Industrial Health 2014, **52**, 367–376

Short Communication

A Cross Sectional Study on Hand-arm Vibration Syndrome among a Group of Tree Fellers in a Tropical Environment

Anselm Ting SU[1, 2]*, Setsuo MAEDA[3], Jin FUKUMOTO[2], Nobuyuki MIYAI[4], Marzuki ISAHAK[5], Atsushi YOSHIOKA[6], Ryuichi NAKAJIMA[7], Awang BULGIBA[8] and Kazuhisa MIYASHITA[2]

[1]Department of Community Medicine and Public Health, Faculty of Medicine and Health Sciences, Universiti Malaysia Sarawak (UNIMAS), Malaysia
[2]Department of Hygiene, School of Medicine, Wakayama Medical University, Japan
[3]Faculty of Applied Sociology, Kinki University, Japan
[4]School of Health and Nursing Science, Wakayama Medical University, Japan
[5]Centre for Occupational and Environmental Health, University of Malaya, Malaysia
[6]Measurement and Information Technology Department, Trust Co., Ltd., Japan
[7]Department of Medical Equipments, Rion Co., Ltd., Japan
[8]Julius Centre University Malaya, University of Malaya, Malaysia

Received July 15, 2013 and accepted March 24, 2014
Published online in J-STAGE April 17, 2014

Abstract: This study aimed to explore the clinical characteristics of hand arm vibration syndrome (HAVS) in a group of tree fellers in a tropical environment. We examined all tree fellers and selected control subjects in a logging camp of central Sarawak for vibration exposure and presence of HAVS symptoms utilizing vibrotactile perception threshold test (VPT) and cold water provocation test (CWP). None of the subjects reported white finger. The tree fellers reported significantly higher prevalence of finger coldness as compared to the control subjects (OR=10.32, 95%CI=1.21–87.94). A lower finger skin temperature, longer fingernail capillary return time and higher VPT were observed among the tree fellers as compared to the control subjects in all fingers (effect size >0.5). The VPT following CWP of the tree fellers was significantly higher (repeated measures ANOVA p=0.002, partial η^2=0.196) than the control subject. The A (8) level was associated with finger tingling, numbness and dullness (effect size=0.983) and finger coldness (effect size=0.524) among the tree fellers. Finger coldness and finger tingling, numbness and dullness are important symptoms for HAVS in tropical environment that may indicate vascular and neurological damage due to hand-transmitted vibration exposure.

Key words: HAVS, Hand-transmitted vibration, Warm environment, Forestry, Cold provocation test

The clinical characteristics of hand arm vibration syndrome (HAVS) have been extensively described in temperate climatic environments[1, 2)] but not in tropical environment. The reports on HAVS in tropical environment are scanty and so far only six papers reported epidemiological studies among vibratory tools workers in Singapore, Indonesia, Papua New Guinea, Southern Vietnam and Malaysia[3–7)]. In the tropical environment,

*To whom correspondence should be addressed.
E-mail: anselmsuting@yahoo.com

secondary Raynaud's phenomenon was not reported and the symptoms were predominantly neurological. Cold provocation test is an important test to manifest the clinical features of HAVS in tropical environments should the condition be masked by the absence of cold stress in the pathogenesis of the disease. However, the test was often either not done in tropical environments[7] or its detailed results not reported[4, 5].

The internationally accepted limit values for hand transmitted vibration (HTV) exposure were determined from the dose response relationship specified in the Annex C of the "ISO 5349-1, Mechanical Vibration − Measurement and Evaluation of Human Exposure to Hand-transmitted Vibration − Part 1: General Requirements" (ISO5349-1)[8]. The dose response relationship curve relates the values of daily vibration exposure − expressed in eight-hour time weight average vibration exposure, A (8) − which may be expected to produce episodes of finger blanching in 10% of persons exposed to HTV for a given number of years to the duration of exposure. This curve was derived from the Brammer's review[9, 10] which was limited to the prevalence of episodic finger blanching from seven epidemiological studies from temperate temperature countries published before 1980. Since the clinical manifestation of HAVS differs between temperate and tropical areas, the dose response relationship between the HTV exposure and its clinical effects cannot be assumed to be the same in both areas. Hence, theoretically the ISO5349-1 dose response relationship curve cannot be used the tropical climate countries for the evaluation of HAVS.

The objective of this study was to establish the clinical characteristics of HAVS among a group of tree fellers exposed to HTV from chainsaw operation in a tropical environment using the cold water provocation test involving finger skin temperature and vibrotactile perception level measurement. This study also aimed to explore the relationship between the A (8) and the clinical outcomes of HTV exposure in a tropical environment. This study is a part of the bigger project carried out by our team to investigate and compare the clinical characteristics of HAVS among various groups of vibratory tools workers in the tropical environment with the findings from Japanese workers.

