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Effect of Frequently Using Workshop Tools on Worker's Hand Arm Vibration and Safety

Hamed, A. R.; W. F. El-Metwally; I. F. Sayed and M. E. El-Iraqi
Agricultural Engineering Research Institute (AEnRI), ARC, P. O. Box 256, Giza, Egypt

ABSTRACT

In the workshops of agricultural sector there are a lot of technical jobs which widely use hand-held or bench-top workshop power tools such as angle grinders, drills, riveters, chain saw, pneumatic hammers and torque wrenches. Which consider the most important sources of hand arm vibration (HAV) These workshop power tools are known to transmit substantial vibrations to the operators/worker's hand and arm and act as vibrations resource consequently, create problems for operators/workers who regularly exposure to hand arm vibrations. Therefore, the main objective of this investigation is to study the effect of frequently using of workshop tools on worker's hand arm vibration and safety. The study selected eight representatives healthy workers were well familiar with the workshop power tools control levers and had sufficient experience of operating some power tools from both bench-top and hand held workshop power tools (stand drill, wheel grinder, disc cutter, angle grinder impact drill, and rotary hammer drill with different spare discs under two different working postures as vertically erected and squeeze) during five different operations, namely, grinding, drilling, cutting, breaking and polishing using three types of materials (metal, wood and concrete). Parameters such as frequency-weighted vibration acceleration in root mean square (RMS), heart pulses rate (HR), blood pressure (BP), work related body pain (WRBP), stand height, arm length and mass of operators were evaluated. Vibration measurements were performed according to (ISO 5349-2: 2001). Workshops operations were conducted in a statistically designed layout (randomized complete blocks design) and were conducted at applied research farm of Rice Mechanization Center, Meet Eldeeba, Kafr El-Sheikh Governorate, in the 2018. The obtained results indicated that the cutting by the angle grinder gives the highest HAV data of the frequency weighted RMS acceleration magnitude while, the largest single orthogonal axis is in the axis (X) which exceeded than both of exposure action value and exposure limit value. This causes a high risk on the worker hand-arm which increases the heart rate and blood pressure followed by the polishing by the hand angle grinder. On the other hand, the HAV emission level recorded the lowest values during grinding by the bench-top wheel grinder and drilling by the bench-top stand drill consequently; there is no risk on the operator hand-arm and also the heart rate and blood pressure. Using rubber gloves during cutting by the hand angle grinder leads to a decrement percentages in the HAV values and so heart rate and blood pressure. The maximum WRBP values were obtained during the cutting by the angle grinder on working squeeze posture followed by cutting by the angle grinder on working normal posture and polishing by the angle grinder. Maximum pain levels of 15.6, 14.8 and 13.6 (Borg scale) were observed respectively. Results showed that there are significant differences between RMS, SBP, DSBP and heart rate during the different workshop operations.

Keywords: workshop power tools, hand-arm vibration (HAV), body mass index (BMI), heart pulses rate (HR), blood pressure (BP), work related body pain (WRBP).

INTRODUCTION

Hand-arm vibration (HAV) is vibration transmitted into workers' hands and arms (HSE, 2008; HSE, 2005) which generated by operating hand-held power workshop tools and by working components of agricultural machines, as control and driving levers, steering wheels or when holding materials being processed by bench-top workshop power tools. Workers using hand-held power tools in workplaces can be exposed to harmful levels of hand–arm vibration. 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 USA alone, are daily exposed to hand-arm vibration from the power tools they use on their jobs (Wilhite, 2007). Approximately, 24% of Australian workers are exposed to vibration in their workplace, 43% of who are specifically exposed to only HAV (National Hazard Exposure Worker Surveillance 2009). The exposure to vibration from the use of grinders and hammers correspond to 96-98% of the total daily use of hand-held tools. The measured vibration magnitude shows that grinders have a larger variability in measured magnitudes compared to hammers. Moreover, the grinders are equipped with a variety of different grinding wheels (flap discs, cut-off wheels, grindstones, etc.) that influence vibration level (Dong *et al*., 2005a; McDowell *et al*., 2007). Different grinders with vibration acceleration of 4–8 m/s^2 (Health and Safety Executive, 2008). The effects of exposure to hand–arm vibration are influenced by duration of exposure during each work shift and number of years of exposure; duration and frequency of work-rest periods; hand-grip/push forces applied; working hand-arm posture during tool operation; use of personnel protective equipment, including gloves and individual operator's skill, technique and his medical history and habits. The others were types of tool and task; tool speed; frequency and magnitude of the vibration; tool maintenance state, type of insulation on the tool handle. Also there are some factors related to workplace environment such as climatic conditions and the structure of the work surface (Mallick, 2008; and Mallick, 2010).

The effects of vibration appear as mechanical and psychological disorders, including stress reactions, cognitive, movement disorders and damage joints in the hands and arms of workers in any occupation involving repetitive use of vibrating tools (Campbell *et al*., 2017). Excessive use of vibrating power workshop tools can lead to a number of adverse health effects, neurological, vascular and musculoskeletal systems (Lawson *et al*., 2010). One of the exposure effects to HAV is Raynaud's phenomenon or vibration-induced white finger, which is a vascular disturbance (Ye and Griffin, 2011, Shen and House, 2017). The other effects of vibration were happened in muscles, bones, joints, and tendons. These effects disturb the comfort and performance of the workers in intensive or durable exposure to HAV (Mirta and Dawal, 2010). (Buhaug *et al*., 2014) indicated that severe HAVS can lead to difficulties in performing everyday activities with lowered work ability and quality of life. Some of the power hand held workshop tools such as hammers, grinders, and drills are also introduced as the instruments in emerging HAV syndrome (Gerhardsson and Hagberg, 2014; Sauni *et al*., 2015).

