Comparison of Muscle Activity and User Perception When Using Rivet Hammer Designs with and without Vibration-damped Properties

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Introduction

Percussive riveting is the primary process for attaching the outer sheet metal "skins" of an aircraft to its airframe. Workers using manually operated riveting tools (riveting hammers and rivet bucking bars) are exposed to multiple ergonomic risk factors such as repetition, force, duration, mechanical compression, and vibration. Workers using manually operated rivet hammers are exposed to significant levels of hand-transmitted vibration.[1,2] Strategies for reducing risk factors often consider the development and/or selection of tools with lower vibration levels.[3] However, the impact that tool design has on muscle exertion and end users' perceptions of comfort when using a rivet hammer is overlooked. This project illustrates these aspects of rivet hammer use to gain a better understanding of riveters' needs.

Purpose

The purpose of this project is to compare riveter muscle activity, ease of use, and perceptions of tool design between the Honsa® HTOP-38 rivet hammer **(Figure 1)**, designed with vibration dampers, and the ATI® ATC rivet hammer (**Figure 2)**, in use at Corpus Christi Army Depot. The Honsa rivet hammer is advertised as "reducing harmful riveter vibration without sacrificing power or performance." This improvement to riveter workplace safety was achieved through reduction in tool weight and vibration reducing properties.

Figure 1. Honsa® HTOP-38 rivet hammer DCPH-A photo by John Pentikis

Figure 2. ATI® ATC rivet hammer DCPH-A photo by John Pentikis

Methods

Fourteen experienced sheet metal workers were divided into seven two-man teams. Each team consisted of one rivet gun operator and one bucking bar operator. The bucking bar operator provided the force necessary to buck (insert) the rivet **(Figure 3 and Figure 4)**. This allowed each operator to concentrate on either operating the rivet gun or the bucking bar and provided a more uniform approach to riveting the rivets.

One riveter from each two-person team was selected as the "odd" riveter and the other as the "even" riveter to determine the order of rivet hammer use. Workers who were assigned an odd subject number used the existing ATI® ATC rivet hammer first. Riveters assigned an even number used the Honsa® HTOP-38 first. Riveters practiced with the Honsa rivet hammer until they felt comfortable using the tool. A DCPH-A ergonomist handed each worker their assigned rivet hammer. Each worker bucked 10 aluminum #5 rivets with the first assigned rivet hammer and another 10 rivets with the second rivet hammer.

Objective 1 – assess forearm muscle activity differences

Muscle activity was measured using electromyography (EMG) sensors placed on the flexor and extensor muscle groups of the forearms. This measures forearm flexor and extensor muscle activity in microvolts (μV). The lower the muscle activity, the less force needed to operate the rivet hammer. After bucking the first 10 rivets, electromyography data was downloaded and checked for discernable discrepancies. The DCPH-A ergonomist then handed the worker the second rivet hammer to buck the next 10 rivets and complete the trial. Once again, EMG data was downloaded and checked for discernable discrepancies. All riveters used the same section of the metal structure to minimize variability **(Figure 5)**.

Objective 2 – assess perceived exertion differences

Perceived exertion was measured using the Borg Rating of Perceived Exertion (RPE) scale immediately after using each hammer. Additionally, riveters' comments regarding rivet hammer design, comfort, and ease of use were also collected immediately after use. The lower the RPE value, the less exertion the riveter felt they had to use. Use of the RPE scale to quantify user acceptance of a tool has been cited in literature.[4] Statistical analysis consisted of a Paired Samples-Test for muscle activity and perceived exertion. Significance was set at $\alpha<0.05$.

