

Hand-arm Vibration Effects on Performance, Tactile Acuity, and Temperature of Hand

Abstract

Effects of vibration appear as mechanical and psychological disorders, including stress reactions, cognitive and movement disorders, problem in concentration and paying attention to the assigned duties. The common signs and symptoms of hand-arm vibration (HAV) in the fingers and hands may appear as pins and needles feeling, tingling, numbness, and also the loss of finger sensation and dexterity. Laboratory Virtual Instrument Engineering Workbench programming software designed for occupational vibrations measurement was used to calculate HAV acceleration. Hole steadiness test is designed to measure involuntary movement of people. V-Pieron test is designed for one of the other aspects of the psycho motor phenomena of steadiness by moving the stylus across a V-form ruler. The two points test was an experiment of touch acuity, which used a caliper by placing the two styli very close on the pad of finger knuckles. The temperature of finger skin is also measured simultaneous to the above tests. Wilcoxon test indicated that a significant decrement in hand steadiness occurred after gripping a vibrating handle for 2 min ($P \leq 0.003$). Wilcoxon test also represented a significant change in errors after gripping a grinder vibratory handle ($P \leq 0.003$). The differences at all of the knuckles were significant with a confidence interval percentage of 99%. There was a significant reduction in finger skin temperature before and after exposure to vibration (mean = 0.45°C, based on paired sample test). The obtained results considerably demonstrated the relation between hand performance and vibrations due to gripping a grinder. It can be concluded that an injury or accident may happen after exposure to vibrations for the fine duties, in fast actions.

Keywords: Hand performance, hand-arm vibration, tactile acuity, temperature

Introduction

Vibration affects the bodies of people in many different methods. The human body response to vibrations depends on the amplitude, frequency, the duration of exposure, vibration input direction, type and sensitivity of the tissues. About 2.5 million workers, in the U. S. A. alone, are exposed daily to hand-arm vibration (HAV) from the power tools they use on their jobs.^[1] Approximately, 24% of Australian workers are exposed to vibration in their workplace, 43% of whom are specifically exposed to only HAV.^[2] The effects of vibration appear as mechanical and psychological disorders. As a mechanical damage and with regards to the vibration input area, vibration resonance may happen to various tissues, and the body tissues are damaged directly. From the viewpoint of psychology, the syndrome may be appeared as stress reactions, and cognitive or movement

disorders. Concentration and paying attention to duties may be influenced, too. Various studies have indicated the influence of vibration on general consciousness in people. For example, the frequency of 1–2 Hz may cause a reduction of sleep duration. For instance, for a dentist, the exposure is only fingers in contact with the hand piece with a frequency of 1000 Hz. The common signs and symptoms of HAV in the fingers and hands may be appeared as pins and needles feeling, tingling, numbness, and also loss of finger sensation and dexterity. Of course, nightly awakening with painful fingers and hands is also reported.^[1] Table 1 demonstrates the symptoms of vibration exposure in a frequency range of 1–20 Hz.^[1]

There are a lot of jobs, which act as vibrations resource and create problems for operators due to exposure to hand arm vibrations. Chain saw, pneumatic hammers and drills, ballast stop machine, straight and angle grinders, dental high-speed drills, and

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ultrasonic therapy devices are the typical examples of HAV generators. For example, ultrasonic therapy devices provide the exposure of the frequency of above 10,000 Hz to skin and superficial tissue layers of fingers of the physiotherapist working with the devices. Different grinders with vibration acceleration of 4–8 m/s²^[3] and a peak frequency of 100–150 Hz^[4] may damage the both hands and arm of a mechanical workshop worker. The vibration acceleration magnitude may be increased depending on the typical duties, loads and the size of the applied disk. In general, the mentioned devices are capable to injure people, who are exposed to the vibrations transmitted to their bodies from hands and arm. The symptoms of this kind of exposure can be appeared as cold, numb, lifeless, white, stiff, and clumsy hands.^[4] A vascular and sensorineural assessment has been done in this respect by the American Conference of Governmental Industrial Hygienists (ACGIH), which is given in Table 2. Now, the question is that how the vibration can affect the vascular and sensorineural system? Does it can impress the performance of a worker?

Some of the hand held pneumatic tools such as hammers, grinders, and rock drills are also introduced as the instruments in emerging HAV syndrome. As the vibration syndrome, Raynaud’s phenomenon or vibration-induced white finger (VWF) are referred in the HAV syndrome.^[5] As shown in Table 3, ACGIH defined the stages of neurosensory symptoms.

