Prevalence of Hand-transmitted Vibration Exposure among Grass-cutting Workers using Objective and Subjective Measures

N. A. Azmir1,*, M. N. Yahya1
1Noise and Vibration Analysis Research Group, Faculty of Mechanical and Manufacturing Engineering, Universiti Tun Hussein Onn Malaysia, Batu Pahat, Johor, Malaysia
*azali@uthm.edu.my

Abstract. Extended exposure to hand-transmitted vibration from vibrating machine is associated with an increased occurrence of symptoms of occupational disease related to hand disorder. The present case study is to determine the prevalence and correlation of significant subjective as well as objective variables that induce to hand arm vibration syndrome (HAVS) among hand-held grass-cutting workers in Malaysia. Thus, recommendations are made for grass-cutting workers and grass maintenance service management based on findings. A cross sectional study using adopted subjective Hand Arm Vibration Exposure Risk Assessment (HAVERA) questionnaire from Vibration Injury Network on hand disorder signs and symptoms was distributed to a sample of one hundred and sixty eight male workers from grass and turf maintenance industry that use vibrating machine as part of their work. For objective measure, hand-transmitted vibration measurement was collected on site during operation by the following ISO 5349-1, 2001. Two groups were identified in this research comprising of high exposure group and low-moderate exposure group. Workers also gave information about their personal identification, social history, workers’ health, occupational history and machine safety inspection. There was positive HAVS symptoms relationship between the low-moderate exposure group and high exposure group among hand-held grass-cutting workers. The prevalence ratio (PR) was considered high for experiencing white colour change at fingers and fingers go numb which are 3.63 (1.41 to 9.39) and 4.24 (2.18 to 8.27), respectively. The estimated daily vibration exposure, A(8) differs between 2.1 to 20.7 ms⁻² for right hand while 2.7 to 29.1 ms⁻² for left hand. The subjects claimed that the feel of numbness at left hand is much stronger compared to right hand. The results suggest that HAVS is diagnosed in Malaysia especially in agriculture sector. The A(8) indicates that the exposure value is more than exposure limit value which is 5 ms⁻². Thus, control measure such as engineering and administrative control should be implemented to reduce the severity of hand-transmitted vibration hazard.

1. Introduction
Hand-held grass-cutting machine is widely applied in various tropical countries for maintenance of grass area landscape. A typical public grass compound needs monthly grass-cutting operation either in highway or facilities location. It produces a service industry with large numbers of workers involved
using the hand-held grass-cutting to maintain grass growth. The workers involved in these duties are generally contract workers with less awareness related to occupational safety and health such as hand arm vibration syndrome [1]. Statistics of occupational accidents by sector, which caused death, permanent disability and non-permanent disability, have been widely investigated and represented a significant problem to the Malaysian industry. Hand-held grass-cutting workers were investigated under the agricultural sector which reported the second highest cause to non-permanent disability behind industrial sector [2]. Information from the Social Security Organization (SOCSO), Malaysia shows increased number of cases related to occupational musculoskeletal disorder from year 2005 to 2014 [3].

Extended exposure to hand-transmitted vibration (HTV) can interfere the normal circulation as well as nervous and musculoskeletal system that causes a syndrome known as hand arm vibration (HAVS). HTV occurs when vibration enters the body through the hands, for example in various work activity where rotating or percussive power tools or vibrating machine was held by the hand or fingers [4]. HAVS developed after long exposure of hand vibrating instrument which are irreversible injury, chronic pain in the hands and arms which also lead to difficulties in the implementation of daily activities and introduce work incapacity [5].

The prevalence of HAVS ranged from 2.5% to more than 82.8% globally depending on the duration and magnitude of vibration exposure as well as climatic factors [6]. However, this percentage has increased as the working environment temperature decreased. Thus, the vibration white fingers (VWF) are renowned by low ambient temperature countries compared to warm environment countries. Its prevalence in Malaysia is not well established compared to European Union (EU) countries since there is no regulation concern about occupational HTV hazard. Recent study from Malaysia showed that the prevalence of HAVS among construction workers exposed to hand vibration from hand-held power tolls in warm environments was 18% [7].

