International Journal on Engineering Technologies and Informatics

Gender Effect on Hand-Transmitted Vibration and Muscle Fatigue Recovery Time During Drilling Operation

Review Article
Volume 5 Issue 2- 2024

Author Details
*David Imuetinyan and Fereydoun Aghazadeh**
Department of Mechanical and Industrial Engineering, Louisiana State University, USA

*Corresponding author
Fereydoun Aghazadeh, Department of Mechanical and Industrial Engineering, Louisiana State University, USA

Article History
Received: June 01, 2024 Accepted: June 04, 2024 Published: June 04, 2024

Abstract

Workers exposed to hand-transmitted vibration are at excessive risk of developing musculoskeletal disorders, affecting the muscles, cartilage, ligaments, bones, joints, etc. To minimize the impact of hand-transmitted vibration, appropriate work design is needed to reduce vibration and provide sufficient rest intervals to avoid muscle fatigue. This research aims to investigate the effect of gender on the vibration level transmitted and the muscle fatigue recovery time during the drilling task. Eight healthy university students, equally divided between genders, participated in the study. The vibration emission was recorded using an accelerometer sensor as participants drilled an aluminum sheet metal for 7 minutes at a constant feed force of 45N. After the drilling task, the participant rested for 7 minutes while the muscle fatigue recovery time was monitored using the Electromyography (EMG) sensor. The results indicate that the female participants had a higher mean vibration level with a percentage increase of 6.1% and a higher mean muscle fatigue recovery time with a percentage increase of 18.2% compared to the male participants.

Keywords: Gender; Hand-Transmitted Vibration; Muscle Fatigue Recovery Time

Introduction

Harada and Mahbub [1] define Hand-Arm Vibration (HAV) as the process by which tool vibration is transferred to the worker's hand. More than two million workers in the United States are exposed to HAV at work, with experts predicting that almost half of them develop long-term effects of Hand-Arm Vibration Syndrome (HAVS) [2, 3]. Harada and Mahbub [1] defined HAVS as a complex condition comprising one or more specific neurological, vascular, and musculoskeletal features related to hand-transmitted vibrating tools. The early signs of HAVS are hand weakness, tingling, loss of feeling, pain, and numbness [4, 5]. In 1999, the United Kingdom Medical Research Council reported that approximately 4.9 million employees were exposed to HAV weekly, and 288,000 workers were affected by HAVS in Great Britain [6]. The American National Standards Institute (ANSI) recommends that for HAV, the Daily Exposure Action Value (DEAV) and the Daily Exposure Limit Value (DELV) for an 8-hour exposure be 2.5m/s^2 and 5m/s^2, respectively.

In 2019, the U.S. Bureau of Labor Statistics reported that over 1.6 million commercial construction workers use hand-held drilling tools [7]. Workers in this trade include laborers in foundations, carpenters, cement masons, electricians, plumbers, etc., The vibration level emitted by hand-held drilling tools may lead to HAVS and other musculoskeletal disorders because studies have shown that drills produce vibration levels higher than the ANSI-recommended vibration limits [8]. Several studies have examined the effect of drilling parameters such as feed force [7, 9], exposure duration [10, 11], material type [4, 12], and drill bit sizes [13, 14] on muscle fatigue and vibration emission during a drilling operation. A study also investigated the effect of gender on muscle activity [15]. However, no study has examined the effect of gender on vibration emission and muscle fatigue recovery time. This study aims to determine the impact of gender on hand-transmitted vibration and muscle fatigue recovery time during drilling operations.

Methodology

Eight university students equally divided between genders with no history of shoulder and arm injuries participated in this study. The mean age of the participant was 23 years. Figure 1 shows the experimental protocol. Before the drilling task, the Delsys Bagnoli EMG sensor was placed on the flexor carpi radialis muscle of the participant's dominant hand. The participant then exerted maximum grip force for three to five seconds without jerks to collect the maximum contraction EMG data. This was done for three trials using the handgrip dynamometer (Model 12-0286), as shown in Figure 2. This activity involved participants seated with their elbows bent at a 90-degree angle. The participant then rested for 7 minutes. While the participant rested, the Vernier Go Direct Accelerometer (GDX-ACC 0H3001A7) was turned on and calibrated for vibration readings. The accelerometer was mounted on the electric drill using a PCS double gum and positioned near the gripping zone where vibrations enter the worker's hand. Safety glasses and earplugs were provided to each participant.