One of the exposure effects to HAV is VWF, which is a vascular disturbance.^[6] Numbness reduced tactile sensitivity, and reduced manual dexterity are neurological disturbances of exposure effects to HAV. The other effects of being exposed to vibration, as the effects on the locomotor system, happens in muscles, bones, joints, and tendons. These effects disturb the comfort and performance of the workers in intensive or durable exposure to HAV. This is that issue which is interested by the authors to show at the present paper.

Human performance in exposure to vibration can influence the motor and tactile control. In fact, exposure to vibration during using hand-held tools can damage tactile sensitivity threshold, i.e., changes at the tactile sensitivity threshold due to loss of sensitivity cause the fingers to have difficulty in judging about the weight, form and texture of the objects being handled. Evidences show that in an intensive and long exposure to vibration, permanent, and irrevocable damages can be happened to the sensory organs.^[4] It probably leads to wrong judgment in gripping the objects or an incorrect sensing by the fingers.

A combination of sensory pathways causes the act of touching to be sensed. This is done through sensory signals reached from distributed sensors in our hands. Movement, pain, location, temperature, texture, shape, and size are the points that may be affected by vibration. Table 4 indicates the different types of receptors observed in the hands.^[7]

Table 1: Symptoms for vibration exposure at frequencies of 1-20 Hz

Symptoms	Frequency
General feeling of discomfort	4-9
Head symptoms	13-20
Lower jaw symptoms	6-8
Influence on speech	13-20
“Lump in the throat”	12-16
Chest pain	5-7
Abdominal pains	4-10
Urge to urinate	10-18
Increased muscle tone	13-20
Influence on breathing movements	4-8
Muscle contractions	4-9

Table 2: Stockholm workshop Hand-Arm Vibration Syndrome classification system for cold-induced peripheral vascular and sensorineural symptoms

Stage	Grade	Description
0	-	No attacks
1	Mild	Occasional attacks affecting only the tips of one or more fingers
2	Moderate	Occasional attacks affecting distal and middle (rarely also proximal) phalanges of one or more fingers
3	Severe	Frequent attacks affecting all phalanges of most fingers
4	Very severe	As in Stage 3, with trophic skin changes in the finger tips

The staging is made separately for each hand. In the evaluation of the subject, the grade of the disorder is indicated by the stages of both hands and the number of affected fingers on each hand; example: 2L (2)/1R (1) = Stage 2 on left hand in 2 fingers: Stage 1 on right hand in 1 finger

Table 3: Sensorineural assessment

Stage	Symptoms
0SN	Exposed to vibration but no symptoms
1SN	Intermittent numbness, with or without tingling
2SN	Intermittent or persistent numbness, reducing sensory perception
3SN	Intermittent or persistent numbness, reducing tactile discrimination and/or manipulative dexterity

Table 4: Types of Tactile receptors found in the hand

Adaptation speed	Psychophysical channel	Receptor ending	Receptive field size	Frequency range (Hz)
Fast acting I	Nonpacinian I	Meissner	Small	5-60
Fast acting II	Pacinian	Pacinian	Large	40-400
Slow acting I	Nonpacinian III	Merkel	Small	0-5
Slow acting II	Nonpacinian II	Ruffini	Large	100-500

Surveillance research would also benefit from the collection of health status information from the workers exposed to vibration. Such information could be used to determine whether or not exposures to vibration are causing or contributing to the workers’ injury or disease.

The chief objective of this study was to assess whether there was a difference in motor control and tactile problem after exposing to HAV acceleration. How and to what extent the temperature of the fingers will be changed? Does the vibration impress the vascular system of the fingers significantly? The study indicates the effectiveness of the vibration on the performance controls and the loss of sensitivity at the finger skin by three tests and the temperature changes of the fingers due to damage to vascular system.

Materials and Methods

The study has semi-experimental interventional approach with prior and subsequent observations regarding exposure to vibration, to investigate the hand arm vibrations of a metal finishing activity and its effects on the related workers' hands. This study was done on 12 workers in a motorcycle chassis production firm. The study started by participating twelve male volunteers with a mean age of 26.5. All individuals were selected from healthy office workers with no history of significant exposure to HAV in their occupation or other activities. According to the responses given in questionnaires, no one of the participants reported the disorders such as cardiovascular or neurological symptoms, injuries related to upper extremities, or history of cold hands. All the selected individuals were nonsmokers. The maximum rate of exposure to vibration by the individuals was less than the recommended exposure limits expressed by Iranian Occupational Health Center.^[8] In respect to ethical considerations, a vibration accelerometer installed on the wrist of people to measure the value of acceleration. All of the exposures determine under the permission limits. In each case, no extra exposure given to the individuals.

