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Original Article

The Relationship between Vibrotactile Perception and Chemical Exposure among Vehicle Service Technicians in Klang Valley, Malaysia

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Abstract

Background: Hazardous chemicals, which give detrimental effect to the central nervous system, are widely used in the vehicle services industry. The use of Vibrotactile Perception Threshold (VPT) as a screening tool for chemical exposure is new in developing country such as Malaysia. Therefore, this study determined the relationship between VPT and chemical exposure among vehicle service technicians in Klang Valley.

Methods: Chemical Health Risk Assessment (CHRA) was conducted in 2014 at Klang Valley Vehicle Service Centers among the technicians using the method from Department of Occupational Safety and Health (DOSH) Malaysia. HavLab Tactile Vibrometer, UK was used to determine the VPT at the fingertip for the assessment peripheral nerve impairment. Questionnaires were used to obtain the respondents' background.

Results: Results showed the Log VPT 31.5Hz & 125Hz for workers exposed to chemicals was significantly higher compared to the non-exposed workers (31.5Hz: T=4.776 (P<0.001), 125Hz: T=4.775(P<0.001)). There was significant relationship between VPT at Log 31.5Hz, Log 125Hz and overall VPT with diesel, mixture of gasoline and benzene, gasoline only, and the use of personal protective equipment.

Conclusion: The overall VPT model demonstrated that the exposure to an organic solvent and the usage of PPE contributed to vibro tactile threshold among vehicle service technicians in Malaysia.

Keywords: Chemical exposure, VPT, Vehicle service technicians

Introduction

Solvents are widely used in the industrial sector especially in manufacturing and automotive industries. There are more than 100 types of solvents widely used in this sector (1). The numerous solvent exposure will eventually effect to the central nervous system if the exposure through inhalation, dermal and ingestion is not properly controlled. VPT is one of the methods for early detection of peripheral neuropathies. The VPT method is able to screen the neurotoxic effects on peripheral nerves (2) and it is proven as very useful for evaluation of sensory nerve impairment (3). In Malaysia, there are no studies evaluated the effect of peripheral nerve impairment using VPT techniques. Most of the technique used such as Neuro Core Test Battery method (NCTB) is time consuming and have a setback of having various tests to be conducted. In addition, some of the test conducted is inaccurate when the instruction given to the patient is not clearly understood.

According to Malaysian Development Investment Authority (MIDA), Malaysia was classified as one of the countries in the south East Asia (ASEAN) having high volume of vehicles due to economic stability and high purchasing power. Due to the increasing demands of vehicles, hence, the neces-

sity for services and maintenance of vehicles, which are equally on the rise. According to Department of Statistics Malaysia (DSM), there are approximately 18, 000 service outlets for vehicle services and maintenance in Malaysia with total of 209,835 employees who are the vehicle repair technicians or mechanics most exposed to the hazardous chemicals. There are over 100 chemicals that exist in vehicle services outlets such as oil, solvent and paint. This chemicals (containing solvents) being sprayed to the vehicle surface, will then vaporized and easily inhaled into the respiratory system which could also affect the central nervous system (2, 4)

The common types of chemicals that are typically used in vehicle service industries are gasoline, diesel and mixture of gasoline and benzene (unleaded gasoline). The exposure to the gasoline, diesel and benzene will cause harm to humans especially to workers, which use these chemicals in their daily work tasks. Out of the 4 main chemicals used by the technician, gasoline, benzene and diesel (petroleum distillates) are listed as chemicals hazardous to health under the Occupational Safety and Health (Use and Standard of Exposure Chemical Hazardous to Health) Regulation, 2000 in the Malaysia Occupational Safety and Health Act (OSHA) 1994.

By using VPT method, we are able to conduct a detailed assessment on the relationship between the exposure and effect of the chemicals at subclinical stage. Therefore, the objective of this study was to determine the relationship between chemical exposure and contributing factors (i.e. age, the use of personal protective equipment, body mass index, working information and exposure to hard arm vibration) with vibrotactile perception threshold (peripheral nerve impairment) among vehicle service technicians in Malaysia.