The HTV exposure could be limited by decrease the tool speed and the daily exposure duration, tool design, nature of the task and the other operating conditions (Griffin, 1996; and Pelmear and Wasserman, 1998). Control or limit the HTV exposure at the source could be obtained through designs of low vibration tools and handles as well as using the anti-vibration gloves (Dong *et al*., 2005b; Dong *et al*., 2009, Oddo *et al*., 2004). Their results showed that the characteristics vibration transmission by anti-vibration gloves is strongly dependent upon the elastic properties of the coupled hand forces; vibration excitation levels and hand-glove system. The gloves can often reduce high-frequency vibration and can play an important role in reducing the risks from hand-arm vibration (Dong *et al*., 2003; 2005; 2009). So workshop power tools are used for different purposes of many fields such as agricultural, construction, logging and manufacturing. In the workshops of agricultural sector there are a lot of technical jobs which widely use hand-held power tools such as angle grinders, drills, riveters, chain saw, pneumatic hammers and torque wrenches. The main objective of this investigation is to study the effect of frequently using of workshop tools on worker's hand arm vibration and safety.

MATERIALS AND METHODS

Study workers and its measurements

Total of eight representative healthy workers of workshop tools with no physical ailment chosen from available workers in workshop of the applied research farm of Rice Mechanization Center (RMC), Meet Eldyeba, Kafr El-Sheikh Governorate; Agric. Eng. Res. Institute.

Three different physical of stand height, arm length and mass were taken for each worker in this investigation using a measuring tape and weighing balance. Height and mass were used to calculate the workers body mass index (BMI) according to the World Health Organization (WHO, 2000). The measurements posture was done such that the subject stands with his feet close and his body vertically erected.

Two physiological measurements of systolic blood pressure (SBP), diastolic blood pressure (DSBP) and heart pulses rate (HR) were taken using blood pressure monitor UA-651. The cuff which was attached to the worker wrist or upper arm was connected to an electronic monitor.

The measurements were immediately carried out before and after each work operation to clarify the effect of hand arm vibration on the workers physiological conditions. The classifications of blood pressure were shown in Table 1 (WHO, 2003).

Table 1. Standard classifications of blood pressure.

Categories of blood pressure	Systolic, mmHg	Diastolic, mmHg
hypotension	Less than 90	Less than 60
Normal	90 to 120	60 to 80
Prehypertension	120 - 139	80 – 89
hypertension stage 1	140 - 159	90 – 99
hypertension stage 2	160 or higher	100 or higher
seek emergency care, crisis	180 or higher	110 or higher

Scope of study variables

The study selected eight workers were familiar with the workshop power tools and had enough experience of the power tools operating under actual conditions during done five different operations, namely, grinding, drilling, cutting, breaking and polishing. The workshop power tools under study were divided into two group categories. The first group is bench-top workshop power tools such as stand drill, wheel grinder and disc cutter, while the second group is the hand held workshop power tools such as angle grinder (with spare discs for cutting, grinding and polishing), impact drill, hammer drill and rotary hammer drill. The worker using these tools under two different working postures as vertically erected and squeeze with three types of materials (metal, wood and concrete). Then, with different combinations of variable study we select eleven treatments as shown Table (2), while the main technical specifications of the workshop power tools under study are given in Table (3a and b).

Statistical analyzing of experimental data

The experimental data for this study were statistical analyzed in a randomized complete blocks design using statistical package for social science (SPSS software, version 20) and a probability value of $p \leq 0.05$ was considered to show a statistical significant difference among mean values (Snedecor and Cochran, 1989). The data were processed for frequencies procedure and analysis of variance taken where subjects as replications.

Table 2. Study treatments.

Treatments	Tool	Accessories	Working Postures
cutting metal by the hand held angle grinder	Angle grinder	Cutting disc, (ϕ=7")	Normal
cutting metal by the hand held angle grinder			Squeeze
polishing metal by the hand held angle grinder	Angle grinder	Polishing disc, (ϕ=5")	Normal
breaking concrete by the hand held Rotary hammer drill	Rotary Hammer drill	Breaking bit, (ϕ=30 mm)	
grinding metal by the hand held angle grinder	Angle grinder	Grinding disc, (ϕ=9")	
drilling walls by the hand held Rotary hammer drill	Rotary Hammer drill	Drilling bit, (ϕ=30 mm)	
drilling metal by the hand held impact drill	Impact drill	Drilling bit, (ϕ=13 mm)	
drilling wood by the hand held impact drill	Impact drill	Drilling bit, (ϕ=13 mm)	
cutting metal by the bench-top disc cutter	Disc cutter	Cutting disc, (ϕ=9")	
grinding metal by the bench-top wheel grinder	Wheel grinder	Coarse abrasive wheel (ϕ=250mm)	
drilling metal by the bench-top stand drill	Stand drill	Drilling bit, (ϕ=16mm)	

Table 3a. The main technical specifications of bench-top workshop power tools under study.

Type	Wheel Grinder	Stand Drill	Disc Cutter
Model	NEBES, Italy made	M.F., Local made	SLECO, YL 90L-2, China made
Rated power	0.96 kW	0.37 kW	2.2 kW
Speed	2800 rpm	1400 rpm	2800 rpm
Weight	17.3 kg	38.3 kg	26 kg
Volt/Ampere /Hz	220/3.80/50	220/4.24/50	220/13.7/50
Used Accessories	Fine and abrasive wheels, ϕ =250mm	Drill bit, ϕ = 16mm	Cutting disc, ϕ = 9"

Table 3b. The main technical specifications of hand held workshop power tools under study.

Type	Angle Grinder	Impact Drill	Rotary Hammer Drill
Model	Bosh, GmbH, Germany made	APT CROWN CT3262, China made	APT CROWN CT3262, China made
Rated power	2.2 kW	0.81 kW	1.02 kW
Speed (RPM)	6500 rpm	2800 rpm	2800
Weight	5.0 kg	2.5 kg	5.0 kg
Volt/Ampere /Hz	220-230/9.7/50	220-230/50-60	220-230/50-60
Drilling capacity		Steel 13mm, Wood 40 mm, Concrete 16 mm	Steel 13mm, wood 40 mm, Concrete 30 mm
Used Accessories	Grinding disc, ϕ = 9" Cutting disc, ϕ = 7" Polishing disc, ϕ = 5"	drill bit ϕ =13 mm	Rotary hammer bits ϕ = 30 mm

Measuring vibration methodology & instruments

A portable human vibration analyzer type 4447 was used to measure vibration characteristics at the handle of the workshop power tools during actual operation. The accelerometer was mounted and fixed on the workshop power tools handle by the worker hand (as shown in Figure 2). The commendation of ISO 5349-2: (2001) was followed for orientation of the measurement axes as shown in Figure (2) Zh-axis was directed along the second metacarpus bone of the hand; Xh-axis was perpendicular to the Zh-axis (both these axes are normal to the longitudinal axis of the grip) and Yh-axis was parallel to the longitudinal axis of the grip (Fig. 1). The signal output was pre-amplified by a signal conditioner before recording; the data stored in the data acquisition system during measuring operation, and then was downloaded in a personal computer.