This study was carried out in a timber logging camp in located in the interior of Sarawak state of Malaysia, forming part of the Borneo Island. The climate is tropical with average annual temperature of 28 °C (ranges from 24 to 32 °C) and total annual rainfall of 4,000 mm, of which much of the rainfall is received during the northeast monsoon months of December to March. All tree fellers working in this logging camp were included in the study. A group of age and sex matched control workers who are also working in this logging camp but had never used vibratory tools were also included in this study. The ratio of tree fellers to control workers is 2:1. This ratio is selected because there are not enough control workers who had not used vibratory tools. The control workers consist of camp managers, administrative staff, supervisors, forest research surveyors and catering workers.

The data collection consisted of three parts: face to face interview on the HTV exposure and HAVS symptoms, physical examination of the hands relevant to HAVS and individual vibration measurement of the vibratory tools. All workers were interviewed face to face on the history of HTV exposure which included the following information: years of work in the forestry industry, years of vibratory tools usage, type of tools, and the duration and frequency of use of each tool which included information like hours per day, days per year and total number of years of usage. The symptoms of HAVS were obtained using a standardized surveillance form modified and translated from the English version of the Japanese Questionnaire on Subjective Symptoms in Vibration Syndrome[11] used in Japan for the surveillance of workers exposed to HTV. We decided to use this surveillance form so that the findings are comparable to Japanese population. The surveillance form underwent forward and backward translation from English to Malay language and vice versa. There was no problem in the language translation as all the terminology used in the English questionnaire was available in the Malay language. The workers consisted of Malaysian and Indonesian, and all of them understood and were able to speak the Malay language well without any problem. The questionnaire was administered by an occupational physician and a trainee occupational physician who understand the questions well in Malay language to ensure correct meaning was understood by the participants before answering each question.

The physical examination of the workers consisted of height, weight, blood pressure, pulse rate, finger skin temperature, fingernail capillary return, finger vibrotactile perception threshold (VPT), Tinel's test, Phalen's test and cold water provocation test with continuous finger VPT and skin temperature measurement. The finger skin temperature was measured over the pulp of all fingers using an infrared thermometer, model IT-550S manufactured by Horiba Ltd., Japan. The capillary return was assessed by gently pressing the finger nails of the subjects with exam-

iner's thumb and index fingers until the nail bed colour turned pale. The timer was started immediately once the pressure was exerted. At 10 s, the pressure was released and the timer was stopped once the nail bed colour returns to normal. The capillary return time was calculated as total time recorded minus 10 s. One trained assessor was allocated to perform this examination for all participants to ensure consistency of the finding.

The VPT was measured for all fingers using the vibration sensation meter, model AU-02 manufactured by Rion Co., Ltd., Japan, with the vibration frequency setting at 125 Hz. During the test, the subject was asked to touch the vibrator probe without a surround with the pulp of the finger while other fingers, hand, wrist and arm positioned to prevent contact with the surface of the vibrator and examination table. The vibration level was then increased gradually at 2.5 dB interval from −10 dB. The patient was asked to lift up the other hand immediately when he felt the vibration. If the responses from the patient were inconsistent, the examiner turned the vibration down and increased gradually again repeatedly to ensure the exact ascending vibration perception threshold was obtained. The procedure was repeated for a minimum three testing and maximum of five testing. The vibration level with at least two out of three similar responses was considered as correct vibration perception threshold. If any of the participants required more than five rounds of testing, the result will be excluded from the analysis. The VPT measurements were carried out by one trained investigator for all subjects to preserve as far as possible the consistency of the readings obtained.

The cold water provocation test was carried out to evaluate the change in the response to skin temperature measurement and vibration perception threshold following immersion of the dominant hand in the water at 5 °C for 1 min. A K-type thermocouple temperature probe from Takara Thermistor model D922 was attached to the pulp of the middle finger of the dominant hand or the hand with any of the symptoms of HAVS and masked with paper tape. White paraffin gel was then applied to cover the whole tape to prevent water from wetting the paper tape and seeping into the paper tape. The cable was secured at the wrist level using a paper tape. The skin temperature was monitored at zero, one, two and three minutes before immersion, 15, 30, 45 and 60 s during immersion, and at every minute after immersion until 10 min post immersion. The vibration perception threshold was measured at the index finger immediately post immersion and at five minutes and ten minutes post immersion. Throughout the test, the water temperature was maintained at 5 ± 0.5 °C and the room temperature was maintained between 21−23 °C.