Materials and Methods

Study Design

This study was conducted in 2014 at the 8 vehicle service outlets in the Klang Valley (located 50km from Kuala Lumpur) and the headquarters of the vehicle service outlets located in Shah Alam (located 20 km from Kuala Lumpur). This comparative cross-sectional study was conducted among 120 vehicle service technicians (occupationally exposed to solvent group) and 120 office workers (non-exposed to solvent group). Samples were randomly selected after sample size was calculated. Both groups consisted of healthy males, fulfilled the inclusion criteria namely age between 20-50 yr old, fulltime worker, and with no history of neurobehavioral related diseases. Non exposed group were selected among office workers at the headquarters of vehicle service centers. The office workers were selected due to difficulty to get a set of workers performing the same task but without the chemical exposure. In order to determine the health hazard of the office workers, hazard identification and risk assessment was carried out to identify the hazard and the risk exposed among them. Non-exposed group was not exposed to any significant type of chemical at the office, with low risk of direct exposure to vibration.

Briefing was given to all the respondents pertaining to the study and a consent letter was given for their approval.

Respondents for both exposed and non-exposed were matched in terms of age (T = 1.91, $P = 0.06$), smoking habit (χ^2 =2.59, $P = 0.611$), number of cigarettes per day (T = 0.20, $P = 0.84$), years of smoking (T = 0.13, $P = 0.90$), years of employment (T = 0.341, $P = 0.73$), daily working duration (T = 0.265, $P = 0.79$), overtime per week (T = 0.766, $P = 0.45$) and others activity outside work (painting activities ($\chi^2 = 1.44$, $P = 0.84$), gardening activities ($\chi^2 = 2.85$, $P = 0.42$), house chores ($\chi^2 = 1.96$ $P = 0.74$). Respondents were asked to complete a set of questionnaire before the test was conducted. Questions included previous and present occupations, activities at home indicating exposure to chemicals, vascular or neurological dysfunction symptoms, injuries to the upper extremities and other diseases such as skin diseases and diabetes. Respondents were also asked on the consumption of alcohol as well as smoking habit. Anthropometric measurements of weight and height were taken and the body mass index was calculated (kg/m^2). For the exposed

group, additional information pertaining to the use of personal protective equipment (PPE) such as respirator, glove, safety shoes and goggles were asked.

Hand Arm Vibration Measurement

The level of hand arm vibration acceleration magnitude was assessed among the technician using human vibration meter (HAVpro) (Larson Davies, USA). A tri-axial accelerometer embedded in an adapter was attached to the tool handle at grasping area. The magnitude of vibration was measured while workers performed their job. The accelerometer was attached to the tool handle close to the gripping area. Measurement was conducted in A (8) acceleration unit (m/s^2) r.m.s., complied with the ISO 5349-1 Standard (5).

Vibro Tactile Perception Threshold

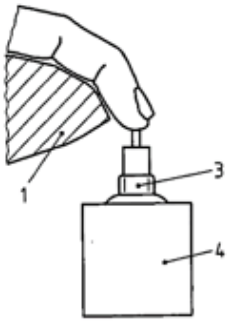
The finger skin temperature was measured on the distal phalanx before VPT measurement conducted using a non-contact infrared thermometer to avoid individual variation in vibrotactile sensitivity. Skin temperature ranged between 28 ℃ and 30 ℃. The tactile acuity at the fingertips were measured using ISO 1309-1 standard equipment (HavLab Tactile Vibrometer, UK) (Fig. 1).

The measuring system consisted of a vibrometer unit, a subject response button, a set of vibrotactile meter, working state indicators and vibrometer software. The measurement needed each respondent to sit with their forearm laying on the unit box to act as an armrest which helps to support the palm on a special support to ensure the required contact between the fingertips and the probe (Fig. 2) are aligned.