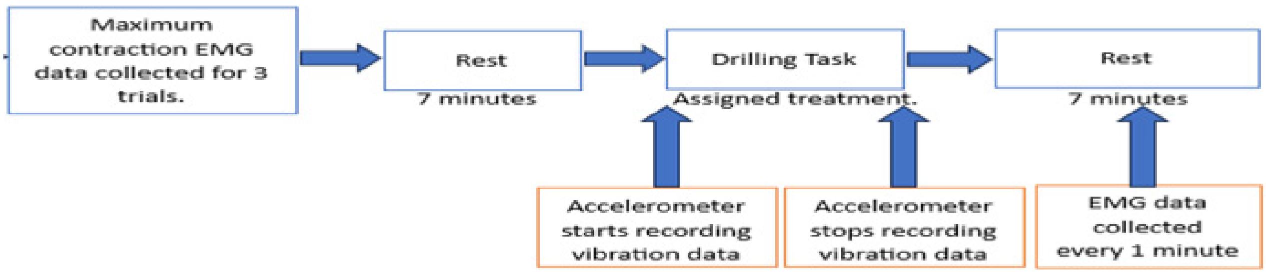

Figure 1: Experimental Protocol.

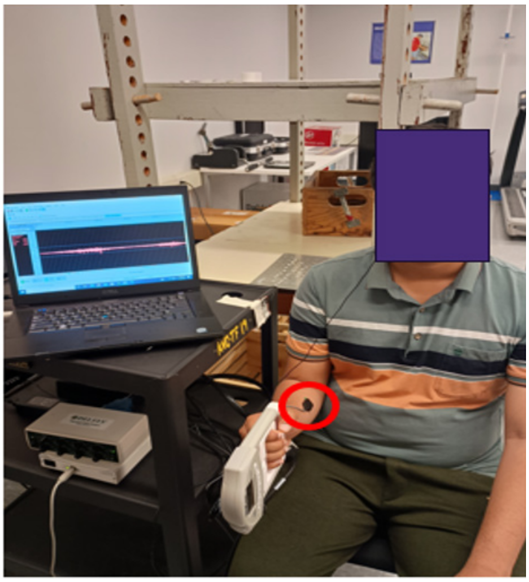

Figure 2: Participant Performing Maximum Contraction.

The participant started the drilling task using the SKIL variable speed electric drill (120V, 3.5A, 50-60Hz, 0-2250rpm, Ø10mm (3/8”)) to drill an aluminum sheet metal of dimensions of 12x12 inches with a thickness of 0.125”. The electric drill was hung from a woodwork using the TGK ES 620 spring balancer. The spring balancer supports and balances the weight of the drill by providing a counterbalancing force. The participant drilled for 7 minutes with an applied force of 45N, monitored using the SM-500 load cell and force monitor (Model ST-1). During the drilling task, the participant’s neutral posture was standing erect, 90-degree elbow flexion, mid-pronated with the wrist at a neutral angle, arm adducted, and forearm parallel to the floor [16], as shown in Figure 3. Once the task was completed, the participant was guided to sit down and rest for 10 minutes while exerting their maximum grip force every 1 minute for three to five seconds to get the EMG data for analyzing the MFRT.

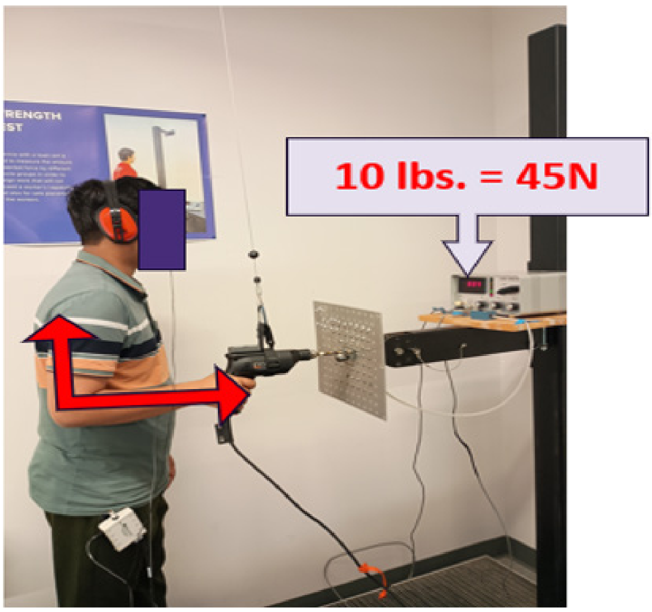

Figure 3: Participant Performing Drilling task.

Citation: Imuetinyan D, Aghazadeh F. Gender Effect on Hand-Transmitted Vibration and Muscle Fatigue Recovery Time During Drilling Operation.*Int J Eng Tech & Inf.*2024;5(2):1-4. DOI: 10.51626/ijeti.2024.05.00079

Results

The mean and standard deviation of the vibration emission for males is 19.2 (2.29) m/s², while the mean and standard deviation for females is 20.37 (3.62) m/s². From the results, the mean value of the vibration emission for the females is higher with a percentage increase of 6.1% compared to the males. For the muscle fatigue recovery time, the mean and standard deviation for the males is 2.75 (2.06) minutes, while the mean and standard deviation for the females is 3.25 (1.89) minutes. The result shows the females have a higher mean muscle fatigue recovery time with a percentage increase of 18.2% compared to the males. Figures 4 and Figure 5 show the changes in the mean vibration emission level and muscle fatigue recovery time, respectively, for both genders.

