

**Effects of a One-day Krav Maga Training: Early Stages of
Skill Acquisition of a Krav Maga Kick and Punch**

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ii) Abstract

Krav Maga (KM), inspired by various forms of martial arts, is a form of self-defence training intended to teach civilians the necessary techniques required to fight against street violence. KM offers self-defence training in over 70 countries to a variety of populations. Moreover, in countries such as U.S.A and France, KM is an integral part of the military and police training. Although many forms of martial arts have been studied for decades, there's few mentions of KM in the current literature. The current study investigated the effectiveness of a 30-minute instructional session among seventeen female volunteers. The participants displayed a 42% increase in kick peak force when compared to their baseline. This change in performance is most likely associated with KM instruction and is perhaps demonstrating characteristics of learning among novice.

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1.0 General Introduction

Krav Maga (KM) or “contact combat” translated from Hebrew is the official hand-to-hand combat system used in the Israeli defense force (Levine and Whitman, 2007). Originally, KM was designed to educate citizens and to help them learn to defend themselves in hostile environments in a matter of days. When the Israeli defense force was created, it became the official program for the rapid training of soldiers (Aviram, 2014).

The founder of KM, Imi Lichtenfeld, was an accomplished wrestler, boxer and gymnast (Keren, 2014; Khan, 2004). He used his knowledge from martial arts and his experience observing street fights to design defensive techniques that could be learned quickly. Unlike martial arts where practitioners need many years of training to produce graceful and fluid movements, Lichtenfeld narrowed his teachings down to a few techniques and skills that he believed were extremely valuable in self-defense (Aviram, 2014). These techniques were designed to be accessible to an average person and not just an athlete. Moreover, to ensure the retention of these techniques, he designed them based on his understanding of the body’s natural instinct under stress. Therefore, he believed that the KM techniques are easy to remember and are very valuable when under attack (Keren, 2014).

International Krav Maga Federation (IKMF) offers self-defense training in 70 countries. These classes are offered throughout the year and are designed for a variety of populations (IKMF, 2017). The following are a few examples of the classes offered by KM federation: civil instructors course, instructors training, women’s instructor course, children’s instructor course, and VIP protection. The courses offered by KM federation are usually short in duration and are 3-14 days long. (IKMF, 2017, Aviram, 2014). The KM courses focus on different aspects of self-

defense such as striking, defending when in a disadvantage, defending against a weapon or defending against multiple opponents at once (Levine and Whitman, 2007).

It is a common teaching strategy amongst the KM instructors to teach in the checkpoint format. Checkpoints are the stages necessary for the most effective response to a threat (Khan, 2004). Checkpoints are taught in sequential order. KM instructors adhere to this teaching method as it is believed that the checkpoints will help trainees reduce their movement time, and increase their impact force of a punch or kick. It is believed that the checkpoints are easy to comprehend and can be learned in a short period of time (Aviram, 2014).

1.1 Motor Learning

Learning is defined as a change in capability of a person to perform a skill (Magill, 2006). It begins from the moment a person is born and continues across the entire lifetime. Learning cannot be measured directly and can only be inferred from relatively permanent improvements in performance as a result of practice or experience (Schmidt, 2005). Every person experiences learning differently based on unique experiences, life history, physiology and anatomy. However, there are common observations across individuals that allow us to characterize the learning process. At early stages, attempts are made to generate an idea of the movement (Gentile, 1972) and the learner is focused on basic pattern coordination (Newell, 1986). As the skill is practiced, movements become smoother, the learner gains confidence and the performance becomes more consistent (Hodges, 2012). Improvements in performance during training, referred to as online effects (Hodges, 2012), begin within minutes of a single training session. The improvements in performance continue over days and weeks of repeated training sessions. Changes in performance that happen between training sessions are referred to as “Offline effects” (Robertson et al., 2004).

Observational Learning

Observational learning is one of the most common means of acquiring a new skill, where the learner simply observes a demonstration by a skilled performer (Magill, 2006). As research has shown, observation is a successful strategy in motor learning and it promotes learning in a variety of motor skills (McCullagh et al., 1989; Ste-Marie et al., 2012; Lago Rodriguez et al., 2014; Horn et al., 2007). Zelaznik (1996) suggests that intrinsic feedback such as visual and sensorimotor feedback is essential to maximize motor learning. Zelaznik (1996) further expands that motor learning occurs on necessity of augmented information feedback. Augmented feedback refers to extrinsic feedback provided to the learner, such as knowledge of the results and knowledge of the performance, and is a concept used by many coaches and trainers.

1.2 Motor Learning and Age

Although the decline in motor learning capability associated with age has been reported in numerous studies (Buch et al. 2003; McNay and Willingham, 1998; Harrington and Haaland, 1992), some research supports older adults' ability to learn fine motor skills. Seidler (2006) reported that older adults (mean age=69.6 years) demonstrated similar sequence learning when compared to younger adults (mean age= 24.6 years). Review by Ketcham and Stelmach (2001) reported that older adults (65 and older) with extensive practice can display improvement in tasks such as aiming or tracing. Moreover, Fraser et al. (2009) reported a slight age-related difference after investigating a multi finger tapping task such that the older adults (mean age=65 years) needed one extra day of learning to reach the same level of performance accuracy as the younger adults (mean age=24 years). Both groups performed a cognitive measure and were within the normal range of their age group. Additionally, reaction time analysis showed older adults demonstrating similar learning patterns compared to younger adults (Fraser, 2009).