The center of the stimulating probe tip was positioned on the distal phalanx at a midway point between the center of the whorl and the fingernail (Fig. 3) to avoid contacting thick skin.

Fig. 1: Havlab Tactile Vibrometer

Fig. 2: Contact between Fingertips and Probe



Key:
1 Finger
Support
3 Sensor
4 Stimulator

Fig. 3: Measurement at the fingertips
(Source: ISO 13091-1: 2001)

The probe was pressed by the respondent's finger with a constant force of 0.1 N. Initially, the respondent will practice several times for them to familiarize the vibrating sensation at the fingertips. Von Bekesy algorithm was used by this equipment in determining the vibrotactile perception thresholds. The vibration magnitude introduced increases until the respondent was able to perceive it. The respondent pressed the response button held in the other hand until he cannot perceived the stimulus. The vibration magnitudes introduced were at frequencies of 31.5 and 125 Hz. The vibrotactile meter was equipped with an automatic test program to establish the threshold level at the selected vibration frequencies by repeating the test procedures. The value of this measurement was expressed in meters per second squared (m/s^2) r.m.s, which complies with ISO13091-2 (6).

Chemical Risk Assessment

Chemical risk assessment was conducted using chemical health risk assessment method by DOSH Malaysia to determine the chemical exposure rating. Total duration of exposure to the diesel, gasoline and mixture of gasoline and benzene was identified for each exposed respondent and then the total duration of exposure was converted into duration rating (DR). The magnitude rating (MR) was determined based on the degree of chemical release and degree of chemical absorbed or contacted for each of the chemicals. Finally, the exposure rating (ER) was determined based on the magnitude rating and duration rating.

Data Analysis

All data gathered in this study were analyzed using SPSS version 21 (Chicago, IL, USA). Data were analyzed based on the questionnaire, vibration acceleration magnitude, chemical risk rating and vibrotactile perception threshold. Descriptive analysis was used to obtain the frequency, standard deviation, mean and percentage in order to summarize and explain the general background of the respondents, employment background of the respondent and others activities outside work. The normality of distribution of continuous data was observed based on skewness analysis. Data were normally distributed as the skewness value was within -2 to +2 except for the VPT at 31.5Hz and 125Hz. Therefore, the VPT at 31.5Hz and 125Hz was transformed to Log 31.5Hz and Log 125Hz. The transformed value was normally distributed (Table 1). The score of PPE was calculated based on the types of PPE used by every respondent. Total VPT was calculated through adding the value of VPT at 31.5 Hz and 125 Hz. In order to determine the comparison of the general background, employment background, others activities outside work for both exposed and non-exposed group, independent *t*-Test was used for parametric data and Chi Square Test was used for non-parametric data.

Table 1: Normality Test for VPT at 31.5Hz, 125Hz, Log 31.5Hz & Log 125Hz

Frequency	31.5Hz	125Hz	Log 31.5Hz	Log 125Hz	Total VPT	Log total VPT
Skewness	4.386	5.735	0.774§	-0.238§	5.005	0.160

§ Value between -2 to +2

Chemical exposure rating among vehicle service technicians in different service center were compared using the Kruskal Wallis Test. The vibrotactile perception threshold for Log VPT at 31.5 Hz and 125 Hz for both exposed and non-exposed group were compared using Independent *t*-Test. Simple linear regression was used to determine the relationship between the Log VPT 31.5 Hz, 125 Hz and total VPT with the chemical exposure and others contributing factors. VPT model for total VPT was developed using multiple linear regression using variables with cut-off point of *P* value <0.25 in simple linear regression.

Results

General background and employment of respondents

The mean age for the exposed group was 30.2 yr old and non-exposed group was 28.4 yr old. The

majority of the respondents perform overtime work (exposed group, 85.7% and non-exposed group, 89.5%) and no significant different observed between exposed and non-exposed group (χ^2 = 0.76, *P* = 0.38). Most of the respondents had previous work experiences and there were no significant differences observed between exposed and non-exposed group (χ^2 = 0.01, *P* = 0.91).

