.95) | <.001 | 1.67(1.42,1.96) | <.001 |

*Note:* Constant −4.902.

Forward LR and Manual method applied.

No multicollinearity and no interaction detected.

Hosmer-Lemeshow test, *P*-value = .202.

Classification table 81% correctly classified.

Area under the receiver operating characteristic (ROC) was 86.5.

[a]A(8) = 8 hours time-weighted average of hand-arm vibration exposure.

impact wrench exposure as compared with the shops with fewer tire changes per day.

Only about 25% of the workers were aware that prolonged and repeated exposure to HAV from tools could have a detrimental effect on their hands. This low awareness level is most likely due to the lack of legislation to control and limit the exposure to HAV and lack of medical surveillance for workers exposed to HAV in Malaysia. The level of awareness of the availability of protective device was also deficient with only 12 workers were aware of any such device. Only 11% of the workers were provided by Personal Protective Equipment (PPE). However, only five were provided with certified anti-vibration gloves, while the rest of the workers were provided with rubber gloves.

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 with tropical countries where the prevalence of finger blanching reported tends to be less than 5%.[18] 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 complications, its prevalence in this study population is 12.5%. This finding is congruent with a systematic review of vibration white finger in tropical countries, where the prevalence of vascular component was reported to be between 10% and 30%.[18]The prevalence of neurological complications of HAVS among the workers was 37%. This number is higher than the prevalence of neurological component among car mechanics in Sweden of 25%.[19] However, the Swedish study only considered persistent numbness as neurological complications of HAVS. In this study, we also considered tingling as a complication of the neurological component. A systematic review of HAVS among warm countries reported that both tingling and numbness are commonly used as a neurological component of HAVS with the prevalence of neurological component ranging between 18% and 68%.[4] A study among shipyard workers in Malaysia reported that the prevalence of neurological component included both tingling and numbness of about 30%.[20]From multiple logistic regression analysis, only A(8) of vibration exposure was significantly associated with the development of vascular complications. With every one unit increase in A(8) of vibration exposure, the odds of developing vascular complications increased by about 1.3 times when adjusted for other factors. This is supported by a cohort study done among workers exposed to HAV that reported A(8) of vibration exposure as being the most important factors for the development of vascular complications.[21] A systematic review has done looking at 41 studies done on vibration white finger phenomenon reported that the odds were increased by about 1.09 times for every one unit increase in A(8) of vibration exposure.[22] However, almost all the studies in the systematic review were based on studies done in Europe, where the workers were exposed to cold weathers, and all the study only considered vibration white fingers as a complication of HAVS. In this study, only coldness of finger was included as the vascular complication. Therefore, a direct comparison cannot be made with a systematic review.

Multiple logistic regression analysis of factors associated with neurological complications of HAVS found that three factors were significantly associated with it. The three factors were A(8) of vibration exposure, age, and BMI. Similar to vascular complications, increased in A(8) of vibration exposure was associated with increased odds of developing neurological complications. With every one unit increased in A(8) of HAV exposure, the odds of having neurological complications was increased by 1.67 times when other factors were adjusted for. Studies among tree fellers in tropical environment showed that higher A(8) of vibration exposure level was associated with a higher presence of neurological symptoms.[23] Studies among motorcycle rider in India also reported that the incidence of neurological complications of HAVS increased with higher A(8) of vibration exposure.[7] A(8) of vibration exposure is probably the most crucial factor in the development of HAVS, and therefore currently it is being regulated in Europe.[9] Exposure to A(8) of HAV can be calculated, regulated, and monitored at the workplace.[24] Therefore reducing A(8) will have a significant effect on the development of HAVS. In Europe, the European Parliament has set the permissible exposure limit to not exceeding 5 $ms^{-2}$ and action limit when exceeding 2.5 $ms^{-2}$.[9]For every one-year increased in age, the odds of developing the neurological complications of HAVS were increased by 5%. This is congruent with a study among oil workers in the Middle East who were exposed to HAV.[25] However, Ali (2018) used a different questionnaire than this study and only taken into account finger numbness as a neurological complication. Therefore, the operational definition of neurological complications was different from this study. With increasing age, there are age-related structural and neurological changes that can cause symptoms similar to a neurological deficit caused by exposure to HAV.[26] It is also possible that some of the older workers in this group have developed medical conditions that affected their hand neurological functions but have yet to be medically diagnosed.

