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https://doi.org/10.5109/6781034

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(Received January 16, 2023; Revised February 27, 2023; accepted March 4, 2023).

Abstract: Woodworkers commonly perform operations like sawing, chipping, planning, shaping, nailing and drilling in daily work environment. This study focused the consequences of exposure to hand arm vibration among woodworkers working with handheld drill machine. Subjects' hand grip strength was measured by a digital hand grip dynamometer. The vibration generated by a handheld drill machine was the main concern and hence the same handheld drill machine was used during this study. The results showed that workers exposed to hand arm vibration had higher prevalence of musculoskeletal disorders. Future studies should include other contributing factors also like ergonomic interventions and workers' postures.

Keywords: drilling; HAV; hand grip strength; hand tools; MSD

1. Introduction

In India there are millions of wood-work industries. A huge number of workforces are working in these industries. With the increasing awareness, work related musculoskeletal disorders (WMSDs) are becoming more important in the field of prevention of occupational health diseases. In the manual operations, upper limb related musculoskeletal disorders (MSDs) are the most common occupational health issues in the industries. One of the major sources of such MSDs is hand arm vibration (HAV)[1)]. The drilling operation is one of the most often performed operations in the wood-work industries. The hand-held drilling machines generate vibrations those are further transmitted to hand-arm and workers' body. The vibration transmissibility generally increases with an increase in hand grip force[2)]. When this vibration is transmitted to the worker upper limb system, peripheral disorders can take place in the forms of a variety of symptoms in the hand-arm joints below the elbow. Additionally, the loss of sensation in the fingers of the workers and grip strength reduction frequently take place reason being muscular disorders are developed inside the vascular system, musculoskeletal hand-arm system, joints, or bones[3,4)]. The posture during the manual operation plays a very important role when its effect on grip strength is to be studied. The grip strength is much greater in neutral position of wrist compared to other wrist positions. This grip strength varies with many factors like age, experience and anthropometric dimensions of the workers. The grip strength of experienced workers is much higher than that of beginner level workers. The grip strength also varies with age of workers and it generally decreases with increase in age[5)]. The daily manual operation should be performed in the posture with optimum grip strength which is suggested for good occupational health and their safety at workplace. The suitable grip strength data is recommended for tool/equipment design for manual working in unorganized sectors[6)].

Push and pull strength are also affected by anthropometric factors like stature, weight and posture. Previous research provided evidence that the push/pull

strength is maximum at low (elbow) height[7]. When maximum push/pull strength is needed to be estimated artificial neural network (ANN) method is found better compared to the linear regression technique. The investigation proved that ANNs should be applied more frequently in ergonomic assessment[8]. Upper limbs are quite frequently used in daily work operations and so have higher prevalence of MSDs. Previous studies have shown that the body parts most commonly used in operations are highly exposed to different work-related MSDs[9]. Simultaneously, MSDs are the most common health issue among workers highly exposed to HAV[10].

The fitness of workers should be on utmost priority to productively complete the task[11]. The efficiency of workers declines with increasing age due to the high prevalence of MSDs[12]. It is important to study the adverse health effects due to hand transmitted vibration in order to guarantee the sufficient safety to workers who are working with hand-operated tools in manual operations. Some appropriate action should be taken to prevent health issues among workers to increase productivity of the organization. In order to take appropriate action, it is essential to identify the exact reason behind the health issues of the workers and accordingly the best solution can be identified. Hence the identification of the comparatively more stressed body part is of prime importance[13]. An early ergonomic intervention is more effective and can protect workers from HAV-related health problems with very little investment[14,15]. The International Organization for Standardization ISO 5349[16,17] proposes that a worker who is often exposed to hand-arm vibration at the limit values of vibration exposure and vibration action will have a higher possibility of getting change of finger color into white (finger blanching) over a long period of exposure to the hand-arm vibration. Prolonged exposure to vibration leads to various adverse effects[18].

The measurement of this transmitted vibration remains quite tedious task. Researchers have not developed any feasible method to measure the vibrations transmitted inside the hand-arm system of a worker. Such vibrations are mostly measured at outside the hand-arm system using appropriate vibration measuring device[19].