Also, it could be mentioned that the hand-arm vibration measurements were taken with & without using worker hand rubber gloves during workshop operations as a method for reducing HAV effects as shown in Fig. (2).

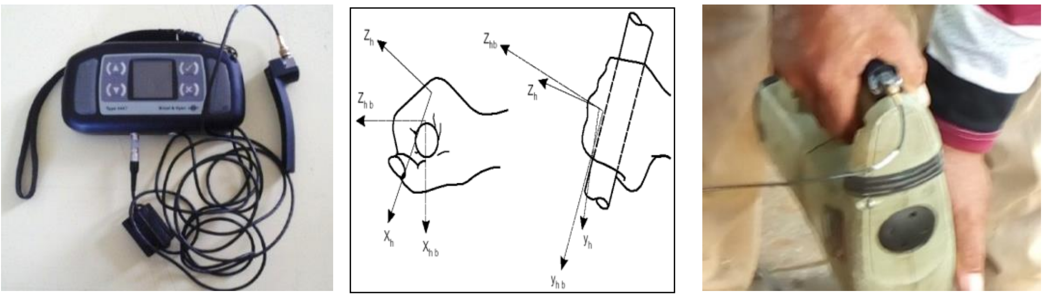


Fig. 1. Human vibration analyzer and coordinate system for the hand.

Fig. 2. Worker hand rubber gloves.

Human exposure to hand-arm vibration evaluated by the method defined in ISO 5349-2: 2001. The root mean square, RMS vibration magnitude is expressed in terms of the frequency-weighted (m/s²). The RMS magnitude represents the average acceleration over a measurement period. Measurements should be made over periods of at least 20 minutes to produce vibration values that are representative of the average vibration throughout the operator's working period. Griffin (1996), Scarlett *et al.* (2005) and ISO 5349-2: 2001).

They mentioned that HAV emission levels are evaluated in terms of (RMS). This technique generates a single value to represent a period of vibration measurement. Moving components of the power tool causes vibration. Vibrations transmitted into the human body by contact with the power tool are made up of vibrations of different frequencies. Human perception to vibration is high at low frequency, the frequency-weighted vibration acceleration is calculated as

$$a_w = \left[\frac{1}{T} \int_0^T a_w^2(t)\,dt \right]^{1/2} \qquad (1)$$

Where: **aw (t) = frequency-weighted acceleration time history (m/s²).**
T= duration of measurement (s).

The (frequency-weighted) energy- equivalent acceleration (Aeq) corresponding to the total duration of exposure may be derived. This is effectively an overall average RMS acceleration value for the total period (ΣTi).

$$A_{eq} = k\left[\frac{\sum a^2_{wi}.T_i}{\sum T_i}\right]^{1/2} \qquad (2)$$

Where:

Aeq = axis-weighted energy-equivalent continuous acceleration (RMS acceleration (m/s^2))

awi=vibration magnitude (RMS acceleration (m/s^2)) for exposure period Ti

ΣTi = total duration of exposure / measurement

k = orthogonal (measurement) axis multiplying factor specified by ISO 5349-2: 2001.

For hand-arm vibration (HAV), The Exposure Action Value (EAV) and the Exposure Limit Value (ELV) defined as a daily vibration exposure, expressed as frequency weighted, energy-equivalent continuous RMS acceleration over an eight-hour period (A(8)) as shown in Table (4).

Table 4. Vibration exposure values specified by ISO 5349-2: 2001.

Vibration Magnitude, RMS. acceleration – A (8) (m/s2)	Daily exposure action value: If reached, technical and organizational actions must be taken to reduce vibration exposure	Daily exposure limit value: Should never be exceeded
2.5	8 h	>24 h
5	2 h	8 h
10	30 min	2 h
15	13 min	53 min
20	8 min	30 min

In either case, the vibration exposure levels are evaluated individually from the acceleration recorded in each of three orthogonal axes (X-longitudinal, Y-transverse & Z-vertical). The resulting A (8) values for each (X, Y and Z) axes are then compared individually with the EAV and ELV. The daily vibration exposure level (A (8)) (units: m/s^2), expressed as eight-hour energy equivalent continuous, frequency-weighted RMS as below:

$$A(8) = A_{eq}\sqrt{\frac{t}{8}} \qquad (3)$$

Where: t = daily exposure period (hours)

Aeq = the energy-equivalent continuous RMS acceleration which is representative of the exposure period (m/s^2)

RESULTS AND DISCUSSION

Workshop workers physical characteristics

The physical characteristics of the selected subjects for the workshop operations under study were measured, calculated and statistically analyzed. Workshop workers characteristics under study showed that the highest percentage of body mass index was (50%) for obesity body followed by ideal body was (25%) and for overweight body was (25%). The workshop power tools workers were classified according to standard categories as follows; Less than 18 consider thin; 18-24 is ideal; 25-29 is overweight; 30-39 is obesity and more than 40 are over obesity. The highest number of workshop power tools workers (37.5%) was classified in the age group of (41-45) years while the age groups of (31-35) (36-40), (46-50), (51-55), (56-60) years was contributed with 12.5% of workshop power tools workers for each group.

