Comparative Study of Lower Arm Muscle Activity of Riveters with and Without a Side Handle

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ABSTRACT

Hand-arm vibration syndrome is an occupational illness that affects a large portion of the workforce around the globe. Using tools with incorrect holding techniques presents a high risk of contracting physical disorders such as hand-arm vibration syndrome, and Raynaud's phenomenon or white finger (Khattel 1998). To date, there has been abundant research on optimizing the design of the tool to reduce the vibrational impact on the human arm system. Research has also found a connection between muscle activity in the lower arm and the vibrational effects of power drills (Wadia & Dawal, 2009). An experiment was designed to measure the muscular activity of the lower arm muscles on the supporting arm of a riveter when using a support handle and when not using a support handle. The investigators measured muscle activity using electromyography readings from palmaris longus, flexor carpi radialis, extensor carpi radialis, and brachioradialis. Participants will finally provide subjective data using the ratings of the perceived exertion (RPE) scale. Data will be analyzed within groups ($P < .05$). Mean and standard deviation will be used to analyze the EMG readings of riveting and the RPE readings under each condition. 6 graduate students were recruited to participate in the study offering practical significance to the results. The purpose of this study is to compare the lower arm muscular activity induced by the two-hand grip methods and to determine the effectiveness of utilizing the side handle as a means of reducing fatigue in the lower arm. Nearly significant muscle activity was measured by EMG in the flexor carpi radialis ($p = 0.1$) when performing riveting activities and compared between trails with a support handle and without a support handle. Significant results were not found in brachioradialis ($p = 0.3$), palmaris longus ($p = 0.4$), and extensor carpi radials ($p = 0.5$). Perceived exertion levels were collected using a Borg CR10 scale. Results revealed significant ($p = 0.02$) lower exertion levels were experienced with the implementation of a horizontal support handle. The results of the study suggest that the use of horizontal support handle while riveting may provide resistance to vibrational effects while lower grip strength requirements provide a more ergonomically sustainable tool configuration.

INTRODUCTION

Hand-arm vibration syndrome (HAVS) is an occupational health hazard that affects a large workforce demographic due to prolonged exposure to vibrating hand tools. Approximately two million workers work under conditions that subject them to hand-arm vibrations in the United States (CDC). This syndrome is generally related to muscles, bones, joints, vascular and nervous systems changes. Experts predict that over fifty percent of the workers are susceptible to developing Hand-arm vibration syndrome (Vi 2020). The primary reason for contracting this syndrome is the improper use of tools (Khattel 1998).

Using incorrect holding tools presents a high risk of contracting physical disorders such as hand-arm vibration syndrome and Raynaud's phenomenon or white finger (Khattel 1998). The initial symptoms of vibration-induced injury are temporary numbness, tingling sensation, and pain in the fingers, but prolonged exposure to vibrations would lead to permanent damage (Zimmerman et al. 2020). Often, the damage is very difficult to treat, and it requires a very long recovery time, which is also uncertain. According to a study, some patients suffering from Raynaud's disease could not recover even after twenty years of recovery (Wang 1999).

To date, there has been abundant research on optimizing the design of the tool to lower the vibrational impact on the human-arm system. However, there has been very little research on the study on the effect of the hand transmitted vibrations on the human body components such as fingers, forearm, and upper arm (Zhang 2021). Investigating the biological effect of vibrations induced on the body segments could help us understand the damage caused due to the vibrations and the necessary mechanisms that can be employed to curb the fatigue and damage imparted on the arm components.

The most vulnerable workers' demographics to contract HAVS are automobile assembly, forestry, mining, and metal-working sector (Chetter 1998). In the case of the metalworking sector, the workers are subjected to the use of tools such as drills, chainsaws, grinders, and riveters. Riveting has multiple applications in the fields of locomotive, automobile, aeronautical, and agricultural equipment manufacturing (US Dept of Labor, 2000). The riveting process generally requires forceful exertions and repetitive actions for a prolonged period. In some scenarios, it might demand awkward hand and figure postures, while working on complex structures. This makes the workers very susceptible to Hand-arm vibration syndrome. This study aims to compute and assess the vibration imparted on the muscles of the lower arm while using a rivet gun with and without a support handle.