The Department of Occupational Safety & Health (DOSH) Malaysia establishes the minimum health and safety requirements regarding the occupational vibration of workers involved in vibrating tools. It states that the vibration transmitted to the hand arm system is to be measured in accordance with the International Standard [8]. Furthermore, American Conference of Governmental Industrial Hygienists (ACGIH) specifies the threshold limit value and duration of exposure to be followed for the purpose of mitigating HAVS [9]. Besides that, European Directive established the regulation to protect workers from vibration hazard [10]. Although, there is several detailed health descriptions related to human response to vibration, it indicated that hand arm vibration disease reduced after implementing the Directive 2002/44/EC in Great Britain [11]. For hand arm vibration assessment, articles 3 of Directive 2002/44/EC established the following safety limits for A(8) by means, exposure limit value (ELV) equals to $5 \text{ ms}^{-2}$ while exposure action value (EAV) equals to $2.5 \text{ ms}^{-2}$. The ELV is the maximum amount of hand arm vibration worker which may be exposed in any single day. It indicates a potential high risk above which workers should not be exposed. The EAV is the daily amount of hand arm vibration exposure which employers are required to take acceptable and suitable control measures.

The purpose of this research was to investigate the prevalence of HAVS among groups of hand-held grass-cutting workers and determine the correlation of significant symptoms. Besides that, the HTV exposure characteristics during onsite operation for five types of grass-cutting machine model were evaluated according to established safety standard. The result of this study would best predict the diagnosis of HAVS. These significant characteristics can be used in occupational safety and health screening as indicator to the health effect due to HTV.

2. Methodology
This is a cross-sectional study among hand-held grass-cutting workers covering highway grass maintenance subcontractor and personal contractor in central and southern region of peninsular Malaysia. Average daily working time is 8 hours starting from 8 am to 5 pm depending on target grass cutting area in a day. About hundred sixty eight hand-held grass-cutting workers were selected into the
The workers were involved in general cutting operation location consists of flat, slope and drain area. Some of the workers were working full time as the grass cutter while others as their part time routine work in maintaining facilities landscape. In this study, high HAV risk exposure group was identified as full time operating grass-cutting machine while low and moderate HAV risk exposure group was classified under part time grass-cutting workers. Furthermore, five different types of hand-held grass-cutting machine were identified and detailed specifications of each machine type are as shown in Table 1.

Table 1. The technical specification of the survey of hand-held grass-cutting machine

| Specification       | Type A  | Type B     | Type C   | Type D | Type E     |
|--------------------|---------|------------|----------|--------|------------|
| Model              | TU33    | TB33 / TL33| KNC 3340 | TB43   | BG328      |
| Discharge capacity (cc) | 32.6    | 32.8       | 33       | 43     | 30.5-32.8  |
| Net weight (kg)    | 9       | 9.5 – 9.8  | 9.7      | 8 – 9.4 | 7.8 – 10.5 |
| Standard power (kW)| 0.97    | 0.9        | 1.26     | 1.25 – 1.57 | 0.81 – 0.85 |
| Max output (rpm)   | 6500    | 6500       | 6500     | 7000   | 6000 - 7500|

All subjects were interviewed using a modified HAVERA questionnaire with Malay translation adopted from the Hand-Transmitted Vibration Health Surveillance – Initial Questionnaire and Clinical Assessment, published by the Research Network on Detection and Prevention of Injuries due to Occupational Vibration Exposure (Vibration Injury Network). Some of questions stated in the HAVERA questionnaire were based on the study of hand arm vibration syndrome among group of construction workers in Malaysia [7] which was found to be reliable and suitable for use in different working activity. The interview consists of questions on personal identification, social history, occupational health, occupational history, machine safety inspection and symptoms. Detailed health effect information including the experience of any finger colour changes and weakness in hand grip strength were also asked. Subjects specifically need to recall any sustained injury to body parts and the curing process to regain normal health condition.

Blaze software version 6.1.1 for Larson Davis human vibration meter (HVM 100, PCB Piezotronic, 00496) was used to analyse hand arm vibration exposures referring to ISO 5349-1. Raw, h-weighted tri-axial hand arm vibration measurements were collected using ICP accelerometer mounted on both left and right handles of hand-held grass-cutting machine, respectively. The tri-axial piezoelectric accelerometer handle mounted adapter inserted between the worker’s fingers and the handle was fixed on the handle by tape [12] [13]. The right handle was used for operating the speed cutting control. Each handle was measured one time with sampling rate of 1 second period for 4 minutes. However, to produce the statistical significance of vibration data, at least 60 seconds should be enough for vibration data collection [14].