All subjects were instructed not to smoke for at least two hours and not to take alcohol for at least one day prior to the conduct of physical examination. The period from last vibration exposure to cold provocation test was at least 14 h. The subjects were registered and interviewed prior to the physical examination in room temperature which allowed an acclimatization period of at least 15 min before the physical examination and 30 min before the cold water provocation test. All subjects underwent the study in following order: physical examination, cold water provocation test, interview and vibration level measurement.

Following physical examination and questionnaire interview, the tree fellers were asked to cut a log horizontally using their own chainsaw in the field. The logs used for cutting were the same logs used for workers' training before they started work. The vibration level of the log cutting task was measured using a triaxial accelerometer, model B&K Human Vibration Analyzer Type 4447. The measurement was conducted by a qualified operator according to the standard of measurements as specified in Mechanical vibration − Measurement and evaluation of human exposure to hand-transmitted vibration − Part 2: Practical guidance for measurement at the workplace[12]. The accelerometer was firmly attached to a moulded (cup-shaped) handheld adaptor and attached to the tool handle by the tree feller during the measurement. A minimum of three readings were taken for each tool and each reading was taken for at least one minute. The result of the measurement and the information on the daily vibration exposure duration obtained from questionnaire interview were used to calculate the daily eight-hour time weighted average vibration exposure level, A (8), of each subject. The A (8) of each subject is calculated based on the following mathematical formula:

$$A8 = \sqrt{\frac{1}{8}\sum_{i=1}^{n} a_{hvi}^2 T_i}$$

where is the vibration total value for each tool and is the total daily duration of exposure for each tool. The vibration total value, , is the root-sum-of-squares of the acceleration magnitudes of each tool in three orthogonal axes and is given by the mathematical formula:

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

Table 1. Basic characteristics of study subjects

Characteristics		Tree fellers				Control subjects				*p* value
		N	%	Mean	SD	N	%	Mean	SD	
Subjects		33	100			15	100			
Race	Iban	17	51.5			4	26.7			0.108
	Others	16	48.5			11	73.3			
Age (yr)				36.76	9.39			35.67	11.50	0.730
Height (cm)				160.68	4.81			166.00	7.55	0.005
Weight (kg)				57.54	6.81			68.56	12.01	0.004
SBP[a] (mmHg)				127.61	11.78			134.63	20.77	0.142
DBP[b] (mmHg)				75.21	11.38			79.70	12.52	0.226
Pulse rate (bpm)				64.95	10.10			66.77	8.69	0.551
Duration in timber industry (yr)				13.55	8.53			11.96	8.05	0.545
Previous disease	Yes	4	12.1			1	6.7			1.000
	No	29	87.9			14	93.3			
Previousinjury	Yes	8	24.2				0	0		0.044
	No	25	75.8				15	100		
Alcohol consumption	Yes	14	42.4				8	53.3		0.482
	No	19	57.6				7	46.7		
Ever smoked		25	75.8			8	53.3			0.180
Never smoked		8	24.2			7	46.7			

[a]Systolic blood pressure. [b]Diastolic blood pressure

where, and are the frequency weighted root mean square accelerations in the x-axis, y-axis and z-axis respectively. The A (8) values obtained from the subjects were analyzed and compared against the European Union Directive 2002/44/EC daily exposure limit value of 5 ms^{-2} and daily exposure action value of 2.5 ms^{-2}.

This study has received written approval from the Committee of Ethics of the Wakayama Medical University, Medical Ethics Committee of the University of Malaya Medical Centre and management of the timber company prior to the conduct of the study. Informed consent was obtained from each subject prior to the interview and physical examination. An explanation was provided to subjects on the purpose of the study which was also stated on the subject information sheet. This was followed by written consent once they had understood the purpose and the conduct of the study. Subjects were given assurance that all reported symptoms or physical examination findings were confidential and the information would not be revealed to their employers, to prevent any possibility of employment discrimination. Subjects were also made to understand that any information provided or obtained in this study would not be used for the purpose of compensation.

The data entry was validated using the double entry method. Analysis was carried out using Statistical Package for Social Sciences (IBM SPSS Statistics) version 19. χ^2 analysis with relevant Yates correction or Fisher's exact test was carried out to compare categorical data from different exposure groups. Analysis of variance (ANOVA) and analysis of covariance (ANCOVA) using the univariate general linear model (GLM) procedure with adjustment for risk factors was used to compare the means of two and more groups of data. The data for cold water provocation test was analyzed using repeated measures ANOVA with multiple comparison test (Bonferroni test) when a significant difference was found. A cut-off value of A (8) which would differentiate the subjects with from those without the HAVS symptoms was determined using the receiver operating characteristic (ROC) curve. The effect size was reported for all statistical analysis together with the *p*-value. The significant level for all statistical tests was set at 0.05 unless otherwise specified.