Non-work activities

Both the exposed and non-exposed respondents perform painting activities (44% and 46.1%) and gardening activities (31.3% and 39.2%) for one to two times per year. There was no significant different between exposed and non-exposed group for both painting activities (χ^2 = 1.44, *P* = 0.84) and gardening activities (χ^2 = 2.85, *P* = 0.42).

Chemical exposure rating

There was no significant difference of chemical exposure ratings in all the 8 different service centers (diesel: Z=6.746(6), *P*=0.345), (mixture of gasoline and benzene: Z=4.075(6), *P*=0.667) and gasoline only: Z=10.001(6), *P*=0.125) (Table 2).

Vibrotactile perception threshold

The exposed group had significantly higher vibrotactile perception threshold at Log 31.5 Hz and Log 125 Hz compared to non-exposed respondents (31.5 Hz: T = 4.776, *P* <0.001, 125Hz: 4.775, *P* <0.001) (Table 3).

Table 2: Chemical exposure rating among vehicle service technicians in different service centers

Locations	Diesel			Mixture of gasoline and benzene			Gasoline only		
	Mean Rank	Z statistic	*P* value	Mean Rank	Z statistic	*P* value	Mean Rank	Z statistic	*P* value
A	57.50	6.746 (6)	0.345	58.94	4.075 (6)	0.667	56.67	10.001 (6)	0.125
B	58.75			58.50			42.25		
C	63.65			63.35			66.91		
D	49.50			52.39			68.25		
E	64.92			64.61			65.00		
F	54.79			54.57			57.57		
G	74.06			70.53			66.91		

Table 3: Vibrotactile perception threshold at Log 31.5 Hz & Log 125 Hz

Variables	Exposed	Non exposed	Value
	Mean(m/s²) ± SD		T (*P* value)
Log 31.5Hz	-0.4403±0.5867	-0.7670±0.3457	5.255(<0.001)
Log 125Hz	0.0177±0.6411	-0.3933±0.5439	5.355(<0.001)

Relationship between chemical exposure & others factors to VPT

There was a significant relationship for vibrotactile perception threshold at Log 31.5 Hz and Log 125 Hz with diesel, mixture of gasoline and benzene, gasoline only and score usage of PPE as shown in Table 4. No significant relationship (*P*>0.05) was observed between age, the use of respirator, body mass index, years of employment, working duration, average overtime per week and the exposure to hand arm vibration.

Based on simple linear regression on the overall VPT, there was significant relationship for Log Total VPT with diesel, mixture of gasoline and benzene, gasoline only, and score of PPE (Table 5 and Fig. 4). Adjusted for Multi linear regression, the predication model of total VPT level shows only exposure to diesel and the use of PPE were significantly associated with vibro tactile perception threshold. The overall model of vibro tactle perception threshold = -2.098+ (0.455*Diesel) + (0.012*Score use of PPE).

Table 4: Relationship between VPT at Log 31.5 Hz & 125 Hz, chemical exposure and others factors

Variables	Log 31.5Hz		Log 125Hz	
	β (95%CI)	*P* value	β (95%CI)	*P* value
Diesel	0.261 (0.098,0.721)	0.002**	0.272 (0.094,0.451)	0.003**
Mixture of gasoline and benzene	0.253 (0.093,0.413)	0.002**	0.225 (0.048,0.401)	0.013*
Gasoline only	0.235 (0.046,0.425)	0.015*	0.231 (0.021,0.438)	0.031*
Age	-0.005 (-0.010,0.10)	0.994	0.004 (-0.008,0.016)	0.550
Use of respirator	0.097 (-0.135,0.329)	0.408	0.064 (-0.190,0.317)	0.619
Score usage of PPE	0.006 (0.002,0.009)	0.002**	0.008 (0.004,0.11)	0.000***
BMI	0.004 (-0.009,0.018)	0.536	0.003 (-0.013,0.020)	0.681
Years of employment	0.004 (-0.008,0.015)	0.550	0.006 (-0.008,0.021)	0.380
Working Duration	-0.033 (-0.094,0.029)	0.295	-0.017 (-0.093,0.059)	0.656
Average overtime per week	-0.001 (-0.009,0.008)	0.866	0.005 (-0.006,0.015)	0.374
Exposure to hand arm vibration	0.005 (-0.083,0.093)	0.909	-0.074 (-0.169,0.021)	0.123