The odds of developing the neurological complications of HAVS were increased by 7% for every one unit increased in BMI. Studies among grasscutter workers in Malaysia reported that increasing BMI does not influence the development of neurological complications of HAVS.[5] However, another study among motorcycle rider in India reported being obese as a risk factor for HAVS.[27] A study among Finnish dentists also supported our findings. Dentists who had a BMI above 25.5 $kg/m^2$ had three times higher odds (95% CI:1.66, 6.25) of developing HAVS as compared with dentists with a BMI less than 22.5 $kg/m^2$, and dentists with a BMI between 22.5 and 25.5 $kg/m^2$ had 1.57 higher odds (95% CI:0.85, 2.91) of developing HAVS as compared with dentists with a BMI less than 22.5 $kg/m^2$.[28] However, Rytkonen et al (2006) conducted the study among female dentists as compared to our study population of male tire shop workers. Rytkonen et al (2006) also combined all three HAVS component into one set of self-administered questionnaires. Despite the fact that BMI is a risk factor in this study, the mean BMI in our study population was at a normal range of 24.7 $kg/m^2$.[29]

Although the exact effect of BMI on the development of neurological complications of HAVS is not fully understood, it has been suggested that biomechanical and metabolic factors are involved.[30] In obese subjects, there is an increased in the secretion of proinflammatory cytokines and decreased in the secretion of anti-inflammatory cytokines from the adipose tissue.[30] This is believed to promote nerve axonal damage, demyelination of the nerve and impaired nerve healing among workers exposed to HAV.[31] With increasing BMI, changes in these factors might predispose the workers to develop the neurological component of HAVS.

Although these findings suggest that 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.[31] As the study population consisted of tire shop workers in Kelantan, the result cannot be generalized to all tire shop workers in Malaysia. Majority of the workers' population in this study were Malays (84.5%) which might be different in other states. This study used a validated questionnaire, and most of the information obtained, especially on 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 shops records the number of tires 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 conducted by one interviewer, there is an element of interviewer bias. This was limited by using a validated standardized questionnaire. To reduce measurement bias, all vibration measurement was done by a trained technician according to ISO 5349-2:2001. The accelerometer used was calibrated annually. 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. Thus, a more accurate and precise exposure level and dose–response association can be established.

## 5 | CONCLUSION

In conclusion, 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. A(8) of HAV exposure was significantly associated with the development of HAVS for both vascular and neurological complications. Hence, Malaysia should consider introducing an exposure limit as implemented in European countries. Risk assessment of the workplace should be carried out with suitable health surveillance system. As this study was conducted in a limited group of workers, further research with a larger sample and broader coverage is required.

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### CONFLICT OF INTEREST

The authors declare that they have no conflict of interest.

### DISCLOSURE

*Approval of the research protocol*: Ethical approval was obtained from the Human Research Ethics Committee (JEPeM), Universiti Sains Malaysia with JEPeM Code: USM/JEPeM/17110582 and performed per the ethical standards as laid down in the 1964 Declaration of Helsinki and its later amendments or comparable ethical standards. *Informed consent*: 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. *Registry and the Registration No. of the study/Trial*: N/A. *Animal Studies*: N/A. *Conflict of Interest*: The authors declare that they have no conflict of interest.

### AUTHOR CONTRIBUTIONS

All authors met the four criteria for authorship of the ICMJE. Asraf AQ, Nik Rosmawati NH conceived the idea; Asraf AQ, Nik Rosmawati NH, Sidek MY, Hanafi MH, Zaidi MR collected the data; Asraf AQ analyzed the data; Nik Rosmawati NH supervised the process of data analysis; Asraf AQ, Nik Rosmawati NH led the writing process; Nik Rosmawati NH led the funding acquisition; Nik Rosmawati NH, Sidek MY, Hanafi MH, Zaidi MR revising and editing the manuscript.

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### REFERENCES

1. Bovenzi M. Health effects of mechanical vibration. *G Ital Med Lav Ergon*. 2005;27(1):58-64.
2. DOSH, *Guidelines on Occupational Vibration*. Putrajaya, Malaysia: Malaysia Ministry of Human Resources; 2003.
3. Su TA, Hoe VCW, Masilamani R, Mahmud ABA. Hand-arm vibration syndrome among a group of construction workers in Malaysia. *Occup Environ Med*. 2011;68(1):58-63.
4. Su AT, Darus A, Bulgiba A, Maeda S, Miyashita K. The clinical features of hand-arm vibration syndrome in a warm environment-A review of the literature. *J Occup Health*. 2012;54(5):349-360.