Usually the operators operating the hand-held power tools to do drilling generally do not put on anti-vibration gloves. The operators sometimes put on simple nylon or cotton gloves to prevent any kind of injuries. Such gloves are not considered to protect the hands against the hand-arm vibration. Anti-vibration gloves can significantly reduce the risk of HAV but have some limitations[20]. It is possible to minimize hand arm vibration (HAV) with economic interventions[21].

Indian woodworkers usually work in furniture factories, construction sites, and shops using various woodworking tools. Sawing, chipping, planning, shaping, nailing and drilling are some of the typical tasks performed by woodworkers in their routine work-life. They use a few vibrating tools like drill machine, power saw, and nail gun to perform daily woodworking operations. This study was held to explore the effect of hand transmitted vibrations on the performance of the woodworkers in daily working environment. The hand-arm vibration exposures of workers working in the local wood-working units located in Jaipur city of Rajasthan, India have been investigated. The effects of hand-arm vibration on hand grip strength of subjects have been examined in this conducted study. Hand held power tools, hand operated industrial equipments, and holding the object against mechanical resistance are identified as main reason of generation of hand-arm vibrations in hand-arm system[22].

2. Materials and Methods

Severe vibrations are produced by most of the power tools and such vibrations are further passed on from its handle to the hands of worker. These passed vibrations from power tools to hands of worker can be decreased by some extent. It is possible by providing isolation on the handle surface using appropriate isolating material or by wearing anti-vibration gloves. This isolation will become the integral part of the power tool then, hence it would be its benefit when compared with use of the anti vibration glove[23]. HAV leads to harmful effect on occupational health of workers working with vibrating tools. This creates the need to provide the ergonomically designed hand tools for the workers of less developed sectors.

This divisional study was performed in Jaipur, Rajasthan, India from May 2022 to June 2022. Jaipur is located in the north-western part of India with latitude 26.9124° and longitude 75.7873°. Jaipur has a really hot climate with a gentle breeze during May-June months and temperature ranging from 26°C to 42°C.

All the selected subjects were woodworkers working in various woodworking units in Jaipur. The frequently performed tasks by woodworkers are sawing, chipping, planning, shaping, nailing and drilling. In order to perform these operations they have to use various woodworking tools. A few operations can only be performed using vibrating tools like drill machine, power saw, and nail gun. In this study ergonomic risk for MSDs with only drilling operation was investigated. Fourteen male subjects were considered in this investigation. The age of selected subjects was ranging from 23 to 35 years old with an average age of 28.93 (SD 3.32) years. The standard anthropometric equipment was used to measure the anthropometric dimensions of the subjects. The key anthropometry data are presented in Table 1.

Table 1. Key anthropometry data.

Subject	Age	Height (cm)	Weight (kg)	BMI
1	28	157.5	59.4	40.25
2	32	162.6	67.3	40.40

3	27	164.5	64.6	42.30
4	23	167.7	62.3	40.30
5	29	170.4	68.1	41.70
6	26	177.8	70.9	39.45
7	33	165.8	64.7	37.00
8	32	183.2	76.4	39.95
9	30	175.5	77.8	38.10
10	30	166.2	67.2	38.95
11	27	184.1	75.8	37.30
12	25	169.3	70.1	39.75
13	28	183.7	77.1	38.95
14	35	174.1	75.5	36.85
Mean	28.93	171.6	69.8	39.38
SD	3.32	8.38	5.97	1.65

All the selected subjects were local woodworkers. Each subject got selected for this study only if he was right handed and used hand held drill for 30 minutes or more per day. No subject was selected who had any past record of upper limb injury and/or who were recognized as left handed. This experimental study is demonstrated in Fig. 1.