All 33 permanent tree fellers and 15 age and sex-matched control subjects working in the camp were recruited into the study. All subjects were male and their mean age was 36 (standard deviation (SD)=10, min=17, max=59) yr old. The majority of the subjects were local Iban whereas other ethnicity consisted of Indonesian, Melanau, Chinese and Malay. All subjects reported the right hand as their dominant hand in this study. The basic

Table 2. Hand transmitted vibration exposure information for tree fellers (n = 33)

Exposure information	Mean	SD	Median	Minimum	Maximum
A(8)[a] (ms^{-2})	4.59	1.90	4.12	1.80	9.65
a_{hv}[b] (ms^{-2})	6.48	2.08	5.85	3.97	14.02
Daily HTV contact[c] (hours/day)	4.16	1.97	4.00	1.00	8.00
Yearly chainsaw use (days/year)	275.00	45.10	300.00	90.00	330.00
Duration of chainsaw use (years)	13.16	8.47	12.00	0.25	30.00

[a]Eight-hour time weighted average vibration level. [b]Vibration total value. [c]Hand transmitted vibration

Table 3. Symptoms related to hand arm vibration syndrome reported by the subjects

Symptoms		Tree fellers		Controls		*p*	OR[a]	95%CI
		N	%	N	%			
White finger	Yes	0	0	0	0	-	-	-
	No	33	100	15	100			
Finger coldness	Yes	14	42.4	0	0	0.018	10.32	1.21–87.94
	No	19	57.6	15	100			
Finger tingling, numbness, dullness	Yes	12	36.4	1	6.7	0.147	5.64	0.54–58.60
	No	21	63.6	14	93.3			
Upper limbs pain	Yes	10	30.3	0	0	0.136	6.09	0.70–52.80
	No	23	69.7	15	100			

[a]Odds ratio; for zero value cell, obtained by adding one to the cell.

characteristics of all subjects are shown in Table 1. The control subjects were heavier and taller than the exposed subjects. Besides, the tree fellers had a higher prevalence of ever smokers than the control subjects although this was not statistically significant. The subsequent statistical analyses were adjusted for age, weight, height and smoking status.

Almost all tree fellers were using the light chainsaw (model STIHL® 038) for tree felling task. The older tree fellers used to operate heavier chainsaws before but the vibration level of those chainsaw was undetermined. Thirty subjects were exposed to A (8) of more than 2.50 ms^{-2} and among those, 12 subjects were exposed to the A (8) of more than 5.00 ms^{-2}. The average and range values of A (8), daily HTV exposure duration, frequency of chainsaw use per year and total number of years of chainsaw use for all tree fellers are summarized in Table 2.

None of the subjects reported white finger. The tree fellers reported significantly higher prevalence of finger coldness as compared to the control subjects (OR=10.32, 95%CI=1.21−87.94) (Table 3). Out of the 14 workers who experienced finger coldness in the exposure group, four were feeling cold hands at all the time while 10 experienced during rainy seasons. Two subjects experienced the cold hands every day, four several times a week and eight several times a month. Six experienced cold hands after exposure to cold environment, three experienced in the morning and five experienced in the evening after working with vibratory tools. The finger coldness did not interfere with work or with leisure time activities. Although the prevalence of finger tingling, numbness and dullness sensation and pain over the upper limbs was also higher among the tree feller, the results did not achieve statistical significance.

The skin temperature of the index and middle fingers of both hands of the tree fellers was found to be lower than the controls for about two to three degree Celcius. The values of capillary return time and VPT were significantly higher in all the fingers for tree fellers as compared to the controls. None of the participants required five VPT testing to obtain the final reading. The details of physical examination results are shown in Table 4.