The connection between muscle activity and vibrational effects is an area that has been recently explored. When using vibrating hand tools, some lower arm muscles are flexed while others are extended. The extensor carpi radials have measured greater vibrational effects during drilling activity than the flexor capri radialis which has led researchers to believe that there is a link between vibrational effects and muscle activity (Wadia & Dawal, 2009). When measuring the grip force applied to a tool while in use, ratings of perceived exertion (RPE) are useful as they do not require outside equipment, nor do they inhibit the operation of the task being performed. RPE has been observed to have a very significant ($p < 0.0001$) relationship to resistance load levels and grip force (McGorry et al, 2010).

METHODS/PROCEDURES

Participants

A total of six healthy volunteer test subjects (male) were recruited locally to perform a riveting task in this study. All the participants were right-handed and in the age group of 18-35 with corrected or normal vision and had no cognitive or physical disabilities that would hinder their ability in performing a riveting task. The participants were paired to perform the practical experiment. Participants were compensated with reciprocal participation in concurrent graduate studies.

Apparatus/Equipment:

This experiment was conducted in a controlled environment at Louisiana State University Machine Shop. The riveting assembly comprises a 12” x 12” aluminum sheet with a thickness of 0.0125”. The assembly was mounted rigidly onto a mechanical workshop table. The rivets used for this experiment are level 6 rivets with a diameter of 3/16" and a length of 3/8".

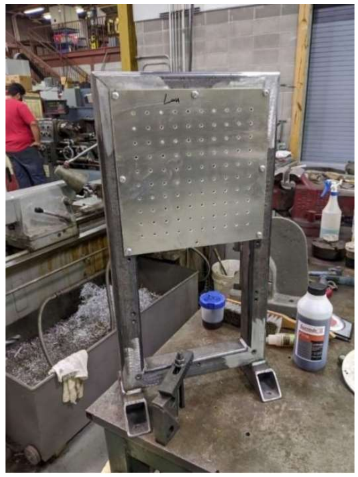

Figure 1. Aluminum Riveting Assembly

The rivet gun employed in this experiment is an Aero Industrial TP84 rivet gun which is widely used in aircraft manufacturing (Aero, 2022). The specifications of the rivet gun are as described below (Figure 2). A tungsten bucking bar was used weighing 2.8 lbs. and has dimensional measurements (4.3"x 1.6" x 0.6").

Manufacturer	**Model**	**Blow per minute (BPM)**	**Capacity**	**Length (inch)**	**Stroke**	**Weight (lbs.)**	**Piston Material**
Aero Industrial Tool Co., inc.	TP84 (4X)	1740	1/4"	8-1/2"	3-1/16"	2.75	Steel

Figure 2. Riveting Gun Specifications

Figure 3. Riveting Gun

Figure 4. Tungsten Bucking Bar

An electromyography (EMG) device is used to interpret the electric impulses generated by the muscle cells while performing the riveting task. The device consists of four surface electrodes that are positioned on the muscular components in the forearm namely brachioradialis, extensor carpi radialis, palmaris longus, and flexor carpi radialis as depicted in the picture below. The EMG device is used to store and translate the electrical impulses generated in the muscles while performing an activity. For this study, we used a Bagnoli-2 EMG device.

Figure 5. Bagnoli-2 EMG system

(Picture from https://delsys.com/bagnoli/integration/)

Figure 6. Surface Electrode
(Picture from https://delsys.com/bagnoli/#sensor)

