The Effect of Locking out Radial and Ulnar Deviation with an Upper Body Exoskeleton on Handgun Training

Thomas M. Schnieders
Iowa State University, tms@iastate.edu

Richard T. Stone
Iowa State University, rstone@iastate.edu

Tyler Oviatt
Iowa State University

Eric Danford-Klein
Iowa State University

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Abstract
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THE EFFECT OF LOCKING OUT RADIAL AND ULNAR DEVIATION WITH AN UPPER BODY EXOSKELETON ON HANDGUN TRAINING

Thomas M. Schnieders, Richard T. Stone, Tyler Oviatt, and Erik Danford-Klein
Iowa State University

This paper presents the first version of the ARCTiC LawE, short for the Armed Robotic Control for Training in Civilian Law Enforcement. The ARCTiC LawE is an upper body exoskeleton designed to assist in training civilians, military, and law enforcement personnel. The first iteration of this exoskeleton tests the effect of locking out radial and ulnar deviation for handgun training. The project trained and tested subjects with little to no handgun training/experience utilizing the ARCTiC LawE. An analysis of accuracy and precision was conducted with 24 participants. The experimental group scored statistically significantly higher than the control group at 21 feet and at 45 feet. Most police altercations with handguns occur at 10 feet or less. The results imply the ARCTiC LawE version one has enough statistical support for a second iteration to address some of the quantitative and qualitative results.

1. INTRODUCTION

Recent research shows that tremors in the arm have a negative effect on training (Lakie, M., 2009; Mihelj, M., Nef, T., & Reiner, R., 2007; Schiele, A., 2007) Accuracy when aiming and firing a handgun depends on three primary factors: (1) environmental, (2) hardware, and (3) human factors (Baechle, D.M. 2013). A lot of devices have been developed to mitigate the impact that environmental and hardware factors have on accuracy, while few devices exist to assist in training or augmenting humans. The human factors that affect aim include (1) fatigue (Fröberg, J.E., Karlsson, C., Levi, L., and Lidber, L. 1975), (2) experience (Goontilleke, R.S., Tharion, W.J., Santee, W.R., and Wallace, R.F. 1992), and (3) body sway (Ball, K.A., Best, R.J., and Wrigley, T.V., 2003), (4) heart rate (Tharion, W.J., Santee, W.R., and Wallace, R.F. 1992), and (5) arm tremors (Baechle, D.M. 2013).

One exoskeleton designed for handgun training is the MAXFAS, developed by Dan Baechle. The mobile arm exoskeleton designed for firearm aim stabilization, or MAXFAS is an exoskeleton that utilizes an algorithm to mitigate natural arm tremors while allowing intended motion. This exoskeleton is comprised of a series of cuffs, motors, tension sensors, and cables that connect the MAXFAS to a large aluminum frame that sits behind and above the shooter. The handgun used for training their 20 participants was an airsoft pistol. The pistol used a CO2 cartridge to replicate recoil and had a red laser pointer for aiming (Mihelj, M., Nef, T., & Reiner, R. 2007). Ultimately, Baechle’s research demonstrated that an exoskeleton is a viable method of improving pistol-shooting performance, but requires a redesign to reduce potential risk to participants, using a different handgun replacement (or an actual handgun), longer training period, and evaluation of the effect of learning later than 5 minutes after removing the exoskeleton (Baechle, D.M. 2013).

The ARCTiC LawE, short for Armed Robotic Control for Training in Civilian Law Enforcement provides a more mobile training method compared to The MAXFAS. This paper covers the design and evaluation of that upper body exoskeleton designed to assist civilian, military, and law enforcement personnel in accurate, precise, and reliable handgun techniques. This paper looks specifically at how locking out radial and ulnar deviation in the wrist with an upper body exoskeleton has an impact on handgun training. The training includes the use of the ARCTiC LawE and a laser based handgun with similar dimensions, trigger pull, and break action to a Glock ® 19 pistol, common to both public and private security sectors as their firearm of choice. The laser based handgun ensures the safety of the participants and provides a method to alleviate any impact on bullet trajectories (as in traditional handguns) due to humidity and/or temperature.