*** Significant at $P<0.001$/ ** Significant at $P<0.01$/ * Significant at $P<0.05$

Table 5: Relationship between Log Total VPT with chemical exposure and others factors

Variables	SLR[a]		MLR[b]		
	b(95%CI)	*P* value	Adjusted b (95%CI)	T statistics	*P* value
Diesel	0.533 (0.230,0.836)	0.001	0.455 (0.165,0.746)	3.104	0.002
Mixture of gasoline and benzene	0.478 (0.178,0.778)	0.002	-	-	-
Gasoline only	0.465 (0.109,0.821)	0.011	-	-	-
Age	0.004 (-0.017,0.024)	0.719	-	-	-
Score of respirator	0.161 (-0.275,0.597)	0.466	-	-	-
Score use of PPE	0.013 (0.007,0.020)	<0.001	0.012 (0.006,0.018)	3.773	<0.001
BMI	0.008 (-0.020,0.036)	0.587	-	-	-
Years of employment	0.010 (-0.014,0.034)	0.419	-	-	-
Working Duration	-0.050 (-0.178,0.078)	0.441	-	-	-
Average overtime per week	0.004 (-0.013,0.021)	0.656	-	-	-
Exposure to hand tools vibration	-0.069 (-0.234,0.955)	0.406	-	-	-

[a]Simple linear regression, [b]Multiple linear regression (R^2=0.192). Method SLR = Enter. Method MLR = Stepwise