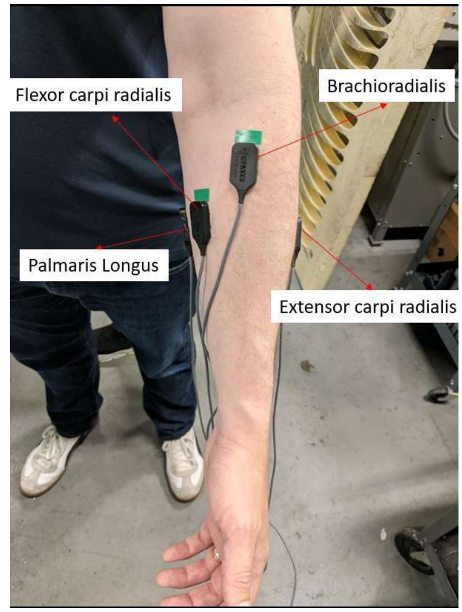

Figure 7. Surface electrodes on a participant

Experimental Design

This experiment will follow a true experimental design with 1 independent variable and 2 dependent variables. The independent variable is the addition of a support handle to the rivet gun. The dependent variables will be the electromyography (EMG) readings and the ratings of perceived effort (RPE). The hypotheses considered for this experiment were as follows:

- Null Hypothesis: The muscle activity would remain constant when performing a riveting process with and without a support handle.
- Alternate Hypothesis: The muscle activity would not remain constant when performing a riveting process with and without a support handle.

The primary objective of this study is to evaluate and compare the muscle response induced in the lower arm area. Assuming that the supporting handle would be effective, the scope of the research is to determine the effectiveness of the handle, and the significance in reducing the muscle response. The experiment will occur in Baton Rouge Louisiana at Louisiana State University in 185 Engineering Laboratory Annex Building (ELAB).

Participants will be paired where one participant will perform the riveting task while their partner holds the bucking bar. They execute the following steps, then switch positions and repeat. Participants will be given an orientation to the equipment, the experiment environment, and the specific procedures involved in the execution of the experiment. They will then be allowed the opportunity to ask questions to the investigator. The investigator will then affix the EMG to the participants' supporting arm segments. Participants apply rivets to a section of sheet metal using the two-handed pistol grip technique within 60 seconds and most participants were able to successfully complete riveting 4 rivet nuts. See (Figure 1: Rivet Gun) for an orientation to the equipment specifications. Participants then apply 4 rivets to a section of sheet metal using the pistol grip and side handle technique. See (Figure 2: Rivet Gun Side Handle) for an example of the pistol grip and side handle technique. The participant's partner will provide bucking bar support during each iteration of the experiment. Finally, participants will provide RPE data based on their subjective experiences. (See Appendix 1: Ratings of Perceived Effort Chart).

Figure 8. Riveting with support

Figure 9. Riveting without support

Analysis

Statistical analysis will be performed using Excel and JMP. *T*-tests ($p < .05$) will be performed in the following areas under each condition. Comparing the EMG readings of riveting and comparing the RPE measurement of the participants between riveting with and without support. Within groups mean and standard deviation will be used to analyze the time to complete ten rivets under each condition. Statistical results will be displayed in bar charts.

RESULTS:

Comparative Analysis of Lower Arm Muscular Activity

Mean absolute value was collected for the brachioradialis, flexor carpi radialis, palmaris longus, and extensor carpi radialis from six participants performing one minute of riveting with and without the use of a side handle, then *t*-tests ($p < 0.05$) were performed to determine significance. The brachioradialis means absolute value with a side handle measuring 0.0027 mV (SD 3.73) compared to without a handle measuring 0.0018 mV (SD 3.18). These two measurements were compared and found to not be significantly different ($p = 0.3$). The flexor carpi radialis mean absolute value with a side handle measuring 0.0036 mV (SD 3.96) compared to without a handle measuring 0.0018 mV (SD 3.47). These two measurements were compared and the results approach significance ($p = 0.1$). The palmaris longus means absolute value with a side handle measured 0.0008 mV (SD 4.84) compared to without a handle measuring 0.0010 mV (SD 4.21). These two measurements were compared and found to not be significantly different ($p = 0.4$). The extensor carpi radialis mean absolute value with a side handle measured 0.0006 mV (SD 4.6) compared to without a handle measuring 0.0006 mV (SD 4.88). These two measurements were compared and found to not be significantly different ($p = 0.5$) (Figure 10).