Vibration measurements

The results illustrated in Figure (3) showed that the basic vibration measurement parameters were for the x, y, and z direction. The maximum frequency weighted RMS acceleration during cutting by the hand held angle grinder with cutting disc was 7.45, 3 and 3.72 m/s2 for the x, y and z axes respectively. While, the peak vibration acceleration was 3.98, 0.66 and 0.78 m/s2, and MTVV (maximum transient vibration value) was 0.67, 0.25 and 0.32 m/s2 for the x, y and z axes, respectively. This is considerably in excess of the HAV exposure action value (EAV) and exposure limit value (ELV) for x direction proposed by ISO 5349-2: (2001).

However, the basic vibration measurement parameters were for the x, y, and z direction for the maximum frequency weighted RMS acceleration during polishing by the hand held angle grinder with polishing disc was 6.92, 4.45 and 3.65 m/s2 for the x, y and z axes respectively, the peak vibration acceleration was 4.42, 1.26 and 1.29 m/s2, for the x, y and z axes respectively, and MTVV was 1.37, 0.65 and 0.54 m/s2 for the x, y and z axes respectively, this is also considerably in excess of the HAV both exposure action value (EAV) and exposure limit value (ELV) for x direction proposed by ISO 5349-2: (2001) as shown in Figure (4).

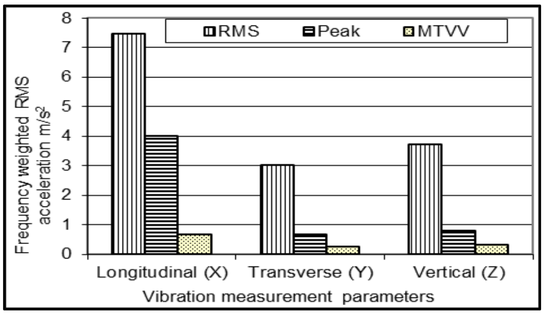


Fig. 3. Vibration measurement parameters for cutting by the hand held angle grinder with cutting disc during measuring time

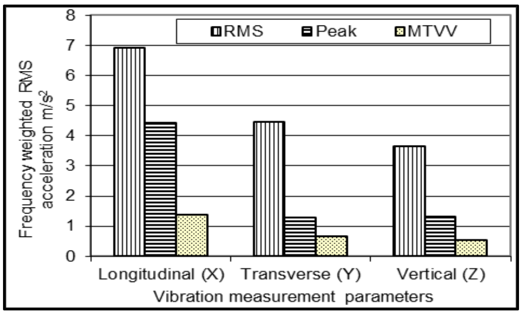


Fig. 4. Vibration measurement parameters for polishing by the hand held angle grinder with polishing disc during measuring time.

The daily vibration exposure level (A (8)) expressed as eight-hour energy equivalent continuous, frequency-weighted RMS acceleration of 7.45, 3 and 3.72 m/s^2, were for the x, y and z direction respectively during cutting by the hand held angle grinder with cutting disc as shown in Figure (5). However, the daily vibration exposure level (A (8)) of 6.92, 4.45 and 3.65 m/s^2, were for the x, y, and z direction respectively during polishing by the hand held angle grinder with polishing disc as shown in Figure (6).

It is clear that the values are exceeded than both of exposure action value and exposure limit value proposed by ISO 5349-2: 2001, especially in longitudinal (x) axis. So there is a need to provide good vibration isolation for the power tools handle to reduce the final transmitted force to the worker hand and ensure operating in safe conditions.

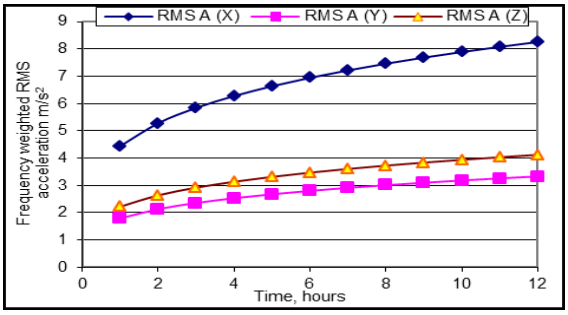


Fig. 5. Vibration measurement parameters for cutting by the hand held angle grinder with cutting disc during twelve hours.

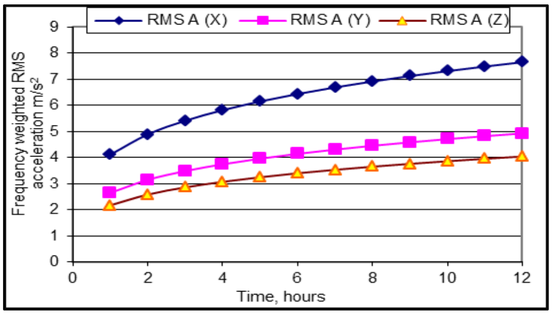


Fig. 6. Vibration measurement parameters for polishing by the hand held angle grinder with polishing disc during twelve hours.

The results illustrated in Figure (7) showed that the maximum frequency weighted RMS acceleration during grinding by the bench-top wheel grinder was 4.69, 4.26 and 4.56 m/s^2 for the x, y and z axes, respectively. While, the peak vibration acceleration was 3.08, 1.52 and 1.85 m/s^2, and MTVV was 1.25, 1 and 1.08 m/s^2 for the x, y and z axes, respectively. This is considerably in excess of the HAV exposure action value (EAV) but did not in exposure limit value (ELV) for x direction proposed by ISO 5349-2: (2001).

However, the basic vibration measurement parameters were for the x, y, and z direction for the maximum frequency weighted RMS acceleration during drilling by the bench-top stand drill was 4.77, 3.28 and 2.98 m/s^2 for the x, y and z axes respectively, the peak vibration acceleration was 4.12, 1.02 and 1.17 m/s^2, and MTVV was 0.99, 0.52 and 0.49 m/s^2 for the x, y and z axes, respectively. This is also considerably in excess of the HAV exposure action value (EAV) but did not in exposure limit value (ELV) for x direction proposed by ISO 5349-2: (2001) as shown in Figure (8).