The subjective data analysis was carried out using SPSS version 19. Categorical data from different exposure groups were compared using two independent sample tests. The corresponding health symptoms among subjects with high versus low-moderate HAV exposure data were analysed using prevalence ration (PR) and Spearman correlation coefficient. The significant level for all statistical tests was set at 95% confident interval. For objective measurement, the hand arm vibration exposure depends on the magnitude of the total vibration and the duration of exposure. According to ISO 5349-1, daily vibration exposure should be stated in terms of 8 hours equivalent energy frequency h-weighted vibration total values, A(8). So, the average value of A(8) will be compared by means of the types of grass-cutting machine.

3. Results

Majority of the subjects were foreigners, with 38% from Indonesia, 26.2% from Bangladesh, 16.7% from Malaysia, 8.3% from India, 7.7% from Pakistan and the rest from Myanmar. The mean age for
subjects was 32.0 (SD 9.57) years old. Most workers (51.8%) had finished at least primary academic level, while 41.1% had completed secondary level. All of them were fluent in Malay language and understood the HAVERA questionnaires. All subjects were in normal build range (mean BMI 22.65) with 97.6% were right-hand dominants. Median duration of working experience using hand-held grass-cutting machines and mean cutting duration of a day were 24.0 (range from 1 to 240) months and 5.46 (range from 2 to 6) hours per day, respectively. Sixty four per cent of the subjects were smokers with ninety one per cent non-alcoholics. None of the subjects had a hobby involving vibration tool and work experience involving neurotoxic chemicals in the past. All workers claimed that grass-cutting operation involved repeated work done with the forearms and hands with forceful and twisting movements. There were 100 (59.5%) workers in high exposure group (working at highway area) and the rest were low-moderate exposure group (working at facilities area).

Physical observation of hand disease symptoms among two group of subject indicates there is a possibility of inducing hand-transmitted vibration disorders as shows in Table 2. Finger colour change and numbness were experienced by 81% and 36% of all subjects, respectively. Thirteen subjects suffered weakness on left hand grip while 14% suffered weakness on right hand grip for high group exposure. Other reported symptoms related to HAVS were experiencing cold fingers (6%), difficulty in manipulating small objects (9%), difficulty in opening tight jars (10%) and experience a tingling sensation in fingers (17%). Reported information and knowledge of health hazard in vibrating machine and awareness of any health control measure taken was 39% and 14% of all subjects, respectively.

| Symptoms                                      | HAV risk exposure, n (%) | PR (95% CI)             | Correlation Coefficient |
|-----------------------------------------------|--------------------------|-------------------------|-------------------------|
|                                               | Low-moderate group (n=68)| High group (n=100)       |                         |
| Experience any colour changes at fingers      | 62 (91.1)                | 74 (74)                 | 3.63 (1.41 to 9.39)     | 0.215                   |
| Experienced a tingling sensation in your fingers | 24 (35.3)                | 17 (17)                 | 2.66 (1.30 to 5.48)     | 0.209                   |
| Fingers go numb                                | 28 (55.9)                | 23 (23)                 | 4.24 (2.18 to 8.27)     | 0.336                   |
| Suffer from weakness at left hand grip         | 13 (19.1)                | 13 (13)                 | 1.58 (0.68 to 3.66)     | 0.083                   |
| Suffer from weakness at right hand grip        | 12 (17.6)                | 14 (14)                 | 1.32 (0.59 to 3.05)     | 0.049                   |
| Experience cold fingers                        | 10 (14.7)                | 6 (6)                   | 2.70 (0.93 to 7.83)     | 0.146                   |
| Difficulty in picking up or handling small objects | 6 (8.8)                | 9 (9)                   | 0.98 (0.33 to 2.89)     | -0.003                  |
| Difficulty in opening tight jars               | 6 (8.8)                | 10 (10)                 | 0.87 (0.30 to 2.52)     | -0.200                  |
| Information of vibratory tools is hazardous    | 32 (47.1)                | 34 (34)                 | 1.73 (0.92 to 3.24)     | 0.131                   |
| Awareness of vibration hazard                  | 13 (19.1)                | 11 (11)                 | 1.91 (0.80 to 4.57)     | 0.114                   |

* CI – Confident interval

Correlation test is a test to measure the strength of the linear relationship between two variables studied. There are three types of relationships that may exist between variables of linear correlation which are positive, negative or no correlation. The magnitude of the coefficient shows the strength of the linear relationship between two variables while the (+) or (-) signs indicate the direction of the
relationship either positive or negative linear correlation. In the case study, fingers go numb is the highest correlation contributing to hand arm vibration syndrome with positive 0.336 value.