The handgrip position is done based on ISO 5349, as in Figure 1.^[9] The magnitudes of vibration acceleration were measured according to the National Instruments data acquisition card and the related vibration analyzer. The vibration accelerations were recorded through the accelerometers from Svantek Company in Poland,

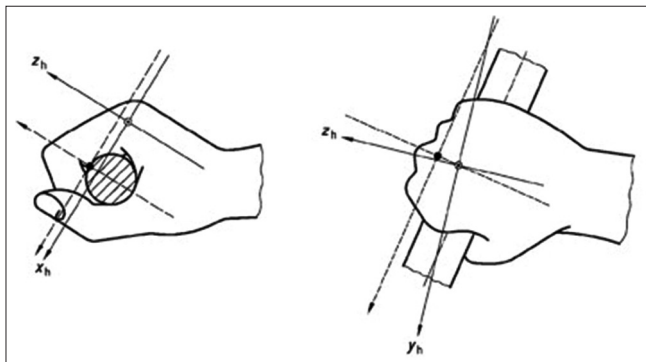


Figure 1: Handgrip position

with a data acquisition card from BSWA including USA national instrument data processor, and software programs of Laboratory Virtual Instrument Engineering Workbench (LABVIEW) for analyzing and simulating vibrations.

LABVIEW programming software was designed for occupational vibrations measurement of the heavy duty right angle sander to finish or polish metals [Figure 2], and it was used to calculate the hand arm vibrations acceleration based on root mean square (rms) [Figure 3]. The workers were exposed to the vibrations of the heavy duty right angle sander for 2 min.

Figure 4 shows how the vibration magnitude and exposure time are combined to give daily exposure rates.^[10] Exposures that lie in the green area (e.g., a magnitude of 3 m/s² and a duration of 2 h) are below the exposure action value, those in the yellow area (the magnitude of 6 m/s² and a duration of 2 h) are above the exposure action value, and the ones in the red area (the magnitude of 12 m/s² and a duration of 2 h) are above the exposure limit value.

The SV 105A triaxial hand-arm accelerometer was worn on a hand. The acceleration vibration of a large angle grinder transmitting to hands was measured in the three axes of X, Y, and Z for 2 min.

The summation of the accelerations in three directions is calculated by the Eq. 1, where a_{hw_x} , a_{hw_y} and a_{hw_z} are the accelerations in the x, y, and z directions, respectively.^[4]

$$a_{hv} = \sqrt{a_{hw_x}^2 + a_{hw_y}^2 + a_{hw_z}^2} \tag{1}$$

The equivalent 8-h acceleration is calculated by the Eq. 2 where $a_{eq(8)}$ is the 8-hour equivalent acceleration, T is the actual exposure time in hours, and a_{hv} is the acceleration during the period of T hours.