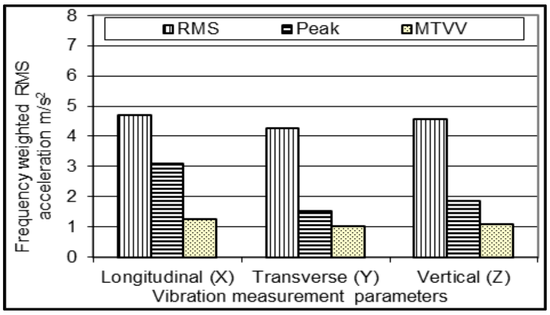


Fig. 7. Vibration measurement parameters for grinding by the bench-top wheel grinder during measuring time.

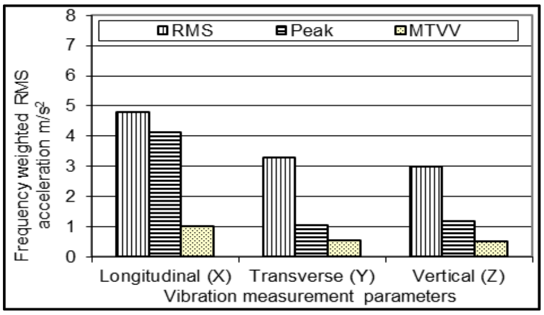


Fig. 8. Vibration measurement parameters for drilling by the bench-top drill during measuring time.

The daily vibration exposure level (A (8)) of 4.69, 4.26 and 4.56 m/s^2, were for the x, y and z direction respectively during grinding by the bench-top wheel grinder as shown in Figure (9). However, the daily vibration exposure level (A (8)) of 4.77, 3.28 and 2.98 m/s^2, were for the x, y, and z direction respectively during drilling by the bench-top stand drill as shown in Figure (10). It is clear that the values are exceeded than exposure action value proposed by ISO 5349-2: 2001, especially in longitudinal (x) axis. So there is a need to provide good vibration isolation for the power tools handle to reduce the final transmitted force to the worker hand and ensure operating in safe conditions.

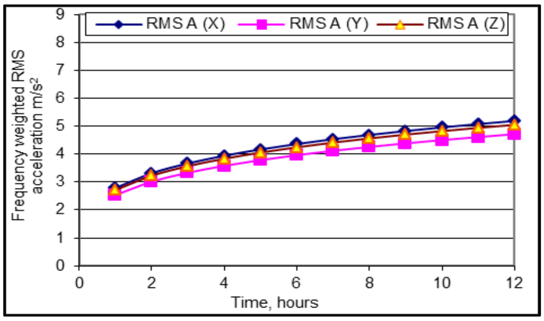


Fig. 9. Vibration measurement parameters for grinding by the bench-top wheel grinder during during twelve hours.

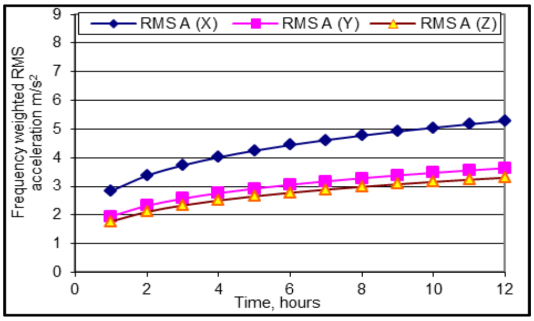


Fig. 10. Vibration measurement parameters for drilling by the bench-top drill during twelve hours.

ANOVA indicated that operation of the workshop power tools have significant ($p < 0.05$) differences on the vibration acceleration. Tables (5, 6 and 7) showed that the statistical analysis of ANOVA for the effect of workshop power tools operations on (RMS) for the x, y, and z direction. Data analysis showed that there was highly significant difference on the mean of all the eleven treatments of cutting metal by the angle grinder on normal working posture; cutting metal by the angle grinder on squeeze working posture; polishing metal by the angle grinder; breaking concrete by the hammer drill; grinding metal by the angle grinder; drilling concrete by the hammer drill; drilling metal by the impact drill ; drilling wood by the impact drill; cutting metal by the disc cutter; grinding metal by the wheel grinder; and drilling by the stand drill.

Among the workshop power tools magnitude of vibration depends on the location of measurement, axis of measurement (direction), the mass, speed (rpm). In the workshop power tools parts rotate at different speeds and vibrate at different frequencies depending on their own degree of freedom and natural frequencies, which contribute to the vibration of the whole system, there are several peaks of vibration acceleration at the handle of workshop power tools it was higher in cutting by the hand grinder during measuring time 7.45 m/s^2 as shown in Figure (3). It was observed that the increase in the mass and speed (rpm), increased vibration measurement parameters frequency weighted RMS acceleration especially in x axis at almost all the frequencies for the workshop power tools vibration as reported with Ren *et al*., (2005); Mandal and Srivastava (2006); Mirta and Dawal (2010) and McDowell *et al*., (2007).

Table 5. Analysis of variance (ANOVA) for the effect of workshop operation on (RMS) for the x-direction

Source	Type II Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	73.542	17	4.326	175.963	0.00
Intercept	2954.210	1	2954.210	120164.877	0.00
Workers	.829	7	.118	4.820	0.00
Treat	72.712	10	7.271	295.763	0.00
Error	1.721	70	.025		
Total	3029.473	88			
Corrected Total	75.263	87			

Table 6. Analysis of variance (ANOVA) for the effect of workshop operation on (RMS) for the y-direction.

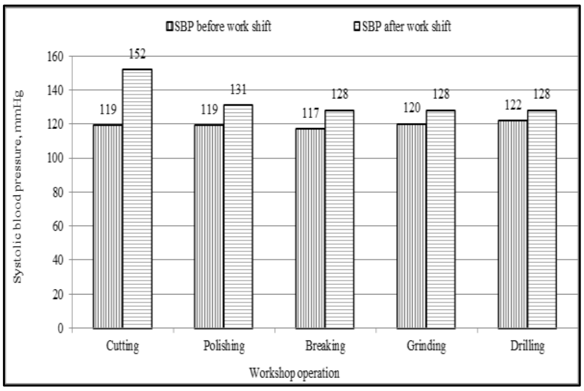
Source	Type II Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	18.560	17	1.092	1.504	0.119
Intercept	868.557	1	868.557	1196.758	0.000
Workers	5.724	7	.818	1.127	0.357
Treat	12.836	10	1.284	1.769	0.083
Error	50.803	70	0.726		
Total	937.920	88			
Corrected Total	69.363	87			

Table 7. Analysis of variance (ANOVA) for the effect of workshop operation on (RMS) for the z-direction.