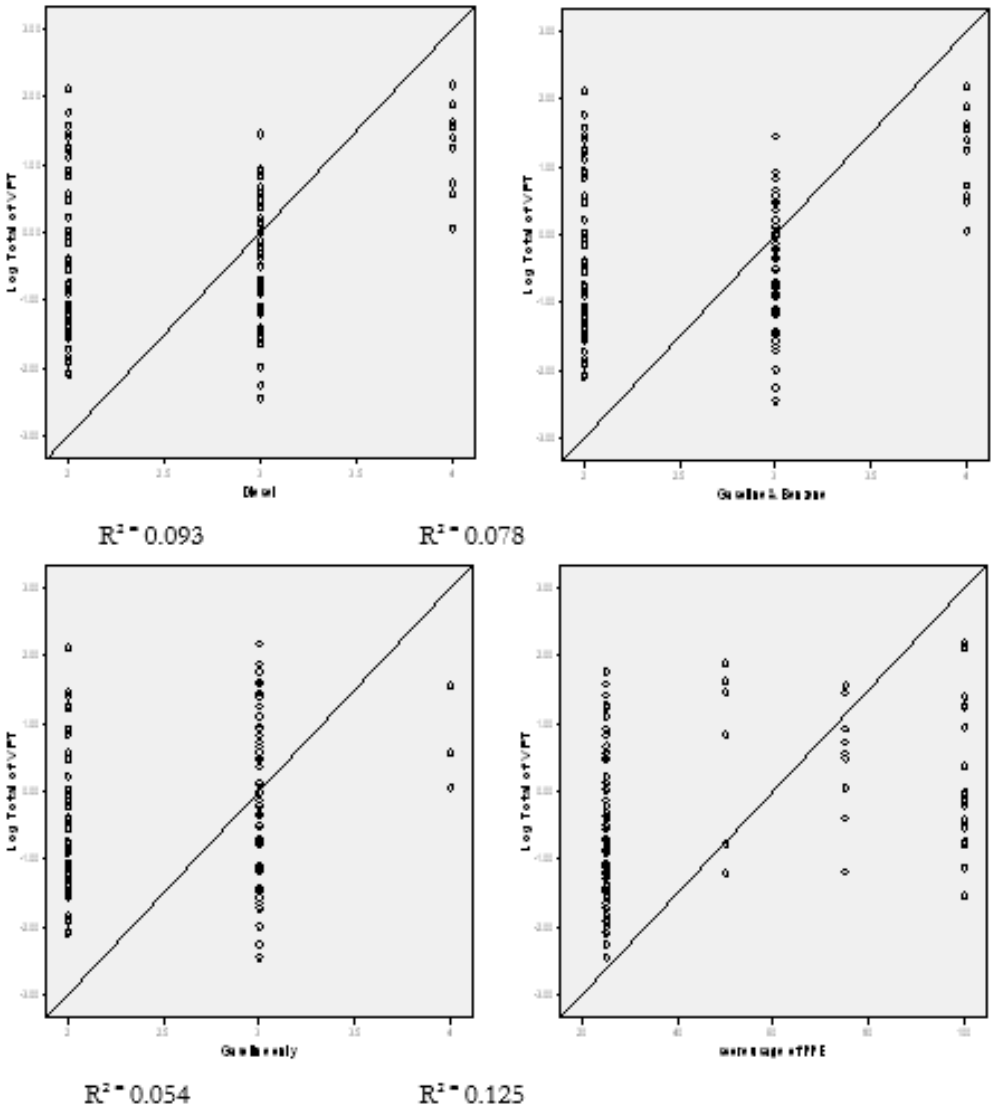


Fig. 4: Scatterplots for the significance variable with the Total VPT

Discussion

There was no significant difference of chemical exposure rating in different service centers. It shows that the vehicle service technicians were exposed to almost similar exposure level. Although during the observation, every location having differences for daily vehicle service demand but the result shows no significance differences for the exposure to chemicals. It is because, based the data given by the vehicle service management, the overall vehicle service per month for each location almost similar.

The chemical exposure rating provided in ranking method ranged based on Malaysia DOSH method. Exposure rating was determined with the purpose to evaluate the potential of hazardous enter into the body via various routes of exposure which can cause systematic effects (7). The risk ranking method can be used to prioritize risk for further control measure to minimize chemical exposure (8). Since this method is qualitative method and can be conducted internally by competent person,

therefore, it is suitable for small and medium industries (SMI) which cannot afford to carry out quantitative analysis. Based on the exposure rating, diesel is the main chemical used compared to gasoline and mixture of benzene and gasoline. Diesel is used mainly and frequently used for engine overhaul and fuel pump replacement. Although mixture of benzene and gasoline were used in the same activities, the frequency was much lower.

Vibrotactile perception threshold at frequencies of 31.5 Hz and 125 Hz were used (9, 10) as both frequencies induce greater changes in finger tactile perception threshold than lower or higher frequencies (9, 10). This study shows that the VPT Level at Log 31.5Hz and Log 125Hz for the workers exposed to chemicals are significantly higher compared to the non-exposed workers. It shows that the exposed group had possible sub clinical neurological effect compared to the non-exposed group and required further examination by the occupational health doctors or physician (11).