Statistical data for daily vibration exposure, A(8) for left and right hands by type of hand-held grass-cutting machine are presented in Table 3. Both left hand and right hand vibration measurement are exceeding the EAV value for mean A(8) for each type of machine. As seen from Table 3, the A(8) values are almost similar for all of the machines except for machine type C which shows less vibration magnitude for both left and right hands. However, the A(8) value exceeded the ELV for left hand and below EAV for right hand. The extreme maximum A(8) value reveals that the workers have high possibility of exposed to impulsive force due to impact between dynamic rotation of cutting blade with stone, wood etc.

4. Discussion

In the early 2000s HAVS was reported in quarry miners using rock drill machine in Vietnam [15]. Subsequent reports came from construction and property management [16], together with detailed research on the quality of HAVS workers life [5]. Previous study revealed that the HAVS prevalence was between 18% to 50%. Based on the onsite observation of physical examination, the prevalence of HAVS was found to be 36% in the study. The result shown slightly corresponds with the prevalence of HAVS among construction workers in a tropical environment in Malaysia [7].

There was positive HAVS symptoms relationship between the low-moderate exposure group and high exposure group among hand-held grass-cutting workers. However, the numbness symptoms showed the highest significant value of 0.336 compared to other symptoms such as finger colour changes and tingling sensation. The prevalence ratio (PR) was considered high for experiencing any colour change at fingers and fingers go numb which are 3.63 (1.41 to 9.39) and 4.24 (2.18 to 8.27), respectively. The current subject reported numbness at left hand is much stronger compared to right hand. Hence, it supports the theory of human response to hand arm vibration stating that the effect of health depends on the vibration exposure either by duration or intensity of exposure [17].

The measurement for 5 types of hand-held grass-cutting machine with the standard power ranged in kilowatt from 8.0 to 10.5 kW and the discharge capacity ranged in cubic centimetre from 30.5 to 43.0 cc. An analysis of monitoring HAVERA measurement has found that the mean value of 168 subjects indicates estimated right and left hand daily vibration exposure, A(8) is 6.05 ± 2.74 m/s² and 8.68 ± 4.41 m/s², respectively. Based on the hand-held grass-cutting machine type, type A machine produces the highest A(8) value at right hand with 6.73 m/s², while type E machine produces the highest A(8) value at left hand with 10.82 m/s². However, only type B and type C machines produce below exposure limit value (ELV) for the right hand daily vibration exposure. The left hand daily vibration exposure exceeds the exposure action value (ELV) for all types of machine.

By referring to the guidelines on occupational vibration, hand-held grass-cutting workers should operate the machine for maximum of 2 hours per day to protect them from HAVS diseases. Thus, risks

**Table 3.** Statistical data for daily vibration exposure, A(8) for left and right hands by type of hand-held grass-cutting machine.

| Type of hand held grass cutter | Mean operating hours in a day | Left hand, A(8) (m/s²) Mean (S.D) | Right hand, A(8) (m/s²) Mean (S.D) |
|-------------------------------|-------------------------------|-----------------------------------|-----------------------------------|
| A                             | 5.57                          | 9.92 (4.92)                      | 6.73 (3.94)                      |
| B                             | 5.40                          | 8.13 (5.27)                      | 5.91 (2.70)                      |
| C                             | 5.96                          | 6.30 (3.34)                      | 4.77 (2.27)                      |
| D                             | 4.70                          | 8.23 (4.60)                      | 6.25 (2.84)                      |
| E                             | 5.62                          | 10.82 (3.94)                     | 6.57 (1.96)                      |

S.D, standard deviation
of HAVS have to be observed not only in the form of high vibration magnitude exposed but will associate to the duration of operating the machine. Control measures were not being implemented in reducing the vibration level such as handle vibration damper or anti vibration glove. So, engineering and administrative control measure will be the most suitable recommendation to reduce the HAV risk exposure and it must be associated with the management safety and health budget.