Source	Type II Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	36.531	17	2.149	2.305	0.008
Intercept	863.621	1	863.621	926.520	0.00
Workers	7.765	7	1.109	1.190	0.320
Treat	28.766	10	2.877	3.086	0.003
Error	65.248	70	.932		
Total	965.4	88			
Corrected Total	101.778	87			

Association between workshop operations and blood pressure & heart rate:

Figure (11) showed that the workshop power tools workers SBP and DSBP are increased due to exposure to high level of frequency weighted vibration acceleration RMS when exceed over the threshold limits. For cutting by the angle grinder on squeeze posture, polishing by the angle grinder, breaking concrete by the hammer drill, grinding by the angle grinder, drilling concrete by the hammer drill of workshop power tools workers, the SBP (upper) values were 119, 119, 117, 120 and 122 (mmHg) before work shift and 152, 131, 128, 128 and 128 (mmHg) after the work shift respectively. However, the workshop power tools workers DSBP (lower) values were 95, 82, 78, 77 and 83 (mmHg) before the work shift and 101, 93, 88, 89 and 91 (mmHg) after the work shift respectively. This indicates that, the workers have exposure to hazard levels of frequency weighted vibration acceleration RMS resulting in high levels of both the SBP and the DSBP. As a result, the workers must work less than 8 hour/day; in general, to ensure operating in safe conditions corresponding to that, the workers' productivity will be less. According the classification of blood pressure (WHO, 2003) as shown in Table 1.



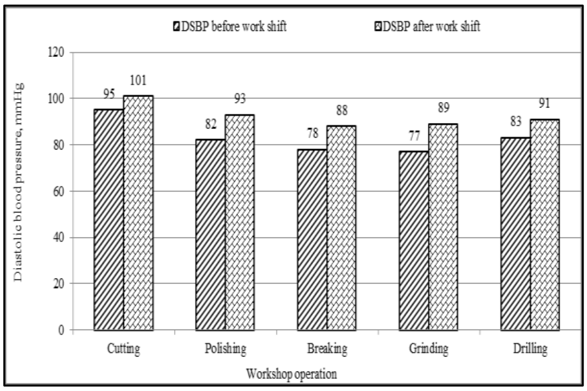


Fig. 11. Comparison of the systolic and diastolic blood pressure for the workshop power tools workers before and after work shift.

The high levels of blood pressure recorded during the workshop power tool operation were to cutting by the hand grinder on squeeze posture, the workers SBP before and after work shift were classified. The majority of the workers SBP after work shift were stage one hypertension (87.5%) and stage two hypertension (12.5%) and before work shift was normal (62.5%) and pre-hypertension (37.5%). The workers DSBP after work shift were stage one hypertension (37.5%), followed by stage two hypertension (50%) and high blood pressure crisis (12.5%) and before work shift were stage one hypertension (87.5%) and stage two hypertension (12.5%). It concluded that there was a positive correlation between frequencies weighted vibration acceleration RMS exposure and blood pressure among the workers. Table (8, 9 and 10) present the statistical analysis of ANOVA for the workshop power tools workers SBP and DSBP measured before and after work shifts as affected by frequency weighted vibration acceleration RMS on the eleven treatments of cutting metal by the angle grinder on normal working posture; cutting metal by the angle grinder on squeeze working posture; polishing metal by the angle grinder; breaking concrete by the rotary hammer drill; grinding metal by the angle grinder; drilling walls by the rotary hammer drill; drilling metal by the impact drill ; drilling wood by the impact drill; cutting metal by the disc cutter; grinding metal by the wheel grinder; and drilling by the stand drill. The obtained results showed that there was highly significant difference in the SBP before and after work shift. Similar results were found on the DSBP and worker's heart rate.

Table 8. Analysis of variance (ANOVA) for the effect of RMS on worker's SBP

Source	Type II Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	7227.932	17	425.172	22.405	0.000
Intercept	1528563.682	1	1528563.682	80548.446	0.000
Workers	216.864	7	30.981	1.633	0.141
Treat	7011.068	10	701.107	36.945	0.000
Error	1328.386	70	18.977		
Total	1537120.000	88			
Corrected Total	8556.318	87			

Table 9. Analysis of variance (ANOVA) for the effect of RMS on worker's DSBP

Source	Type II Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	2369.943	17	139.408	5.313	0.000
Intercept	734746.375	1	734746.375	28002.807	0.000
Workers	198.443	7	28.349	1.080	0.385
Treat	2171.500	10	217.150	8.276	0.000
Error	1836.682	70	26.238		
Total	738953.000	88			
Corrected Total	4206.625	87			

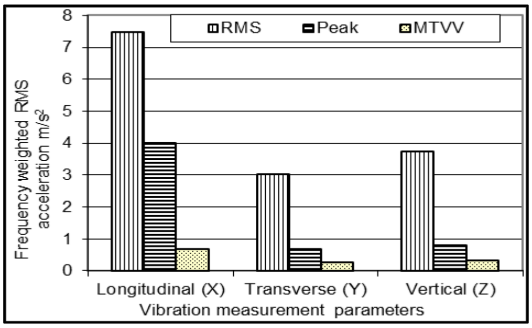
Table 10. Analysis of variance (ANOVA) for the effect of RMS on worker's heart rate

Source	Type II Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	28076.500	17	1651.559	12.807	0.000
Intercept	911476.545	1	911476.545	7068.093	0.000
Workers	3614.545	7	516.364	4.004	0.001
Treat	24461.955	10	2446.195	18.969	0.000
Error	9026.955	70	128.956		
Total	948580.000	88			
Corrected Total	37103.455	87			

Exposure to a high level of hand-transmitted vibration for long periods can have detrimental effect on health. Hand vibration exposure produces various disorders; neurological, musculoskeletal, white finger and causes work-related body pain (WRBP). The Borg rating of perceived exertion (RPE) scale measures perceived exertion, the original scale introduced by Gunnar Borg rated exertion on a scale of 6-20. Borg then constructed a category (C) ratio (R) scale, the Borg CR10 Scale. The CR-10 scale is best suited when there is an overriding sensation arising either from a specific area of the body, the seemingly odd range of 6-20 is to follow the general heart rate of a healthy adult by multiplying by 10. For instance, a perceived exertion of 12 would be expected to coincide with a heart rate of roughly 120 beats per minute. It ranges from 6 to 20 where 6 mean "no exertion at all" and 20 mean "maximal exertion as shown in Table (11).