$$a_{eq(8)} = a_{hv} \sqrt{\frac{T}{8}} \tag{2}$$



Figure 2: The heavy duty right angle sander to finish or polish metal

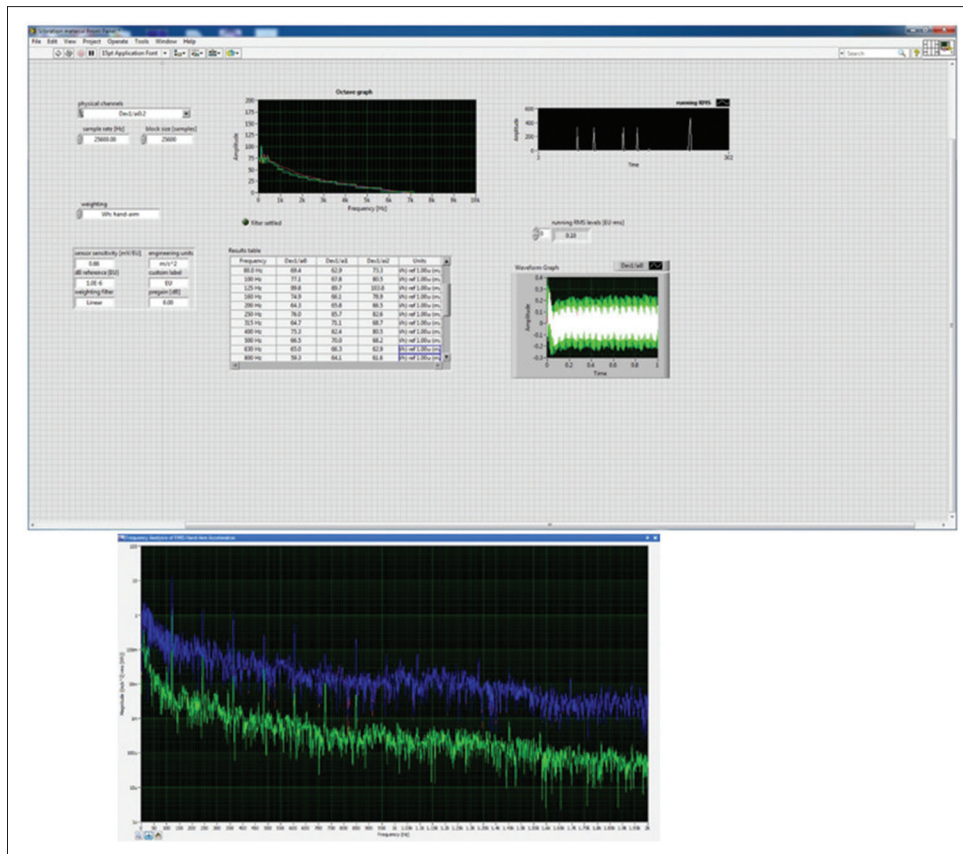


Figure 3: A view of front panel of Laboratory Virtual Instrument Engineering Workbench program

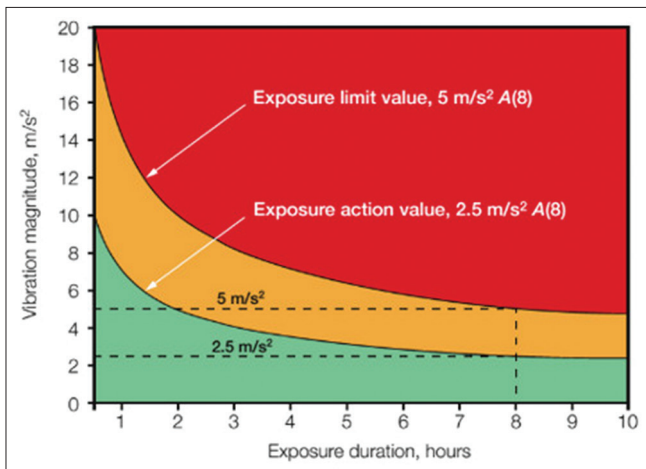


Figure 4: The relationship between vibration magnitude (level), exposure duration and the exposure action

The daily vibration exposure is calculated based on 5 m/s² permitted acceleration limit (ACGIH),^[10] based on Eq. 3.

$$t_{exp} = 8h \left(\frac{5m/s^2}{a_{measured}} \right)^2 \quad (3)$$

Sensitive and dynamic skills of fingers were evaluated with three tests before exposing to vibration. All the processes were performed after exposing to vibration. Some specific

battery tests were fulfilled to investigate the occupational skill performance.

Hand performance evaluation for motor control problem

Hole steadiness test is designed to measure the involuntary movement of people. Individuals were asked to try to insert a metal stylus into a metal plate with several holes in it without contacting the edges of the holes [Figure 5]. Individuals were required to place the metal stylus into the metal plate holes three times from the largest hole.

This instrument has been designed to measure one aspect of the psychomotor phenomena of steadiness. Ten holes, gradually diminishing in size are used, and the participant's task was to hold the stylus in the hole without touching the sides. The parameters including exercising and handedness were considered. Everyone was allowed to do the test three times for each hole before and after the exposure to vibration.

V-Pieron test is designed for another aspect of the psychomotor phenomena of steadiness by moving the stylus across a V-form ruler [Figure 5]. In this regard, the participant's task was defined based on transmitting the stylus through V-Pieron ruler without touching the edges of the ruler. The participants repeated the test three times before and after exposure to vibration.