In cold water provocation test, the tree fellers consistently showed a lower skin temperature than the control subjects throughout the test (Fig. 1). However the between-subjects effects test did not reveal statistically significant differences between the two groups after adjusting for age, smoking status, weight and height. The VPT among the tree fellers were significantly higher than the control subjects before and after the cold provocation test with the between-subjects test *p* value of 0.002 and partial eta squared of 0.196 after adjusting for age, smok-

Table 4. Hand examination findings of study subjects

Test	Tree fellers		Controls		*t*	*p* value[a]	ES[b]	*p* value[c]
	Mean	SD	Mean	SD				
Skin temperature (°C)								
Right thumb	28.29	2.39	29.71	1.15	2.763	0.008	0.859	0.057
Right index	27.67	2.77	29.62	1.17	3.417	0.001	1.063	0.025
Right middle	27.09	2.81	29.32	1.41	3.659	0.001	1.138	0.014
Right ring	27.22	2.56	28.89	1.50	2.842	0.007	0.884	0.070
Right little	26.77	2.54	28.81	1.81	3.177	0.003	0.988	0.035
Left thumb	27.95	2.37	29.49	1.45	2.764	0.008	0.860	0.111
Left index	26.66	2.96	29.10	1.44	3.829	<0.001	1.191	0.014
Left middle	26.76	2.33	28.74	1.85	2.879	0.006	0.901	0.049
Left ring	26.61	2.69	28.33	2.10	2.187	0.034	0.680	0.126
Left little	26.48	2.50	28.12	1.88	2.261	0.029	0.703	0.117
Fingernail capillary return (s)								
Right thumb	1.59	0.34	1.39	0.33	1.924	0.061	0.598	0.102
Right index	1.70	0.34	1.34	0.24	3.556	0.001	1.138	0.025
Right middle	1.59	0.29	1.23	0.17	5.385	<0.001	1.718	0.002
Right ring	1.57	0.37	1.21	0.24	3.903	<0.001	1.249	0.011
Right little	1.63	0.40	1.28	0.34	2.946	0.005	0.916	0.024
Left thumb	1.59	0.30	1.33	0.30	2.810	0.007	0.874	0.030
Left index	1.57	0.30	1.33	0.30	2.569	0.013	0.799	0.014
Left middle	1.50	0.31	1.28	0.23	2.488	0.017	0.779	0.007
Left ring	1.57	0.35	1.25	0.28	3.155	0.003	0.981	0.039
Left little	1.57	0.33	1.25	0.22	3.412	0.001	1.061	0.035
Vibrotactile perception threshold (dB)								
Right thumb	13.79	8.29	4.67	6.33	3.780	<0.001	1.176	0.005
Right index	13.50	8.56	3.83	5.58	3.994	<0.001	1.242	0.004
Right middle	12.95	8.74	3.00	6.35	3.953	<0.001	1.229	0.004
Right ring	13.73	9.46	3.33	6.39	3.862	<0.001	1.201	0.005
Right little	13.86	9.84	3.17	5.63	4.761	<0.001	1.481	0.002
Left thumb	11.59	8.88	2.33	5.86	4.280	<0.001	1.331	0.006
Left index	12.58	10.01	1.50	4.89	5.147	<0.001	1.601	0.002
Left middle	12.03	9.74	2.00	5.76	4.407	<0.001	1.379	0.004
Left ring	13.26	10.13	3.00	6.83	3.562	0.001	1.108	0.008
Left little	14.09	11.12	3.00	6.21	4.411	<0.001	1.372	0.010

[a]*p* value obtained by independent *t*-test. [b]Effect size. [c]*p* value obtained by multivariate analysis of covariance using GLM multivariate procedure, adjusted for weight and height

ing status, weight and height (Fig. 2). None of the subjects developed Raynaud's phenomenon following the cold water provocation. In the current study, the cold water provocation test was carried out on the dominant hand of all subjects because all symptomatic subjects complained of finger tingling, numbness or dullness and finger coldness over both hands.

The A (8) level was associated with the presence of neurological symptoms (tingling, numbness and dullness sensation) and cold finger sensation (effect size >0.5) among the tree fellers (Table 5). The cut-off value of A (8) to differentiate the tree fellers with neurological symptoms (tingling, numbness and dullness of the fingers) from those without was 4.08 ms^{-2}, determined from the ROC curve (area under the ROC curve =0.754, 95%CI=0.584−0.924) (figure not shown). The total years of chainsaw use does not show association with any of the HAVS symptoms among the tree fellers.