5. Azmir NA, Ghazali MI, Yahya MN, Ali MH. Hand-arm vibration disorder among grasscutter workers in Malaysia. *Int J Occup Saf Ergon*. 2016;22(3):433-438.
6. Su AT, Fukumoto J, Darus A, et al. A comparison of hand-arm vibration syndrome between Malaysian and Japanese workers. *J Occup Health*. 2013;55(6):468-478.
7. Diyana NurAthirah, Karuppiah K, Rasdi I, et al. Vibration exposure and work-musculoskeletal disorders among traffic police riders in Malaysia: A review. *Ann Trop Med Public Health*. 2017;10(2):334-340.
8. Department of Statistics, Malaysia. *Labour Force Survey Report*. Kuala Lumpur: Department of Statistics, Malaysia; 2010
9. Directive 2002/44/EC of the European Parliament and of the Council of 25 June 2002 on the minimum health and safety requirements regarding the exposure of workers to the risks arising from physical agents (vibration) (sixteenth individual Directive within the meaning of Article 16(1) of Directive 89/391/EEC)*European Community Environmental Law*. 2002;L177:13-20.
10. SOCSO, Annual reports 2010-2015. https://www.perkeso.gov.my/index.php/en/68-report/187-annual-report. Accessed July 10, 2019.
11. Mason H, Poole K. Evidence review on the clinical testing and management of individuals exposed to hand transmitted vibration. *Faculty of Occupational Medicine of the Royal College of Physicians*; 2004.
12. Ishitake T, Ando H. Significance of finger coldness in hand-arm vibration syndrome. *Environ Health Prev Med*. 2005;10(6):371-375.
13. Malaysia Automotive Info. Summary of sales & production data. http://www.maa.org.my/info_summary.htm. Accessed July 16 2017
14. Research network on detection and prevention of injuries due to occupational vibration exposures, guidelines for hand-transmitted vibration health surveillance. 2001.
15. Lim HK, Ghazali SM, Kee CC, et al. Epidemiology of smoking among Malaysian adult males: prevalence and associated factors. *BMC Public Health*. 2013;13(1):8. https://doi.org/10.1186/1471-2458-13-8
16. ISO 5349-1:2001 (en) Mechanical vibration-measurement and evaluation of human exposure to hand-transmitted vibration. https://www.iso.org/obp/ui/#iso:std:iso:5349:-1:ed-1:v1:en. Updated 2016. Accessed May 15, 2018.
17. Department of Statistics Malaysia, Annual reports 2017.https://www.dosm.gov.my/v1/uploads/files/4_Portal%20Content/1_About%20us/7_AnnualReport/Laporan_Tahunan_2017_DOSM.pdf. Accessed January 7, 2021.
18. Su AT, Miyashita K, Maeda S, Bulgiba A. A systematic review of hand-arm vibration syndrome in tropical countries. In *INTER-NOISE and NOISE-CON Congress and Conference Proceedings 2011*. Institute of Noise Control Engineering; 2011:253-258.
19. Barregard L, Ehrenström L, Marcus K. Hand-arm vibration syndrome in Swedish car mechanics. *Occup Environ Med*. 2003;60(4):287-294.
20. Tamrin SBM, Jamalohdin MN, Ng YG, Maeda S, Ali NAM. The characteristics of vibrotactile perception threshold among shipyard workers in a tropical environment. *Ind Health*. 2012;50(2):156-163.
21. Bovenzi M. A prospective cohort study of exposure-response relationship for vibration-induced white finger. *Occup Environ Med*. 2010;67(1):38-46.
22. Nilsson T, Wahlström T, Burström L. Hand-arm vibration and the risk of vascular and neurological diseases-A systematic review and meta-analysis. *PLoS One*. 2017;12(7):e0180795.
23. Su AT, Maeda S, Fukumoto J, et al. A cross sectional study on hand-arm vibration syndrome among a group of tree fellers in a tropical environment. *Ind Health*. 2014;52(4):367-376.
24. Ab Aziz SA, Nuawi MZ, Nor MJM. Monitoring of hand-arm vibration. *Int J Acoust Vib*. 2017;22(1):34-43.
25. Ali M. 1085 Exposure to hand-arm vibration and risk factors for HAVS amongst oil workers in the UAE. *Occup Environ Med*. 2018;75(Suppl 2):A512.
26. Mattay VS, Fera F, Tessitore A, et al. Neurophysiological correlates of age-related changes in human motor function. *Neurol*. 2002;58(4):630-635.
27. Shivakumara B, Sridhar V. Study of vibration and its effect on health of the motorcycle rider. *Online J Health Allied Scs*. 2010;9(2):1-4.
28. Rytkönen E, Sorainen E, Leino-Arjas P, Solovieva S. Hand-arm vibration exposure of dentists. *Int Arch Occup Environ Health*. 2006;79(6):521-527.
29. WHO Expert Consultation. Appropriate body-mass index for Asian populations and its implications for policy and intervention strategies. *Lancet*. 2004;363(9403):157-163.
30. Hozumi J, Sumitani M, Matsubayashi Y, et al. Relationship between neuropathic pain and obesity. *Pain Res Manag*. 2016;2016:1-6. https://doi.org/10.1155/2016/2487924
31. HaS E, ed. Health and safety laboratory. *Data mining in a HAVS referral population*. Buxton, Derbyshire: Crown; 2008.

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