2. Exoskeleton Design

2.1 How it Works

When firing handguns, participants were instructed to squeeze the trigger with the center of the tip of the index finger (distal phalanx). If participants squeezed the trigger with the outer tip of their index finger, their shots erred to the left; if participants squeezed the trigger with the inner portion of the index finger, their shots erred to the right. To help guide participants in using the correct portion of their finger, a neoprene glove, which also acts as padding between the user and the exoskeleton, had a portion of its index finger removed (Figure 1). This allowed the participants to not only more easily feel the trigger, but also served as a reminder as to which portion of the finger to squeeze with. There was also error caused by breaking the wrist up or down, pushing, heelng, thumbing, etc. when handling the handgun which caused the shots to fire up, down, left, right, and diagonally from the center of the target. Much of this result related to: anticipating the recoil of the gun.
pulling the trigger rather than squeezing it, or how the user is holding the grip of the gun.

The cut-out portion of the neoprene glove served to mitigate the effects of too little trigger finger and too much trigger finger, which resulted in hitting the target to the left and right of center, respectively. The stainless plate steel helped mitigate the breaking wrist up and down which resulted in hitting the target above and below center. To mitigate the tightening of the fingers or tightening of grip while pulling the triggers, hook-and-loop fasteners were added to the pinky, ring, and middle fingers horizontal bars. Two bars of hook-and-loop fasteners were sewn onto the proximal phalanges location of the neoprene gloves while one bar of hook-and-loop fastener was sewn onto the intermediate phalanges location of the neoprene glove.

Figure 2: ARCTiC LawE vrs. 1

The ARCTiC LawE can be seen in Figure 2, above. It shows the neoprene glove mated to the metal exoskeleton as well as the hook-and-loop fasteners. The exoskeleton uses nylon webbing that can easily be swapped out to accommodate multiple sizes. The webbing was connected with bolts, washers, and nuts to help facilitate swapping of the webbing. The finger coupling of the exoskeleton also acted as a guide for the participants. They were instructed to keep the hook-and-loop fastener on the neoprene glove mated with the exoskeleton helping mitigate over squeezing. The overlapping plates allowed for some actuation in the flexion/extension of the wrist. This allows participants to easily draw and holster the LaserLyte ® training handgun during the experiment. The overlapping plates also prevented radial and ulnar deviation. The stiffness of the metal would require strong loading be placed on the joints of the overlapping plates. Abduction of the wrist (moving the wrist towards the “thumb side”) is the result of activating the flexor carpi radialis and the extensor carpi radialis longus in radial deviation. Similarly, adduction of the wrist (moving the wrist towards the “pinky side”) is the result of activating the flexor carpi ulnaris and the flexor carpi ulnaris in ulnar deviation. Locking out radial and ulnar deviation with The ARCTiC LawE helps keep the handgun in line with the rest of the forearm and mitigates inaccuracy from breaking the wrist up, breaking the wrist down, pushing forward, or dropping the head of the handgun.

2.2 Materials and Methods
Participants were required to fill out a pre-study survey and sign an informed consent document. The pre-study survey asked participants their experience with guns, their experience with handguns, and questions regarding experience with video games and first person shooters. Participants were comprised of civilians above the age of 18 who could legally give consent and could physically operate a handgun. Ideal participants had normal to corrected vision (contact lenses and glasses are okay except for bi-focals, tri-focals, layered lenses, or regression lenses), and little to no experience using handguns.

Participants were randomly put into a control group or an experimental group. Training for both groups involved teaching participants’ proper use and handgun safety. While the study utilized a laser gun instead of live ammunition, participants were instructed to treat the laser gun as if it were a live gun using live ammunition. Examples of the use and handgun safety training included always pointing the gun towards the ground until ready to fire, participants may not fire the laser gun unless anyone with them (i.e. the Pls) are behind them, etc. Twenty participants originally signed up to participate in the study. However, from the data collected in the pre-study survey, four participants, all pre-allocated to the experimental group, self-identified as having moderate to advanced handgun experience. These four participants were removed from the study.