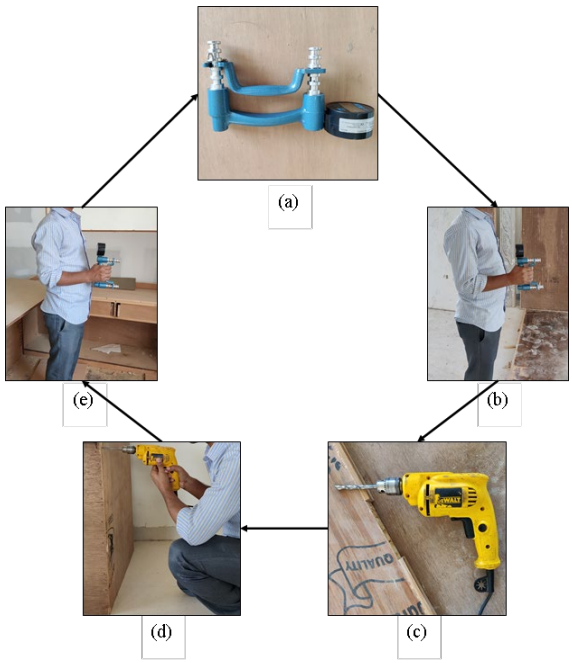

Fig.1: Flow diagram of experimental process; (a) hand dynamometer, (b) collection of hand grip measurements before work, (c) hand tools, (d) hand tool operations, (e) collection of hand grip measurements after work.

In this study the posture of subject was not restricted to any specific one. A single compact and ergonomically designed hand held drill of Dewalt, model number DWD014-IN was used in this study. It was a corded 550 Watt hand drill weighing 2.9 kg and hand grip span of 140 mm with 10 mm chuck capacity and maximum speed of 2800 rpm.

To compute hand grip strength, a digital hand dynamometer was used. The digital hand dynamometer was easy to use and could measure the hand grip strength in pounds and kilograms. All the measurements were recorded in kilograms in the present research study. This dynamometer was having an adjustable handle that provided accommodation to different hand sizes. The handle could be adjusted in many hand grip positions as per subjects' comfort to allow the testing of hand grip strength for different hand sizes. Each subject was informed about the procedure to be followed and was briefly explained about experimentation before commencement of the experiments. A written consent was collected from each subject who participated in this study.

The measurements of hand grip strength of the subjects were noted in two sets of experiments. The subjects were asked to avoid use of any power tool during first set of experiments whereas during the second set of experiments, they were asked to work with the provided hand held drill machine. In both sets of experiments, the subjects' hand grip strengths were initially measured before starting their daily work and then they were informed to follow their regular working schedule. The subjects' hand grip strengths were further measured after performing their daily work. In the second set of experiments, the subjects worked with the hand held drill machine for more than 30 minutes. This time was recorded using mobile stopwatch. The hand grip strength was measured in three trials for each subject in each experiment. Each subject was asked to firmly apply his maximum possible hand grip for 3 seconds on digital dynamometer. A two minutes rest was given between two successive trials to avoid any unnecessary muscle exhaustion. At the end the mean value of all three recorded measurements was used for further analysis in this study.

Thus, in present investigation the measurements were noted in a total of twenty eight trials. This complete data was collected by visiting the respective woodworking unit under regular operating environment.

3. Results and Discussions

Fourteen male workers from different woodworking units of Jaipur, gave their consent for participation in this study. Their average age was 28.93 (SD 3.32) years and they all were exposed to HAV since the early stage of their professional career. This study investigated the measurements of hand grip strength in two sets of experiments. The hand grip strengths of the subjects before starting work in first and second sets of experiments were changed slightly (0.25-0.76%) for each

subject. This change in hand grip strength is not a great deal and so considered insignificant. The collected measurements from both sets of experiments are represented in the Table 2 and Table 3.

Table 2. Measurements from first set of experiments.

Subject	Hand Grip Strength in Morning (kg)	Hand Grip Strength in Evening (kg)	Change in Hand Grip Strength (kg)
1	38	31.9	6.1
2	36.9	32.6	4.3
3	39.9	35.8	4.1
4	40.1	32.2	7.9
5	39.6	35.2	4.4
6	42.2	37.2	5
7	36.9	31.3	5.6
8	40.4	34.9	5.5
9	39	34.6	4.4
10	38.9	33.6	5.3
11	40.3	35.4	4.9
12	37.4	31.4	6
13	41.8	36.1	5.7
14	39.8	35.5	4.3
Mean	39.37	34.12	5.25
SD	1.65	1.93	1.02

Table 3. Measurements from second set of experiments.