The maximum WRBP values were obtained during the cutting by the angle grinder on squeeze posture followed by cutting by the angle grinder on normal posture and polishing by the angle grinder, while the maximum pain levels of 15.6, 14.8 and 13.6 (Borg scale) were observed, respectively.

Comparing the pervious obtained results of the basic vibration measurement parameters for the x, y, and z direction with that obtained using rubber gloves during cutting by the angle grinder it could be cleared that the maximum frequency weighted RMS acceleration were 4.75, 3.30 and 3.78 m/s2, respectively. The peak vibration acceleration was 1.41, 0.45 and 0.58 m/s2, and MTVV was 0.39, 0.17 and 0.21 m/s2 for the x, y and z axes, respectively. The daily vibration exposure level (A (8)) expressed as eight-hour energy equivalent continuous, frequency-weighted RMS acceleration of 4.75, 3.30 and 3.78 m/s2, were obtained for the x, y and z direction respectively. This is considerably not excess of the HAV exposure limit value (ELV) proposed by ISO 5349-2: 2001, especially in longitudinal (x) axis which ensure operating in safe conditions. Therefore, it could be concluded that using rubber gloves results in a decrement percentages in the HAV values and became less than the threshold limit allowed or nearly equaled as shown in Figure (12) and (13).



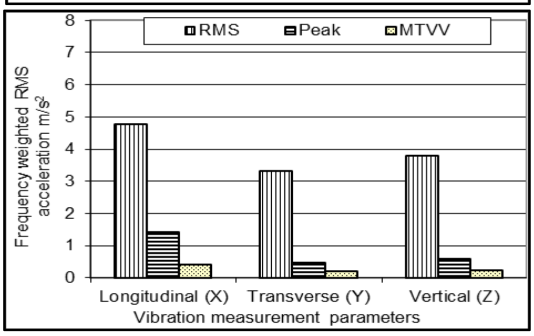


Fig. 12. Vibration measurement parameters for cutting by the hand held angle grinder with cutting disc during measuring time before (left) and after (right) using rubber gloves.

Table 11. BORG 6-20 Rate of Perceived Exertion Scale (RPE).

No Exertion	6	Little to no movement, very relaxed
Extremely Light	7-8	Able to maintain pace
Very Light	9-10	Comfortable and breathing harder
Light	11-12	Minimal sweating, can talk easily
Somewhat Hard	13	Slight breathlessness, can talk
	14	Increased sweating, still able to hold conversation but with difficulty
Hard	15-16	Sweating, able to push and still maintain proper form
Very Hard	17-18	Can keep a fast pace for a short time period
Extremely Hard	19	Difficulty breathing, near muscle exhaustion
Maximally Hard	20	STOP exercising, total exhaustion

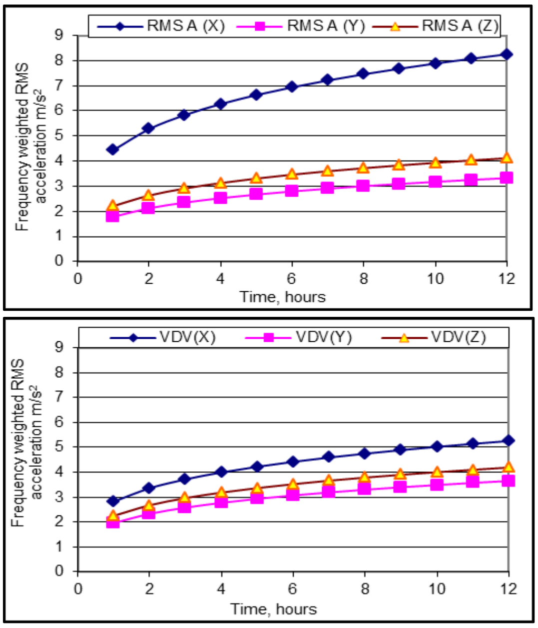


Fig. 13. Vibration measurement parameters for cutting by the hand held angle grinder with cutting disc during twelve hours before (left) and after (right) using rubber gloves.

CONCLUSION

The obtained results concluded that:-

1- The maximum frequency weighted RMS acceleration during cutting by the angle grinder with cutting disc was 7.45, 3 and 3.72 m/s^2 compared with 6.92, 4.45 and 3.65 m/s^2 for the x, y and z axes, respectively during polishing by the angle grinder with polishing disc.

2- The peak vibration acceleration during cutting by the angle grinder with cutting disc was 3.98, 0.66 and 0.78 m/s^2 compared with 4.42, 1.26 and 1.29 m/s^2 for the x, y and z axes, respectively during polishing by the angle grinder with polishing disc.

3- The maximum MTVV during cutting by the angle grinder with cutting disc 0.67, 0.25 and 0.32 m/s^2 compared with 1.37, 0.65 and 0.54 m/s^2 for the x, y and z axes, respectively during polishing by the angle grinder with polishing disc,.

4- There are significant differences between the frequency-weighted RMS acceleration, SBP, DSBP and heart rate results during the different workshop operations.

5- The maximum WRBP values were obtained during the cutting metal using the angle grinder with cutting disc on squeeze working posture followed by cutting metal using the angle grinder with cutting disc on normal working posture and polishing metal using the angle grinder with polishing disc. Maximum pain levels of 15.6, 14.8 and 13.6 (Borg scale) were observed respectively.

6- The long activities duration for cutting metal using the angle grinder with cutting disc have the potential to cause hand arm syndrome.