The main limitation of this study is the small sample size. Random sampling of the tree fellers in the whole of Sarawak is almost impossible due to the unavailability of an official register of tree fellers as well as the mobility

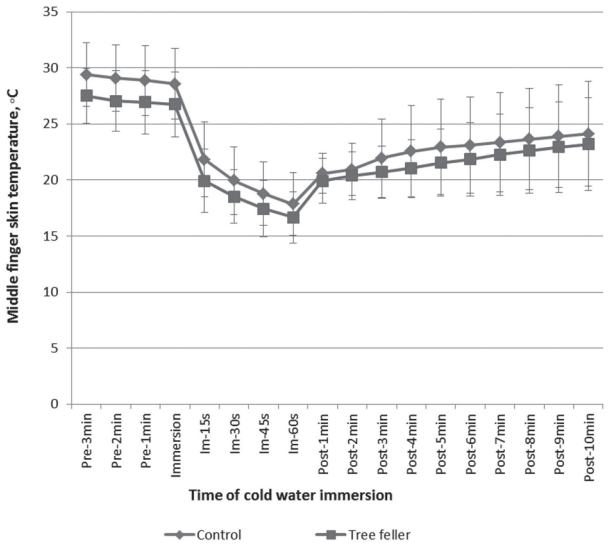

Fig. 1. Comparison of dominant hand's middle finger skin temperature changes between tree fellers and control subjects in cold provocation test. The error bars represent standard deviations. The test of between-subjects effects shows p=0.860 and partial eta squared = 0.001 adjusted for weight and height.

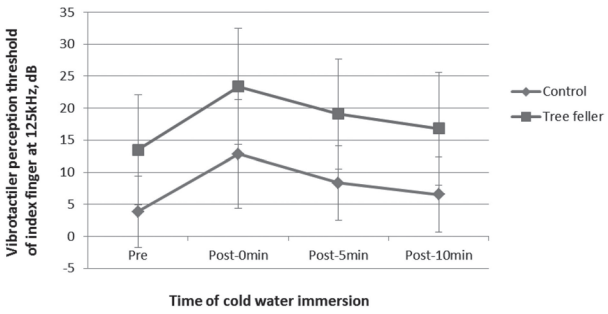

Fig. 2. Comparison of dominant hand's index finger vibratactile perception threshold changes between tree fellers and control subjects in cold provocation test. The error bars represent standard deviations. The test of between-subjects effects shows p=0.002 and partial eta squared=0.196 adjusted for weight and height.

and wide distribution of the workers within the state. A more logical approach to investigate this group of workers would be the cluster selection of the logging camps. However, logistical difficulties especially with regards to transportation of equipment are major issues owing to the geographical location of the logging camp. Hence, the nearest logging camp to the main access town became the choice of study location in this study. Despite the small number of study subjects, we have found some significant results worth reporting in this study.

Iban, Melanau, Malay and Indonesian of Sarawak are basically a homogenous group of local aborigines. They are likely to share the same genetic predisposition, cultural and environmental exposure factors. Chinese are originally migrants from Southern part of China, but the current Chinese population is the third generation born locally. Hence, they grew up with exposure to local environmental factors and practice the local culture and life style. There is no established evidence on how genetic differences among this population might affect the outcomes of exposure to hand transmitted vibration. We have compared the outcomes (symptoms and physical examination results) between Chinese and others (Iban, Melanau, Malay, Indonesian combined), and Iban and others (Chinese, Melanau, Malay, Indonesian combined) and found no statistical differences between the groups. Hence, we assumed the genetic influence, if there is any, on the outcomes of this study was negligible.

The vibration measurement in this study was carried out in a field demonstration rather than in the real work environment because of logistic constraint. This is a limitation of this study. Although the measurement duration was short, the vibration level was consistently stable throughout the measurement. Hence the measurement results might be representative of the daily vibration exposure after coupling with total duration of vibration exposure information obtained from the questionnaire interview.

The common symptoms related to HAVS in tropical environment are finger tingling and numbness and musculoskeletal pain of the upper limbs. The vibration white finger was not reported from the previous literature[5–7]. In the current study, the authors found that finger coldness seems to be an important symptom for vascular disorders in HAVS in the tropical environment. Despite the small sample size, the odds of experiencing finger coldness among the tree fellers was ten times more than the control group. In the previous studies conducted by Futatsuka[6] and Su[7], the authors also reported higher prevalence of finger coldness among the vibration exposed workers as compared to the controls. The current study also found a lower finger skin temperature and longer fingernail capillary return time among the tree fellers which might indicate the damage to the microcirculation of the finger tips. This is an important finding as finger coldness could serve as an alternative surrogate for vibration white finger in the tropical environment.