5. Conclusion

The current study has suggested that HAVS is diagnosed in Malaysia especially in agriculture sector among hand-held grass-cutting workers exposed to hand transmitted vibration in a tropical environment. These findings are indicating significant symptoms which contribute to HAVS prevalence. Employers should provide provision of such information, instruction, training and supervision to ensure, so far as is practicable, to mitigate the hand arm vibration risk. Hence, proper work schedule should be arranged to protect workers induced with HAVS. The machine type C provides the most comfortable operating condition for workers compared to types A, B, D and E. Therefore, machine type C should be recommended for grass-cutting operation. Besides that, the finger colour change and numbness showed high prevalence induced to HAVS. In association with those symptoms, further research will study on the health consequences of hand arm vibration using Vascular and Neurological Stockholm Workshop Scale and hand grip strength assessment.

References

[1] Ko, Y. H., Ean, O. L. & Ripin, Z. M. (2011). The design and development of suspended handles for reducing hand arm vibration in petrol driven grass trimmer. International Journal of Industrial Ergonomics, 41 (2): 459-470.

[2] Department of Occupational Safety & Health. (2013). Occupational Accident Statistics By Sector Online. http://www.dosh.gov.my/index.php?option=com_content&view=article&id=843&Itemid=545&lang=ms. Retrieved on 31st December 2013.

[3] Social Security Organization. (2015). Statistik Penyakit Muskuloskletal Pekerjaan 2005-2014 Online. http://www.dosh.gov.my/index.php?option=com_docman&task=doc_download&gid=330&Itemid=496. Retrieved on 6th July 2015.

[4] Bovenzi, M. (2005). Health effects of mechanical vibration. G Ital med Lav Erg, 27 (1): 58-64.

[5] Cederlund, R. & Iwarsson, S. (2007). Quality of life in Swedish workers exposed to hand – arm vibration. Occup. Ther. Int., 14: 156-169.

[6] Lin, W., Chunzhi, Z., Qiang, Z., Kai, Z. & Xiaoli, Z. (2005). The study of hand-arm vibration syndrome in China. Ind. Health, 43 (3): 480.

[7] Su, T. A., Hoe, V. C. W., Masilamani, R. & Awang Mahmud, A. B. (2011). Hand-arm vibration syndrome among a group of construction workers in Malaysia. Occup. Environ. Med., 68 (1): 58-63.

[8] BS EN ISO 5349-1. (2001). Mechanical Vibration – Measurement and Evaluation of Human Exposure to Hand-transmitted vibration – Part 1: General Requirement. British Standard.

[9] Janicak, C. A. Preventing HAVS in the Workplace. Professional Safety, 49 (1): 35-40.

[10] Directive 2002/44/EC of The European Parliament and of The Council of 25th June 2002 on The Minimum Health and Safety Requirements Regarding The Exposure to Workers to The Risks Arising From Physical Agents (Vibration), The Official Journal Of European Communities, 45, 13-19.

[11] Brereton, P. (2011). Impact of European Directive 2002/44/EC on the risk of developing hand-arm vibration syndrome in Great Britain, Canadian Acoustics, 39 (2): 108-109.

[12] Cakmak, B., Saracoglu, T., Alayunt, F. N. & Ozarsla, C. (2011). Vibration and Noise Characteristics of Flap Type Olive Harvester, Applied Ergonomics, 42 (3): 397-402.
[13] Dewangan, K. N. & Tewari, V. K. (2009). Characteristics of Hand-transmitted Vibration of a Hand Tractor used in Three Operational Modes, *International Journal of Industrial Ergonomics*, 39 (1): 239-245.

[14] Wasserman, J. F., Wasserman, D. E. & Wilder, D. (2005). Occupational Vibration: A concise Perspective, *Handbook of Human Factor and Ergonomics Methods*, CRC Press: 73-1.

[15] Futatsuka, M., Shono, M., Sakakibara, H. & Quan, P. Q. (2005). Hand arm vibration syndrome among quarry workers in Vietnam, *Journal Occupational Health*, 47 (2): 165-170.

[16] Coggins, M. A., Van Lente, E., McCallig, M., Padden, G. & Moore, K. (2010). Evaluation of hand-arm and whole-body vibration in construction and property management, *Annual Occupational Hygiene*, 54 (8): 904-914.

[17] Griffin, M. J. (1997). Measurement, evaluation and assessment of occupational exposure to hand-transmitted vibration, *Occupational Environment Medicine*, 54 (2): 73-89.