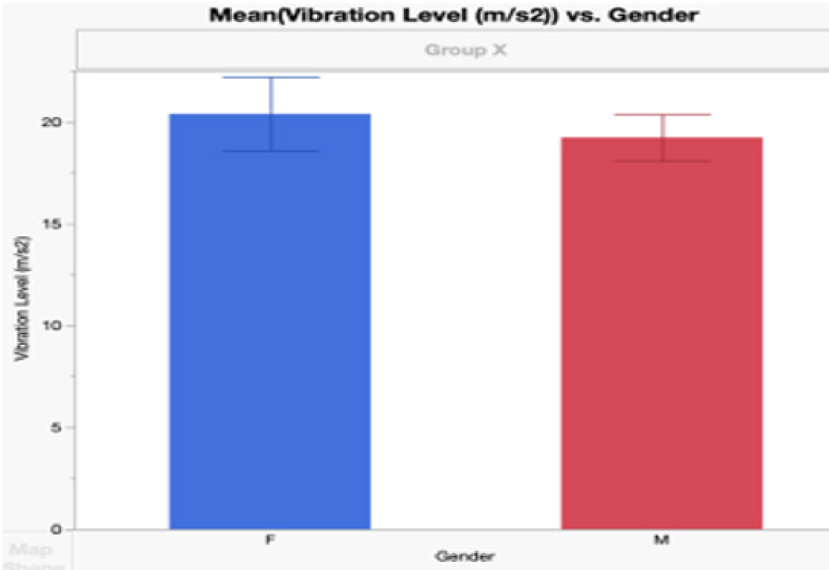

Figure 4: Mean Vibration Level.

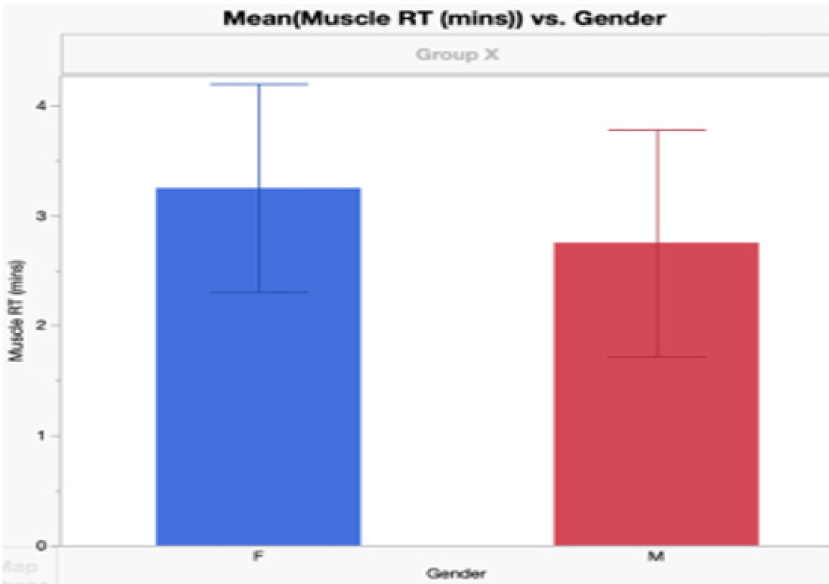

Figure 5: Mean Muscle Fatigue Recovery Time.

A t-test (p=0.05) was conducted to examine if there is a significant difference between genders for both the vibration emission level and muscle fatigue recovery time. The p-values obtained were greater than the threshold p-value, indicating no significant difference between genders for both responses.

Discussion

Although the t-test conducted shows no significant difference between genders for both the vibration emission level and muscle fatigue recovery time, the mean value of the female participants is higher for both responses. The female participants have a higher vibration emission level than the male participants, with a percentage increase of 6.1%. This could result from how the female participants handled the drilling tool. The mean muscle fatigue recovery time for the female participants is also higher than that of the male participants, with a percentage increase of 18.2%. The muscle fatigue recovery time result is consistent with the study by Mehta and Agnew [15,16], reporting that females have higher muscle activities than males during a drilling task. There are some limitations to this study. First, the drilling operation was conducted in a controlled laboratory. A real-world scenario in a workplace might produce a different result. Another limitation is the small sample size of only

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eight participants. A larger sample size would give more accurate results. In addition, the participants were college students with little or no work experience. Future studies could include experienced workers.

Conclusion

This study found that the vibration emission level and muscle fatigue recovery time during a drilling task are affected by gender. Gender differences in vibration emission level and muscle fatigue recovery time led to a 6.1% and 18.2% percentage increase, respectively. This finding highlights the need to consider genders when assigning drilling tasks and designing rest intervals to prevent Musculoskeletal Disorders. (MSDs). To validate these results, further study in real-world conditions with a larger and experienced sample is needed.

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