Participants were started at either 21 feet or 45 feet from the LaserLyte Score Tyme Board and then moved to the next distance to counteract the effect of learning on the results of the participants’ scores. Participants were required to fire 25 shots at each distance for a total of 50 shots. The total score after the 25th shot was tallied and the target was reset. The testing was repeated for the remaining firing distance. Each distance had a potential for 250 points as a high score if each of the 25 shots hit the 10-point bull’s-eye. The outermost ring of the target was worth four points and each ring increased value by one.

After completing the testing, participants filled out a post-study survey, which asked qualitative, self-identified metrics of perceived accuracy, perceived precision, etc.

2.3 Results
The participants were normally distributed. The statistical significance threshold was set at 0.05 with practical significance set at 0.1. On average, the experimental group scored 52.6 points higher than the control at a 21-foot distance and 27.2 points higher than the control at a 45-foot distance (Figure 3).

Figure 3: Average Score
Among the participants in the experiment (N=24), there was a statistically significant difference between the two groups at 21 feet, control (M = 86.84, SD = 47.01) and experimental (M = 139.4, SD = 38.29), t(24) = 0.003, p = 0.007. There was a statistically significant difference between the groups at 45 feet, control (M = 36.00, SD = 22.83) and experimental (M = 63.18, SD = 41.59), t(24) = 0.01, p = 0.05.

In the post study survey, participants were asked about the effectiveness of the training they underwent (Figure 4), their precision (Figure 5), their accuracy (Figure 6), their stability (Figure 7), and how effective they thought the training would be over the course of three months.

On average, participants in the experimental group rated their perceived effectiveness of the training 1.81 points (or ~18%) higher than the control group. There was a statistically significant difference between the two groups, control (M = 6.92, SD = 2.36) and experimental (M = 8.73, SD = 1.01), t(24) = 0.01, p = 0.03.

On average, participants in the experimental group rated their perceived precision 2.14 points (or ~21%) higher than the control group. There was a statistically significant difference between the two groups, control (M = 3.77, SD = 1.54) and experimental (M = 5.91, SD = 1.81), t(24) = 0.003, p < 0.01.

On average, the experimental group rated their perceived accuracy 1.71 (or ~17%) higher than the control group. There was a statistically significant difference between the two groups, control (M = 4.38, SD = 2.10) and experimental (M = 6.09, SD = 1.64), t(24) = 0.02, p = 0.04.

On average, the experimental group rated their perceived stability 2.36 (or ~24%) higher than the control group. There was a statistically significant difference between the two groups, control (M = 5, SD = 1.96) and experimental (M = 7.36, SD = 1.75), t(24) = 0.002, p < 0.01.

On average, the experimental group rated the perceived effectiveness over 3 months 1.28 points (or ~13%) higher than the control group. It is important to note that this measure was taken in the post-study survey immediately following the study and not after 3 months of training (Figure 8).
There was not statistically significant difference between the two groups, control (M = 7.54, SD = 1.90) and experimental (M = 8.82, SD = 1.33), t(24) = 0.03, p = 0.07.

2.4 Discussion
The evidence was enough to warrant a second iteration of the ARCTiC LawE. This second iteration can address some of the qualitative and quantitative results. In particular, the study showed fatigue from the participants attempting to ‘rapid fire.’ The participants were attempting to draw the LaserLyte, quickly, fire the LaserLyte, holster the LaserLyte, and repeat.

The results showed a tendency for participants to miss the target entirely, typically to the left or right of the target. If participants were hitting the target in the outermost ring, they would have a minimum score of 100. This means that the exoskeleton needs to address wrist flexion and extension. Occasionally, participants would miss above or below the target, but this typically occurred within the first 10-15 shots when participants with no handgun experience learned how to aim with the handgun. Future work would look at the transfer of training effectiveness as well as locking out wrist flexion and extension. A larger sample size would also be beneficial.

2.5 Conclusion
The ARCTiC LawE trained and tested 24 participants (13 control, 11 experimental) on how to use a handgun. This upper body exoskeleton designed to assist civilian, military, and law enforcement personnel tested the effect of locking radial and ulnar deviation for handgun training. The results for average score at 21 feet and 45 feet, perceived effectiveness, perceived precision, perceived accuracy, and perceived stability were all statistically significant. The quantitative and qualitative metrics indicate locking out radial and ulnar deviation with an upper body exoskeleton has a positive impact on handgun training.

3. REFERENCES