Subject	Hand Grip Strength in Morning (kg)	Hand Grip Strength in Evening (kg)	Change in Hand Grip Strength (kg)
1	38.2	29.3	8.9
2	36.8	31.2	5.6
3	40	33.8	6.2
4	40.4	30.3	10.1
5	39.3	31.8	7.5
6	42.4	36.1	6.3
7	37.1	31.9	5.2
8	40.2	32.7	7.5
9	38.9	33.9	5
10	39	33.5	5.5
11	40.5	33.6	6.9
12	37.2	31.1	6.1
13	41.6	33.2	8.4
14	39.7	34.6	5.1
Mean	39.38	32.64	6.74
SD	1.66	1.82	1.56

The subjects generally work with miscellaneous hand tools in their daily working environment. Many of the hand tools are power tools that generate vibration that is further transferred to the hands of their operators. This makes the study of HAV effects important and for this reason current study divided the experimentation in two parts. On one day, the subjects were instructed to do not use any power tool and on other day, they were instructed to use only the provided power tool (hand held drilling machine; DWD014-IN) as much as possible along with the other hand tools.

The subjects were noticed working in awkward postures during our study. Whenever the task is performed in an awkward posture it results in poor work efficiency and simultaneously the operator has to apply greater effort with the hand tools. This investigation supports this observation evidently. The average hand grip strengths of the subjects measured in both sets of experiments are represented in Fig. 2. The results evidently indicate 28.38% decrement in average hand grip strength in second set of measurements compared to first set of measurements.

The operator of hand-held drilling machine usually perceives vibrations through its handle. Level of vibrations depends on the parameters settings of tools and equipment. The changes in hand grip strength between the two sets of experiments were found significantly different.

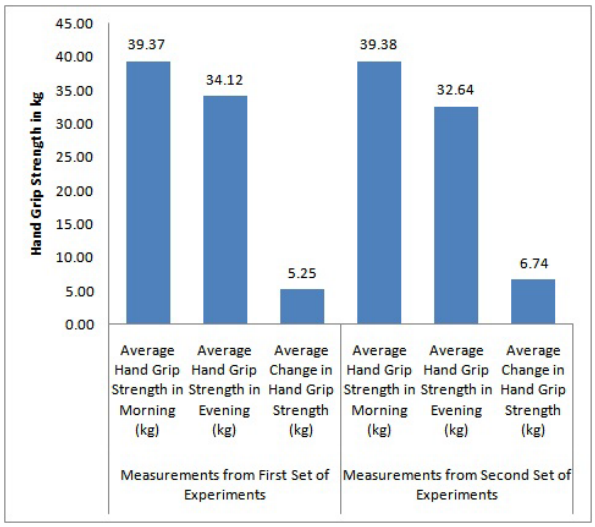

Fig.2: Comparison of average hand grip strengths of the subject in first and second set of experiments.

Previous studies had mostly investigated upper limb MSDs among the subject who usually performs everyday manual operations in awkward posture with physically powerful efforts and repetitive movements of hand and wrist[24]. It has also been evidently presented in the literatures that an ergonomically designed hand tools can decrease the vibration magnitudes notably[25,26].

The MSDs issues caused by hand arm vibration mainly depends on its frequency, magnitude, and vibration exposure duration. The MSDs slowly but surely increases with increase in frequency, magnitude and vibration exposure duration. Researchers in previous studies identified HAV as one of the major reason of threat for MSD issues. Hand arm vibration syndrome is a very common health problem among HAV exposed workers in tropical countries[27,28] and its intensity can be affected by some factors such as gender, body strength and race[29]. Furthermore, this HAV and noise increases discomfort level and thus reduces the performance of the workers[30,31]. Implementation of manufacturing techniques like lean can significantly increase the productivity of the organization[32]. Similarly proper implementation of technology along with ergonomics can definitely reduce MSDs and increase productivity[33]. Small and medium enterprises in developing nations are facing more accidental hazards as compared to developed nations and limited training is the one of the main reasons behind it[34]. The workforce should be provided with timely skill based training as per the need.