Hand Performance Evaluation for Tactile Problems

The two points threshold test was an experiment of touch acuity, which started using a caliper, and placing two styli very close, almost one millimeter from each other) on the pad of finger knuckles with two index and middle fingers [Figure 6]. Both styli touched the finger surface at the same time. Then, the individuals were asked for the points that might have been felt. The response that they felt was only on one point of contact. The test began by moving the stylus slightly apart each time until the individual could feel two distinct points. The distance between the two points was measured; this was the two-point threshold of one millimeter for that finger. The test was repeated for the other spaces to almost the distance of ten millimeters. This was the two-point threshold of one to ten millimeters for the participant, the finger and the knuckle. Then, the working individuals were allowed to work with the angle sander, for approximately 2 min. Afterward the two-point threshold was measured again, and the results were recorded.

Skin temperature measurement

In addition to the above tests, the temperature of finger skin was measured by Lutron, TM-917, and precision thermometer 0.01 degree, simultaneously. A probe (PT-04) was located on the surface of pad of fingers before and after of exposure to vibration.

Results

The vibration acceleration of the grinder was measured by LABVIEW program for the three directions X, Y, and Z, as shown in Table 5. Average acceleration was 23.4 m/s². According to ACGIH standards, vibration acceleration was four times more than the recommended values for 8-h exposure to HAV. The maximum period of exposure in 8 h/day was 36 min.

Table 6 shows the average number of contacts on the hole steadiness test before and after exposure to vibration acceleration. Wilcoxon test indicated that a significant decrement in hand steadiness occurred after gripping the vibrating handle for 2 min ($P \leq 0.003$). The change or the access ratio of the hole steadiness errors after a 2-min vibration exposure with an angle grinder among the twelve office worker participants has been shown in the fourth column of Table 6.

Results indicated in Figure 7 show that a significant decrement in hand steadiness was occurred immediately following a relatively exposure of vibration accelerations in the 8-850 Hz frequency range. The measured amplitude of accelerations in this case for the frequency band was in the range 0.2–17 m/s².

Table 7 represents errors in employing V-Pieron test before and after exposure to vibration. Wilcoxon test represented a significant change in errors after gripping the grinder vibratory handle ($P \leq 0.003$). In the two cases, the access ratio was reached to 100% following an increase in the

Table 5: The vibration acceleration values of the grinder

X	Axis		a_{hv}	t_{exp} (ACGIH)
	Y	Z		
16.22	16.80	1.60	23.4	36 min

ACGIH – American Conference of Governmental Industrial Hygienists

Table 6: The hole steadiness errors before and after exposing to vibration with the access error ratio

	<i>n</i>	Before of exposing	After of exposing	Access ratio
Hole steadiness errors	1	1	5	4
	2	2	4	2
	3	0	3	3
	4	0	2	2
	5	0	1	1
	6	2	2	0
	7	2	4	2
	8	0	1	1
	9	1	3	2
	10	1	3	2
	11	2	5	3
	12	4	5	1
	\bar{X}	1.2	3.1	1.9
	σ_n	1.1	1.4	1

number of errors from zero to 2 in performing the task. According to Figure 6, considerable changes of the number of performance errors were happened after exposing to HAV. Based on Figure 8, a comparison in V-Pieron test results indicated the growing values of the error in performing the task after exposure to vibrations.

Tactile sensitivity was measured by two-point threshold test, so that differences between two points of touch acuity were found significantly across the fingers knuckles. The values of touch acuity were measured by means of an adjustable caliper from 1 to 10 mm for the 3 knuckles of the two index and middle fingers of the right hand. The index and middle fingers showed considerable changes to the tactile sensitivity after exposing to vibration, as compared to the time before the exposure. Table 8 demonstrates the extracted results of the test of touch acuity for three knuckles on the pad of index and middle fingers before and after exposure to vibrations. The differences were significant for the knuckles with a confidence interval of 99% (index finger including first knuckle, $P \leq 0.006$; second knuckle, $P \leq 0.011$; third knuckle, $P \leq 0.004$; middle finger including first knuckle, $P \leq 0.002$; second knuckle, $P \leq 0.006$; third knuckle, $P \leq 0.005$ -based on Wilcoxon signed ranks test). The values regarding millimeter increases in touch acuity threshold after exposure to vibration are given in Table 9. Figures 9 and 10 indicate tactual space variances for the two index and middle fingers before and after exposure to vibration.