In this study, standard deviation for VPT at Log 31.5 Hz and Log 125 Hz was higher compared to mean for exposed group. This indicates that the spread between minimum value and maximum value is large. The prevalence of VPT at Log 31.5 Hz and Log 125 Hz indicate that 46% of the exposed group having threshold above than normal VPT value (12). The level of VPT among both group for frequency at Log 125 Hz was slightly higher than frequency at Log 31.5 Hz. This showed that the respondents have a good sensitivity of tactile at lower frequency due to tactile sensitivity is better in lower frequency rather than in higher frequency. These differences in the response at Log 31.5 and Log 125 Hz occurred due to two different VPT frequencies assessing different mechanoreceptor populations. Pacinian corpuscles were stimulated by higher frequency whereas Meissner corpuscles were stimulated by lower frequency (13). According to ISO 13091-1: 2001 (14), stimulation at recommended frequency of 31.5Hz will permit the determination of the threshold of Fast Adapting I (FAI) mechanoreceptors (Meissner corpuscle), while stimulation at recommended frequency of 125 Hz will permit the determination of the threshold of Fast Adapting II (FAII) mechanoreceptors (Pacinian corpuscle).

This study shows that there was significance relationship between VPT at Log 31.5 Hz, Log 125 Hz and Log Total VPT with the exposure to diesel, mixture of gasoline and benzene, gasoline only. It revealed that the vehicle service technicians having an effect from the exposure to the chemicals. The exposure to chemical significantly correlated with VPT and suggested that the measurement of vibration sensory threshold is a relatively effective tool for detecting chemical neuropathy (15) and neurological symptom (16).

There was no significance relationship between VPT at Log 31.5Hz, Log 125Hz and Log Total VPT with other possible contributing factors (i.e. age, the use of respirator, score use of PPE, BMI, years of employment, working duration, average overtime per week, and exposure to hard arm vibration) except for the usage of PPE. Although the score use of respirator was no significance relationship but the score use of PPE (respirator, glove, goggles, and safety shoes) had significance relationship with VPT level. The usage of PPE is one of the control measure to avoid direct exposure to the chemicals, however, the PPE will cause harm with the incorrect practice such as cartridge used was expired and the respirator used not fit to the workers, wrong glove, goggles and safety shoes were used when perform job involving chemicals. Based on the observation, most of the vehicle service technician wears incorrect PPE. Therefore, it is necessary for the employer to revisit their PPE programme.

This study found that there was no significance relationship between VPT level and age. It was supported by some studies, which found that age did not have any significant relationship with VPT (17-19) and no statistically significance difference in vibrotactile threshold between the younger and older group (20).

Although BMI can influence the VPT value, high BMI indicates that the person is overweight or obese which can impair the tactile sensitivity. However, this study revealed that there was no significance relationship between VPT level and

BMI. It is because; there was no obesity respondents were selected in this study. Years of employment, working duration & average overtime per week had no significance relationship with VPT level. There were no significant correlations between neurobehavioral effects with the years of exposure due the exposure to the chemicals below the current occupational exposure limit (2)

Although exposure to vibration plays an important role to vibration perception threshold, the exposure to hard arm vibration has no significance relationship with VPT level. Based on the observation, the vehicle service technicians have lower exposure to the hand arm vibration as the acceleration magnitude was 4.1±1.2 m/s^2 RMS that was lower that the threshold limits value of 5.0 m/s^2 RMS.

Conclusion

There is significant relationship between VPT level and chemical exposure and usage of PPE was accepted while the relationship between VPT and other contributing factors were rejected.

The overall VPT model demonstrated that the exposure to an organic solvent and the usage of PPE contributed to vibrotactile threshold among vehicle service technicians in Malaysia. Although the overall model is weak, VPT is effective screening sub clinical neuropathies of those exposed to different type of chemical and can act as substitute to other tedious assessment method. Future study should emphasize on validating other type of industries in determining significant relationship between VPT and a broader baseline of abnormal VPT.

Ethical considerations

This research has been approved by the University Research Ethics Committee of the University Putra Malaysia (UPM/TNCPPI/RMC/1.4.18.1 (JKEUP-M)/F1).

Ethical issues (Including plagiarism, informed consent, misconduct, data fabrication and/or falsification, double publication and/or submission, redundancy, etc.) have been completely observed by the authors.

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