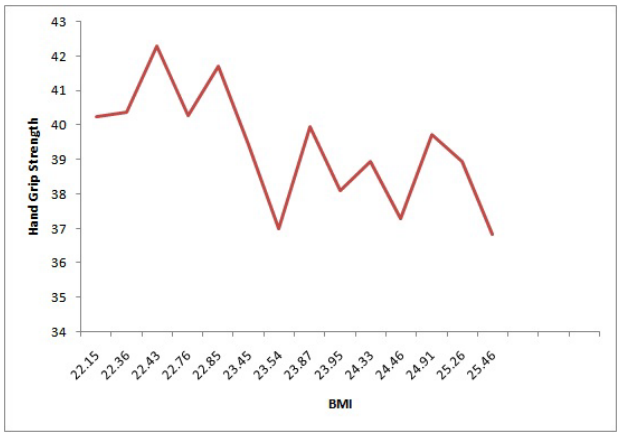

Fig.3: Variation of subjects' hand grip strength with change in BMI.

The hand grip strength is associated with many factors like age, experience and anthropometric dimensions of the workers. This study investigated the effect of change in BMI on hand grip strength of subjects. The results after analyzing the data indicated a negative trade-off between hand grip strength and BMI as shown in Fig. 3. However correlation analysis denotes the strength of this association weakly correlated. Sometimes subjects were observed working in awkward posture. This awkward posture was found to be one of the affecting parameters for hand grip strength. Present research identified decrement in hand grip strength in such cases where the subject adopted an awkward posture. The outcomes of this study support the evidence that the workers involved in operations with hand held power tools are exposed to severe HAV as a consequence of the unergonomic working activities in their daily operations. This develops MSDs among the workers over a long span of working career. The result of current research recommends immediate ergonomic intervention to prevent the development of MSDs among woodworkers adopting unergonomic practices.

There was shortage of time to investigate the impact of different other contributing factors like effect of posture on hand grip strength. Also, this study could not conclude any specific correlation between BMI and hand grip strength. This has been future scope and can be achieved with a greater sample size. The HAV should also be measured using appropriate tools/equipments. Losing hand grip strength with higher rate is a serious problem as the manual operation should be performed with optimal posture (higher hand grip strength) which is considered good for occupational health and safety at workplace. The study also suggests that grip/handle of hand tools should be designed ergonomically and must be used in suitable working posture/manner for the unorganized sectors. Future study should focus on comparison of impact of awkward posture, anthropometry dimensions and HAV exposure on hand grip strength. Since the extent of HAV exposure is one of the major factors that may lead to MSDs in subjects, HAV should also be measured and analyzed in future research. The electromyography technique may also help the researchers to identify the impact of HAV exposure on different upper limbs. Also, the ergonomic guidelines should be provided with the hand held power tool kits/equipments.

4. Conclusion

The subjects who were not exposed to HAV shown 13.34% decrement in hand grip strength whereas the subjects who were exposed to HAV shown 17.12% decrement. This shows that the decrement in hand grip strength of the subjects in first set of experiments was 3.78% more than that of in second set of experiments. This investigation confirmed that HAV exposure has a direct negative impact on workers efficiency. It was concluded that the HAV exposed workers have higher prevalence of MSDs and need well-timed attention of ergonomists. HAV is not the only factor that is influencing the productivity of the organization. Also, the ergonomic practices must be conveyed to the workers. In this study the effect of BMI on hand grip strength was also analyzed. The correlation analysis denoted that there is no strong relation between hand grip strength and BMI. It is also noticed that the ergonomic applications can contribute significantly. Further study should be carried

out extensively in order to validate these findings.

Acknowledgements

Authors are grateful to all the participants of the study including the experts for their onsite valuable advices. Authors are also thankful to the authorities who permitted to conduct experiments during the working hours.

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