The current study also reported higher prevalence of finger tingling, numbness and dullness among the tree fellers. The result is consistent with the other reports from tropical environment. The small sample size could have resulted in the non-significant results. The prevalence of

Table 5. The association of eight-hour time weighted average vibration level, A (8) and total years of vibration exposure with HAVS symptoms

Symptoms	N	A (8)[a]					Total years of vibration exposure				
		Mean	SD	*t*	*p* value	ES[b]	Mean	SD	*t*	*p* value	ES[b]
Tingling, numbness, dullness											
Yes	12	5.679	1.997	2.716	0.011	0.983	14.104	9.954	0.478	0.636	0.173
No	21	3.970	1.579				12.619	7.717			
White finger											
Yes	0	0	0	-	-	-	0	0	-	-	-
No	33	4.591	1.905				13.159	8.474			
Cold finger											
Yes	14	5.155	2.199	1.487	0.147	0.524	13.589	9.538	0.247	0.807	0.087
No	19	4.176	1.589				12.842	7.855			
Pain of the upper limbs, neck and back											
Yes	17	4.605	2.176	0.041	0.968	0.014	14.063	8.721	0.588	0.561	0.205
No	16	4.577	1.639				12.309	8.409			

[a]Daily eight-hour time-weighted average vibration exposure. [b]Effect size

musculoskeletal pain over the upper limbs was also higher in the tree fellers as compared to the control subjects. Majority of the subjects complained of the pain over the upper arms. Only one subject in our study complained of pain over the fingers.

The VPT at 125 kHz was found to be significantly higher in the tree fellers as compared to the control subjects in all fingers. The mean differences ranges from 9 dB to 11 dB. A plot of ROC curve showed an average area under the curve of about 0.8 and a cut-off value of about 10 dB for all fingers differentiating between the tree fellers and control subjects (figure not shown). This finding, however, requires careful interpretation due to two limitations. First, the contact force between the finger and the probe during the VPT test was not measured and hence gave rise to a risk of measurement bias. Second, the tree fellers had lower finger skin temperatures (27−28 °C) than the controls (28−29 °C) which might reduce the sensitivity of the VPT measurements among the tree fellers.

The International Organization for Standardization has proposed a water temperature of 12 °C and an immersion duration of five minutes in cold provocation for assessing peripheral vascular function[13]. Other reports have suggested different levels of water temperature ranging from 5 to 15 °C and the immersion duration of two to five minutes[14–16]. Cold provocation test at 15 °C for 5 min have insufficiency in provoking peripheral vascular dysfunction[14, 16] and the data on the usefulness of 12 °C for 5 min immersion is limited[16]. In the current study, we have used water temperature of 5 °C and immersion time of one minute for the cold water provocation test. These parameters were selected on the basis of the ethical consideration that the subjects from tropical environment might not be able to withstand for such a low temperature for more than one minute while experiencing intense painful sensation of the immersed hand. Besides, the test was simple to administer and agreed by the employer of the company as compared to the 5 min method. The 5 °C one minute immersion method was found to be comparable to other method in the evaluation of vascular function of HAVS as reported by Miyashita[17].

The finger skin temperature reading following the cold water provocation test in our study did not significantly differ between the tree fellers and the control subjects. However, the finger skin temperature of the tree fellers was consistently lower than the control subjects throughout the test. The reason for no significant difference between the two groups could be attributed to the short duration of cold water immersion and under-representativeness of the single middle finger measurement over the whole hand. The VPT however was significantly higher in the tree fellers following cold water provocation test up to the 10 minutes post immersion.

In the current study, the measurement of A (8) among the tree fellers found only 36% of the subjects exceeded the daily exposure limit value. The A (8) level measured in this study could have been underestimated because almost all the tree fellers have changed their chainsaw to a newer model at the time of assessment. Besides, the vibration measurement was carried out as a field demonstration

rather than actual work; hence the vibration level was quite stable throughout the measurement. Most of the tree fellers had used older models of the chainsaw before which were heavier with presumably higher level of vibration. The workers also used bush cutters occasionally but the exact history and level and of exposure could not be determined. Hence, most of the tree fellers could have been exposed to the higher level of A (8) for a long time before the conduct of this study and the vibration exposure results of this study must be interpreted with caution.

Despite possible underestimation of A (8) levels in this study, it was found that tree fellers with neurological symptoms and finger coldness were exposed to higher level of A (8) as compared to those without the symptoms. Since no white fingers were reported in tropical environment, it might be useful to find out the relationship between the A (8) and the neurological symptoms or the complaint of finger coldness and compare the results with the relationship between the A (8) and finger blanching as specified in the Annex C of the ISO 5349-1 standard[8]. In the current study, we are unable to demonstrate the similar graphical relationship as the number of subjects in each category of duration of exposure was too few to determine the level of A (8) which might produce a certain percentage of symptomatic patients.