Recommendation

1. The authors recommended using rubber gloves as a vibration isolator for reducing hand arm vibration parameters: frequency weighted RMS acceleration and MTVV in both of EAV, ELV and the worker SBP, DSBP and heart rate which decrease any significant risk to an acceptable level and ensure operating in safe conditions.
2. It is highly recommended to perform future research studies related the ergonomics and human body vibration for the numerous benefits and impact on the safety of workers under different working postures.

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تأثير الاستخدام المتكرر لمعدات الورش على اهتزاز ذراع العامل وسلامته

احمد رجب حامد ، وائل فتحي على المتولي ، اسماعيل فؤاد سيد و محمود السيد العراقي
معهد بحوث الهندسة الزراعية ، مركز البحوث الزراعية ، ص. ب. 256 ، الجيزة ، جمهورية مصر العربية

يوجد العديد من الأعمال الفنية فى ورش القطاع الزراعى تستخدم أدوات الورش ذاتية القدرة على نطاق واسع سواء المحمولة منها أو المثبتة على مناضد. وأثناء استخدام أدوات الورش يتلامس العمال مباشرة معها ، ويمر الاهتزاز الناجم عن هذه الأدوات في جسد العامل من خلال كف اليد والأصابع وتعتبر أدوات الورش التى تعمل بالهواء المضغوط والكهرباء مثل أدوات التجليخ، الصنفرة، المثاقب، مفاتيح الشد، مطارق التكسير من أهم مصادر اهتزاز ذراع اليد (HAV). وتعتبر متلازمة الاهتزاز HAVS في ذراع اليد هي حالة مرضية مرتبطة باستخدام الأدوات المسببة للاهتزاز والذى قد يؤدى الى تغيرات غير صحية في الأوتار والعضلات والعظام والمفاصل وكذلك يؤثر على الأعصاب. الهدف الرئيسي من هذا البحث هو دراسة تأثير استخدام أدوات الورش بشكل متكرر على اهتزازات اليد وسلامة العاملين بسبب استخدام أدوات الورش الكهربائية خلال خمس عمليات مختلفة ، وهي التجليخ والثقب والقطع والتكسير والتلميع باستخدام فئتين من أدوات الورش الكهربائية التي تم اختيارها للدراسة مثل أدوات الورش الكهربائية الثابتة (مثقاب ذو القاعدة، حجر الجلخ، دسك القطعية)، والمحمولة مثل (الصاروخ بأقراص قطع وجلخ وتلميع، المثقاب، المثقاب المطرقي الدوار) باستخدام وضعية الوقوف مستقيما أو القرفصاء أثناء العمل بها في ثلاثة أنواع من المواد (المعادن والخشب والخرسانة). وتم اختيار ثمانية عمال يتمتعون بصحة جيدة من العاملين في الورش لهذه الدراسة حيث تم تقييم الدراسة بقياس المؤشرات التالية: الجذر التربيعي RMS لمتوسط اهتزازات ذراع الإنسان أثناء زمن القياس الكلى، معدل نبضات القلب، ضغط الدم، طول الإنسان ووزنه وطول ذراعه ودليل كتلة الجسم موضوع الدراسة ومؤشر ألم الجسم، هذا وقد تم قياس مؤشر الاهتزازات الميكانيكية وفقا لمنظمة التوحيد والقياس العالمية (ISO) وتم تصميم التجربة وفقا لتصميم القطاعات الكاملة العشوائية حيث أجريت التجارب العملية وأخذت القياسات بالورشة الفنية لمركز ميكنة الأرز بميت الديبة - محافظة كفر الشيخ خلال عام 2018م. أشارت النتائج التي تم الحصول عليها إلى أن القطع بواسطة الصاروخ مع قرص القطع يعطي أعلى بيانات HAV لقياس التسارع RMS في حين أن أكبر محور تعامدي واحد يكون في المحور (X) الذي يتجاوز قيمة كلا من قيمة التعرض وقيمة حد التعرض وهذا يسبب خطورة عالية على ذراع اليد العاملة مما يزيد من معدل ضربات القلب وضغط الدم يليه عملية التلميع بواسطة الصاروخ مع فرشاة التلميع. من ناحية أخرى، سجل مستوى انبعاث HAV أدنى قيم أثناء التجليخ بواسطة حجر الجلخ الثابت والثقب بواسطة المثقاب الثابت وبالتالي لا يوجد خطر على ذراع اليد للمشغل وأيضا على معدل ضربات القلب وضغط الدم. كما تم الحصول على الحد الأقصى من قيم WRBP أثناء عملية القطع بواسطة الصاروخ مع قرص القطع في وضع القرفصاء يليها عملية القطع بواسطة الصاروخ مع قرص القطع فى الوضع المستقيم ثم عملية التلميع بواسطة الصاروخ مع فرشاة التلميع. حيث سجلت مستويات الألم القصوى القيم 15.6 و 14.8 و 13.6 (مقياس بورغ) على التوالي. أظهرت النتائج وجود فروق ذات معنوية بين تسارع الاهتزازات RMS ، SBP ، DSBP ومعدل ضربات القلب خلال العمليات المختلفة داخل الورش كما أدى استخدام قفازات مطاطية أثناء القطع بواسطة الصاروخ مع قرص القطع إلى انخفاض النسب المئوية في قيم HAV وبالتالي معدل ضربات القلب وضغط الدم . ويوصى الباحثون بضرورة تطبيق استخدام القفازات المطاطية مع أدوات الورش عالية الاهتزاز وتقليل مدة التعرض وزيادة فترات الراحة بين جولات العمل بغرض تقليل خطر الاهتزاز المنقول لكف وذراع العامل إلى الحد المسموح به على الأقل. كما يوصى الباحثون بضرورة إجراء دراسات بحثية تطبيقية في المستقبل على العوامل الهندسية والبشرية المؤثرة على فاعلية الاهتزاز المنقول لجسم العامل تحت ظروف وضعيات العمل المختلفة وكيفية الحد من خطورته على الصحة العامة للعامل لزيادة إنتاجية الآلة والعامل.