The percentage change/variation in the muscle activity in a muscle component for no handle and the use of a support handle is calculated by

$$= \frac{Final\ outcome - Initial\ outcome}{(Initial\ outcome)}$$

	Brachioradialis mean EMG(V)	Flexor Carpi Radialis mean EMG(V)	Palmaris Longus mean EMG(V)	Extensor Carpi Radialis mean EMG(V)
With Handle	0.002654015	0.003608051	0.000826214	0.000644648
Without Handle	0.001780535	0.001785205	0.00099973	0.000623426
% Change	(-)32.91	(-)50.52	21	3.3

Figure 10: Percentage changes in EMG readings

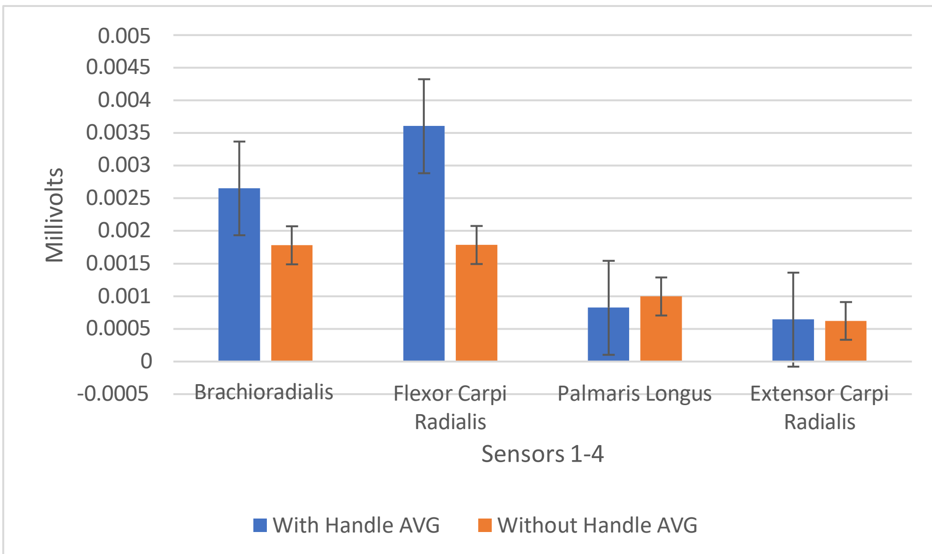

Figure 11: Comparative Analysis of Lower Arm Activity

Ratings of Perceived Exertion (RPE)

The six participants were asked to respond to the rating of perceived exertion (RPE) Borg CR-10 Scale after each trial. The RPE Borg CR-10 Scale rates the subjects perceived muscular exertion on a 0-10 ranking scale with 0 meaning no exertion at all and 10 meaning maximal hard exertion (Appendix 1). Means and standard deviations were calculated for each trial, then *t*-tests ($p < 0.05$) were performed to determine significance. The mean RPE rating for participants performing the riveting task with a support handle was 2.25 (SD 1.17). The mean RPE rating for participants performing the riveting task without a support handle was 4.17 (SD 1.6). When the results were compared, they were found to be significant ($p = 0.02$) (Figure 11).