Finger skin temperature (FST) varied between the individuals before exposure to vibration, being in the

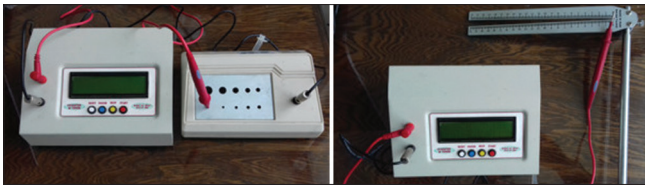


Figure 5: The hole steadiness device (left) and the V-Pieron vibrometer (right)

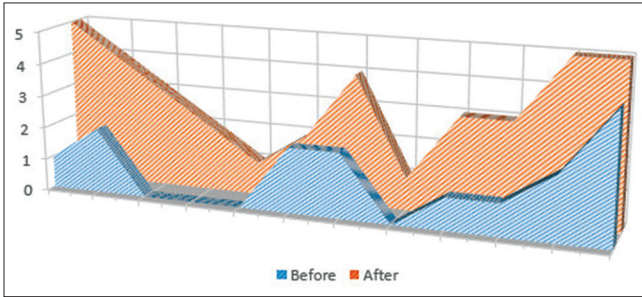


Figure 7: Hole Steadiness test

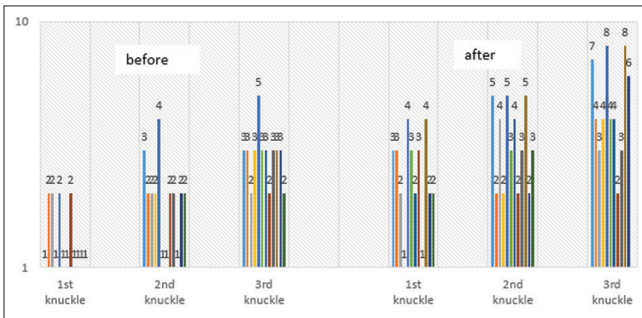


Figure 9: Variation of tactual space in index finger knuckles

range 29.6°C–35.4°C before exposure to vibration, and 29°C–35°C after exposure to vibration [Table 10]. The median FST was 31°C and 30.62°C during the 2-min experimental period, before and after exposure to vibration, respectively [Figure 11].

There was a significant reduction in FST over 24 measurements of FST, both before and after exposure to vibration (mean = 0.45°C, based on paired sample test). The median FST before exposure to vibration was significantly higher than that after exposure to vibration ($P \leq 0.002$; Wilcoxon).

Discussion

Haines and Chong reported the esthesiometer values for the index, middle and ring fingers among workers using grinders and chipping hammers.^[11] The present study indicates the fulfilled test to evaluate the touch acuity of two index and middle fingers similar to Haines and Chong studies. Besides to the fingers, the fingers knuckles have assessed in this study from the viewpoint of the touch acuity and temperature changes. In fact, it can be observed that the loss of sensitivity in the pad of fingers or in other



Figure 6: Adjustable two-point caliper

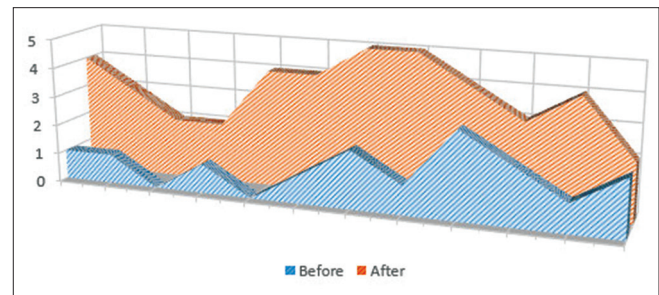


Figure 8: V-Pieron test

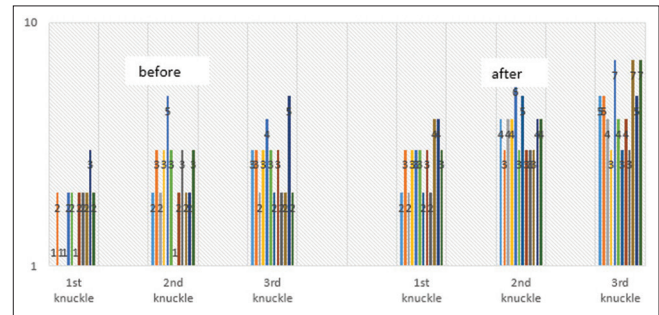


Figure 10: Variation of tactual space in middle finger knuckles

words, the tactile problem may affect the recognition of the objects. In research, Lander *et al.* reported that the workers exposed to HAV are at risk of developing the neurological abnormalities of hand–arm vibration syndrome (HAVS).^[12] Bylund has demonstrated that neurological symptoms were more common, developed after a shorter period of exposure to vibration as compared to vascular symptoms.^[13] A similar exposure to hand arm vibration and the hand steadiness test was implemented in this study. This study has evaluated the performance power of the worker’s fingers in exposure to vibration with three different tools simultaneously. This method give solely more confidence of results to be correct in comparison to studies done by Seeman and Williams about the performance problems or Ye and Griffin about temperature changes on the finger