In conclusion, our study suggested that finger coldness and finger tingling, numbness and dullness are important symptoms for HAVS in tropical environment which could be associated with the A (8) and may indicate vascular and neurological damage due to hand transmitted vibration exposure. The VPT and cold water provocation test seems to be useful to evaluate the extent of neurophysiological impairment but further research utilizing the ISO standard must be carried out to determine the role of these two tests in the screening and diagnosis of HAVS in a tropical environment. The presence of the symptoms related to HAVS and the high level of vibration exposure in a tropical environment could serve as the initiating factor to carry out preventive actions in all workplace after estimating the level of A (8).

Acknowledgements

This study was funded by research grants from University of Malaya Research Grant (Grant sponsor: UMRG; Grant number: RG276/10HTM), Grant-in-Aid for Scientific Research (C) (Grant sponsor: JSPS; Grant number: 23590750) from the Japan Society for the Promotion of Science (JSPS), and financial support from JSPS's RONPAKU (Dissertation PhD) Program.

References

1) NIOSH (1989) Criteria for a Recommended Standard: Occupational Exposure to Hand-Arm Vibration [DHHS (NIOSH) Publication No. 89-106]. US Department of Health and Human Services, Public Health Service, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, Cincinnati.
2) NIOSH (1997) Musculoskeletal Disorders and Workplace Factors. [DHHS (NIOSH) Publication No. 97-141]. US Department of Health and Human Services, Public Health Service, Centers for Disease Control and Prevention, National Institute for Occupational Safety and Health, Cincinnati.
3) Davies TA, Glaser EM, Collins CP (1957) Absence of Raynaud's phenomenon in workers using vibratory tools in a warm climate. Lancet **272**, 1014–6. [Medline] [CrossRef]
4) Futatsuka M, Inaoka T, Ohtsuka R, Moji K, Sakurai T (1991) A preliminary study on the function tests of the vibration syndrome in tropical rain forest workers. J Hum Ergol (Tokyo) **20**, 95–9. [Medline]
5) Futatsuka M, Inaoka T, Ohtsuka R, Sakurai T, Moji K, Igarashi T (1995) Hand-arm vibration in tropical rain forestry workers. Cent Eur J Public Health **3** Suppl, 90–2. [Medline]
6) Futatsuka M, Shono M, Sakakibara H, Quoc Quan P (2005) Hand arm vibration syndrome among quarry workers in Vietnam. J Occup Health **47**, 165–70. [Medline] [CrossRef]
7) Su TA, Hoe VCW, Masilamani R, Awang Mahmud AB (2011) Hand-arm vibration syndrome among a group of construction workers in Malaysia. Occup Environ Med **68**, 58–63. [Medline] [CrossRef]
8) International Organization for Standardization (2001) ISO 5349-1: Mechnical vibration−Measurement and evaluation of human exposure to hand-transmitted vibration−Part 1: General requirements. ISO, Geneva. Switzerland.
9) Brammer AJ(1982) Threshold limits for hand-arm vibration exposure throughout the workday. Wiley, New York.
10) Brammer AJ (1986) Dose-response relationships for hand-transmitted vibration. Scand J Work Environ Health **12**, 284–8. [Medline] [CrossRef]
11) Kaewboonchoo O, Morioka I, Miyashita K, Takeda S, Wang YX, Li SC (1998) Hearing impairment among young Chinese in an urban area. Public Health **112**, 143–6. [Medline] [CrossRef]
12) International Organization for Standardization (2001) ISO 5349-2: Mechnical vibration − Measurement and evaluation of human exposure to hand-transmitted vibration−Part 2: Practical guidance for measurement at the workplace. ISO, Geneva.
13) International Organization for Standardization (2005) ISO 14835-1: Mechanical vibration and shock − Cold provocation tests for the assessment of peripheral vascular

function−Part 1: Measurement and evaluation of finger skin temperature. ISO, Geneva.
14) Harada N (2002) Cold-stress tests involving finger skin temperature measurement for evaluation of vascular disorders in hand-arm vibration syndrome: review of the literature. Int Arch Occup Environ Health **75**, 14–9. [Medline]
15) Poole K, Elms J, Mason H (2006) Cold-provocation testing for the vascular component of hand-arm vibration syndrome in health surveillance. Ind Health **44**, 577–83. [Medline] [CrossRef]
16) Takemura S, Maeda S, Fukumoto J, Yoshimasu K, Nakajima R, Tateno M, Yoshikawa K, Miyai N, Nasu Y, Miyashita K (2011) Measuring condition of cold provocation test: a review of literature. 40th International Congress and Exposition on Noise Control Engineering (Internoise 2011), INCE/J and ASJ, Osaka.
17) Miyashita K (1989) Evaluation of peripheral circulation using simplified cold water immersion test. A report on the occupational safety and science research entrusted by Ministry of Labor, Japan. Wakayama.