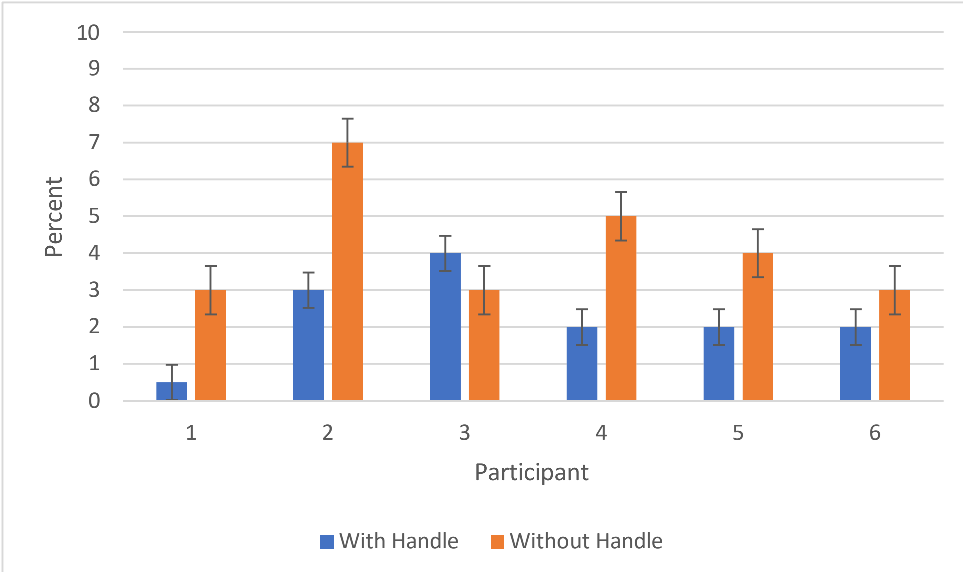

Figure 12: Ratings of Perceived Exertion

DISCUSSION:

The primary goal of this study was to analyze and compare the muscle activity and fatigue in the forearm muscles while performing a riveting task with and without the use of an external side handle. The muscle activity was measured in terms of electrical impulses through the means of an EMG device and the muscle fatigue was measured by a perceived exertion level (Borg scale).

The results highlight values that approached significantly ($p = 0.1$) higher muscle activity in flexor carpi radialis while utilizing a horizontal side handle compared to operating without a handle. These results supported the hypothesis that the flexor carpi radials will experience higher muscle activity when riveting with a support handle versus without a support handle. This could be explained by the forearm being subjected to an inclined supination posture that would increase the muscle response in flexor carpi radialis. The results of the EMG readings in the brachioradialis, extensor carpi radialis, and palmaris longus were not significant when the treatments were compared. This could be explained by the forearm being subjected to an inclined pronation posture which does not utilize flexor carpi radialis muscle response as effectively when compared to being subjected to a supination posture.

Validity

The strength of this study is its external validity. This study was conducted in a working machine shop, and not in a laboratory environment. The results of this study could easily be replicated by future researchers and have industrial applications. External validity, however, is a weakness of this study. The environment was not controlled in a laboratory setting which allowed confounding variables to be introduced to the participants such as prior levels of fatigue, training, and external factors.

Limitations

The major limitation of this study is the training level of the participants. None of the participants had any experience with riveting tools before this study. Without sufficient experience operating a rivet gun or emplacing a bucking bar, the participant has not had time to perfect their form. The probability that an experienced worker would conduct these activities with a slightly different form or procedures than the student participants used is high.

CONCLUSION:

The perceived exertion rates displayed a clear opinion that implementing the use of a horizontal support handle was highly associated with lower exertion rates. Even though there was more muscle activity recorded in the flexor carpi radialis while using a horizontal support handle; participants experienced lower exertion levels while using a support handle. This could be explained as a horizontal support handle would restrict the deviations/kickbacks from the rivet gun and provide a two-axis support for the participant helping them achieve the task in a shorter period. Future researchers should consider collecting EMG and accelerometer data on experienced riveters. These findings would enhance the results of this research by exploring a link between vibrational and muscle extension or flexion as a means of selecting a tool support handle.

The results of this research apply to human factors engineers interested in reducing lower arm effects of vibrational effects in relaxed lower arm muscles. Riveting operations with the side support handle provided flexor carpi radials EMG results that approach significance ($p = 0.1$) indicating greater lower arm muscle activity. The RPE data revealed significant results ($p = 0.02$) indicating that operating the rivet gun without the handle required greater grip strength. Increased muscular activity may provide resistance to vibrational effects while lower grip strength requirements provide a more ergonomically sustainable tool configuration. The results of this study suggest that operating a rivet gun with a side handle is safer than operating a rivet gun without a side handle.

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Appendix 1: Ratings of Perceived Effort Chart

Borg CR10 Ratings of Perceived Exertion	
10-Point Scale	
Ratings	Definition
0	No Exertion at all
0.5	Extremely Light
1	Very Light
2	Light
3	Moderate
4	Somewhat Hard
5	Hard
6	Very Hard
7	
8	Extremely Hard
9	
10	Maximal Hard