Table 7: V-Pieron test errors before and after exposing to vibration with the access error percent

	<i>n</i>	Numbers of errors (average)		Access ratio	Error percent
		Before of exposing	After of exposing		
V-Pieron test errors	1	1	4	3	60
	2	1	3	2	50
	3	0	2	2	100
	4	1	2	1	50
	5	0	4	4	100
	6	1	4	3	75
	7	2	5	3	60
	8	1	5	4	80
	9	3	4	1	25
	10	2	3	1	33
	11	1	4	3	75
	12	2	2	0	0
		$\bar{\chi}$	1.2	3.5	2.2
	σ_n	0.82	1	1.2	28.56

Table 8: Two points threshold test results on the pad of fingers before and after exposure to vibration

	Pad of index finger			Pad of middle finger		
	First knuckle	Second knuckle	Third knuckle	First knuckle	Second knuckle	Third knuckle
Two point threshold	Before of exposing					
	1	3	3	1	2	3
	2	2	3	2	3	3
	2	2	2	1	2	2
	1	2	3	1	3	3
	2	4	5	2	5	4
	1	1	3	2	3	3
	1	1	3	1	1	2
	2	2	2	2	2	3
	1	2	3	2	3	2
	1	1	3	2	2	2
	1	2	3	3	2	5
	1	2	2	2	3	2
	$\bar{\chi}=1.3$	$\bar{\chi}=2$	$\bar{\chi}=2.9$	$\bar{\chi}=1.7$	$\bar{\chi}=2.5$	$\bar{\chi}=2.8$
	$\sigma_n=0.47$	$\sigma_n=0.81$	$\sigma_n=0.75$	$\sigma_n=0.59$	$\sigma_n=0.95$	$\sigma_n=0.89$
	After of exposing					
	3	5	7	2	4	5
	3	2	4	3	3	5
	2	4	3	2	4	4
	1	2	4	3	4	3
	4	5	8	3	6	7
	3	3	4	3	3	4
	2	4	4	2	5	3
	3	2	2	3	3	4
	1	3	3	2	3	3
	4	5	8	4	3	7
	2	2	6	4	4	5
	2	3	4	3	4	7
	$\bar{\chi}=2.5$	$\bar{\chi}=3.3$	$\bar{\chi}=4.75$	$\bar{\chi}=2.8$	$\bar{\chi}=3.83$	$\bar{\chi}=5.0$
	$\sigma_n=0.95$	$\sigma_n=1.1$	$\sigma_n=1.9$	$\sigma_n=0.68$	$\sigma_n=0.89$	$\sigma_n=1.5$

skin. In one hand, Seeman and Griffin have separately demonstrated a variable like the temperature or only one of the hand performance tests in their studies. On the other

hand, Bovenzi *et al.* (2001) used the 30-min exposures to vibration with a frequency of 125 Hz and an acceleration of 87.5 m/s²-rms.^[14] Minimum changes indicated 0.1°C

and the maximum was 0.9°C. The average temperature reduction was 0.45°C as can be seen in Table 10. The reduction was only for 2 min of exposure to an HAV

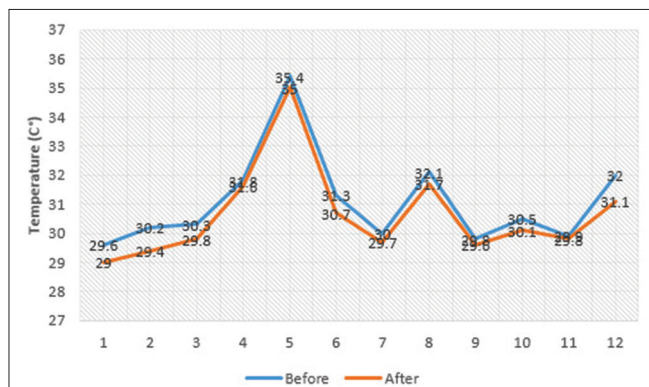


Figure 11: The reduction of temperature

Table 9: The access values of touch acuity evaluated by two points threshold test (mm)