Table 1. Muscle Activity Data

Subject #	Honsa® Extensor, μV	ATI® Extensor, μV	Honsa® Flexor, μV	ATI® Flexor, μV
1	3.16	6.39	14.2	11.4
2	9.16	11.9	8.44	10.1
3	54.7	61.5	20.6	34.2
4	17.1	6.26	7.20	13.3
5	15.1	13.7	6.60	5.58
6	5.29	7.53	3.86	5.17
7	9.1	10.4	4.82	12.2
8	30.1	21.6	16.5	15.3
9	7.87	8.16	10.8	6.80
10	8.66	10.8	7.11	6.54
11	3.08	3.09	11.8	6.83
12	3.68	3.35	6.36	12.5
13	4.28	3.78	4.54	5.13
14	9.25	11.9	7.01	13.7
Ave (SD)	**12.9 (14.0)**	**12.9 (14.8)**	**9.27 (4.92)**	**11.3 (7.47)**

Table 2. Roll Up of RPE Data

Rivet Hammer	Rating of Perceived Exertion Dimensionless	P-value
ATI® ATC	9.79 (2.52)	0.04
Honsa® HTOP-38	11.64 (2.56)	

Figure 3. Riveting operation DCPH-A photo by John Pentikis

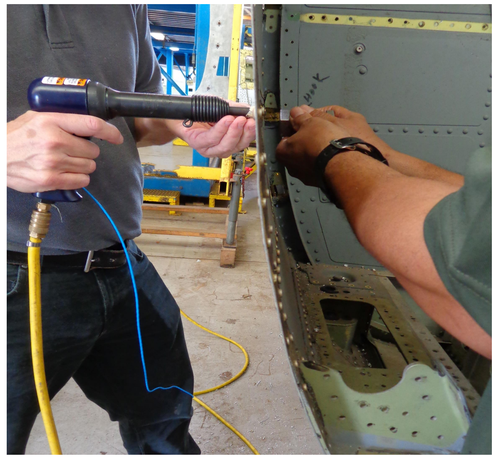

Figure 4. Close up of riveting operation DCPH-A photo by John Pentikis

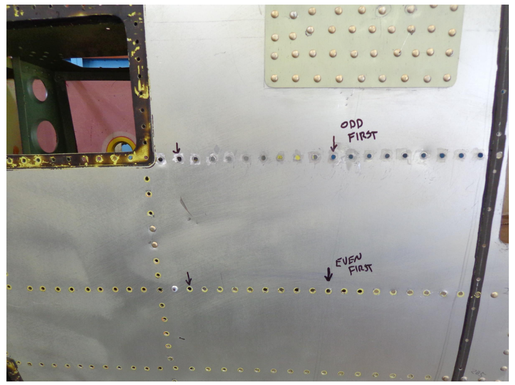

Figure 5. Riveting location on the air skin DCPH-A photo by John Pentikis

Results

Although the Honsa rivet hammer was described by the manufacturer as being the lightest rivet hammer available, there was no statistical difference in muscle activity between the two rivet hammers (forearm extensor, p =0.99 and forearm flexor, p=.16). **Table 1** lists all muscle activity data.

There was a statistical difference (p=0.04) in riveters' rating of perceived exertion values, **Table 2.** The overall average RPE score for the Honsa® rivet hammer was 11.60, which is between the verbal anchors of Light (RPE=11) and Somewhat Hard (RPE=13). The overall average RPE score for the ATI® rivet hammer was 9.80, which is between the verbal anchors of Very Light (RPE=9) and Light (RPE=11).

During interviews with the riveters, three questions were asked to gauge which tool design was preferred. Responses were split between the two rivet hammers.

- Which hammer did you like better? The ATI® hammer was preferred by 8 of 14 riveters.
- Which hammer was easier to use? The ATI ® hammer was reported by 6 of 8 riveters to be easier to use, 6 of the riveters expressed no preference.
- Which hammer was easier to hold? The Honsa® rivet hammer was reported by 5 of 8 riveters to be easier to hold, 6 of the riveters expressed no preference.

The reported comments contributing to user rivet hammer preference include stroke impact (smoother was preferred), trigger shape (concave vs. convex shape was preferred), and trigger sensitivity (more sensitive was preferred).

Conclusions

There was no statistically significant difference in forearm flexor and forearm extensor muscle activity when using the two rivet hammers.

There was a statistical in riveters' rating of perceived exertion values. The riveters indicated that less exertion was needed when using the ATI® rivet hammer.

When comparing the two tool designs users preferred hammers with higher ease of use and comfort.

Users preferred the ATI® hammer despite it being heavier and not having any damping technology.

Manufacturers should consider offering rivet hammers that offers a convex trigger shape, a smooth stroke impact, and slowly ramps up to maximum stroke speed.

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