The access ratio of two points threshold test (mm)					
Pad of index finger			Pad of middle finger		
First knuckle	Second knuckle	Third knuckle	First knuckle	Second knuckle	Third knuckle
2	2	4	1	2	2
1	0	1	1	0	2
0	2	1	1	2	2
0	0	1	2	1	0
2	1	3	1	1	3
2	2	1	1	0	1
1	3	1	1	4	1
1	0	0	1	1	1
0	1	0	0	0	1
3	4	5	2	1	5
1	0	3	1	2	0
1	1	2	1	1	5
$\bar{X}=1.1$	$\bar{X}=1.3$	$\bar{X}=1.8$	$\bar{X}=1$	$\bar{X}=1.2$	$\bar{X}=1.9$
$\sigma_n=0.89$	$\sigma_n=1.2$	$\sigma_n=1.5$	$\sigma_n=0.49$	$\sigma_n=1$	$\sigma_n=1.6$

with a peak frequency of 125 Hz and an acceleration of 23.4 m/s² rms of a grinder. Ye and Griffin reported the FST in the unexposed finger was reduced during exposure to vibration. The reduction of almost 1°C of FST in the 10-min exposure of the right hand was reported in that research. Bovenzi et al. (2001) reported that after 30-min exposures to vibration with a frequency of 125 Hz and an acceleration of 87.5 ms⁻²-rms (unweighted). While the present study had a limitation of time of 2 min compared to Bovenzi study. Although this study had a three parameter index the limitation time may affect the precision of the test compared to 10 or 30 min experimental study of Griffin and Bovenzi.

Conclusions

The present study indicates the significant relation between exposure to HAV and fine hand motor performance disorders of people whom are exposed to vibrations during working. Seeman and Williams emphasized about the effects of oscillations on workers' performances.^[15] The estimated total value of vibration acceleration was equal to 23.4 m/s²-rms. In the case of working for 2 h in an 8-h shift, the total value will be 11.7 m/s². This value is more than twice the recommended limit by ACGIH. Ye and Griffin have implemented an exposure for 10 min to individuals with an unweighted acceleration vibration of 44 m/s²-rms to show temperature changes on the finger skin. In indicating the temperature significant variations, Bovenzi et al. (2001) used the 30-min exposures to vibration with a frequency of 125 Hz and an acceleration of 87.5 m/s²-rms. Popević et al. found a statistically significant decrease in manual dexterity between healthy controls and individuals exposed to vibration.^[16] In a study, Lander et al. demonstrated that severity of patients' symptoms, impairment in grip strength and sensitivity to cold tend to correlate with the magnitude of reduced sensation. They also pointed at the tendency to drop things as well as the presence of numbness and tingling. The

Table 10: The reduction of temperature after exposure to vibration

	n	Before of exposing	After of exposing	Temperature reduction (°C)	Min and Max of reduction
Temperature (°C)	1	29.6	29	0.6	
	2	30.2	29.4	0.8	
	3	30.3	29.8	0.5	
	4	31.8	31.6	0.2	
	5	35.4	35	0.4	
	6	31.3	30.7	0.6	
	7	30	29.7	0.3	
	8	32.1	31.7	0.4	
	9	29.8	29.6	0.2	
	10	30.5	30.1	0.4	
	11	29.9	29.8	0.1	
	12	32	31.1	0.9	
	\bar{X}	31	30.6	0.45	Maximum=0.9
	σ_n	1.5	1.5	0.23	Minimum=0.1

problem will be stepped up with the vibration effects on neurosensory system as temporary or permanent injuries. For instance, after exposing to vibration and while going back home in his car, a worker attempting to activate a touch key may be injured due to using it in a wrong way or attempting to correct it. It concludes access to the errors for given activities after receiving the vibration is by the alarm to the workers with required assignments, who are susceptible for vibration syndromes or injuries by accident.

This study demonstrated the appearance of vibration effects as temperature changes on fingers skin. Reduced blood flow would lead to reduced FST during exposure to vibration. The present findings show the predominant frequency of 125 Hz influenced the FST as in the results obtained by Ye *et al.* (2007).

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Conflicts of interest

There are no conflicts of interest.

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