Berghuis et al. (2015) investigated learning and retention of a 20-minute wrist extension/flexion skill in elderly (mean age=71 years). They reported a 40% increase in motor learning compared to the control group using performance and corticospinal excitability measures (Berghuis et al., 2015). These findings suggest that it is perhaps possible that a variety of age groups are able to acquire new motor skills after a single instructional session.

Consolidation

Consolidation, a component of offline effects, refers to the post acquisition processes including neurological reorganization (Kendal, 2001) where the memory representations of a skill undergo further processing in order to integrate into existing brain networks and ultimately into a non-fragile state (Hodges, 2012). Although the early research on consolidation was mainly focused on memory tasks, it is becoming more and more evident that consolidation is also an essential process in motor learning (Walker and Stickgold, 2006). Looking at Kuriyama et al. (2004) who used a finger sequencing task to analyze gain in speed, fast and easy transitions showed only minimal improvements during acquisition. Gain in speed after consolidation was larger when the subjects had rested and returned to be retested the following day. These findings support the notion that motor learning continues after skill acquisition. Moreover, new evidence suggests the importance of sleep in consolidation of novel motor skills. Walker et al. (2006) who investigated finger tapping performance, observed a 20% increase in motor speed, without loss in accuracy, after a night of sleep. Furthermore, in an experiment where participants had to identify the orientation of a set of bars post training, participants performed significantly better the following day without further training when compared to the end of the initial practice session (Karni and Sagi, 1993). It is worth noting that participants in the current thesis were

tested before and after a 5-minute break post training, therefore the full extent of learning may not reflect in the participant's performance.

1.3 Self-Defense in Current Research

Although most martial arts include a self-defense component in their training, KM experts believe that martial arts training is not sufficient to provide responses to real life threats (Aviram, 2014). A review of traditional martial arts training versus self-defense training for women by Angleman et al. (2008) concluded that traditional martial arts training may not prepare women for the potential threats they may face. Furthermore, they stated that the self-defense studies have primarily relied on self-reports and very few studies have investigated whether self-defense training results in a decreased number of attacks or an increase in the number of attack preventions or escapes. A more recent study by Hollander (2014) analyzed the effectiveness of self-defense training in a group of college students (n=119, mean=21.1 years; 180 enrolled in a self-defense course and 119 volunteered to participate), compared to a control group (n=179, mean=20.7). after a one year follow up, women in the two groups appeared to differ in both quantity and severity of the assault. In total, 12% of the self-defense students and 30.6% of the non-self-defense students reported assault. Hollander (2014) suggests that self-defense training research deserves serious attention as a strategy for reducing sexual assaults.

Self-defense training has also shown to benefit younger age groups. Another recent study by Sinclair (2014) among Kenyan adolescent (n=489, mean age=16.7±1.5 years) reported a significant drop in assault (baseline: 24.5%; Follow up: 9.2%, p=.001) after a 10 month follow up when compared to a control group (baseline: 24.2%; Follow up: 23.1%, p=0.1).

Moreover, Renden et al. (2017) suggest that the self-defense training offered in police training may not be sufficient when performing under stress. Renden et al. (2017) investigated

the effects of reflex-based self-defense on police performance compared to regular police arrest and self-defense training (control). They attributed the improved performance in the reflex-based group to: better communication, situational awareness (alertness), assertiveness and converting primary responses into tactical movements. KM experts also believe that skills are easier to recall if they are reflex based (Khan, 2004). Moreover, a questionnaire study among 922 Dutch police officers reported that the police officers believed that additional training in performing under high anxiety, and in arrest and self-defense skills is required to improve the performance of police officers (Boe, 2015).

Measures Used to Assess Martial Arts: Punch

The various punching techniques taught in martial arts have different kinematic and kinetic properties. Velocity, movement time and impact force are the most common measures used to assess martial arts performance (Gulledge and Dapena, 2008; Piorkowski et al., 2011; Wasik and Nowak, 2015). Piorkowski et al. (2011) studied five common types of punches used in western boxing among 10 advance practitioners and reported unique kinematic characteristics for each type (mean age=21.5 years). They reported that a reverse punch travels at the highest peak velocity of $11.02\text{m/s} \pm 2.21$ and a jab is shortest in duration at $0.59\text{s} \pm 0.16$ (Piorkowski et al., 2011). In a different study, Gulledge and Dapena (2008) investigated the difference between a straight punch and a 3-inch power punch. It was found that a straight punch achieves a greater peak velocity at $6.43\text{m/s} \pm 0.82$ and also produces a much greater peak force of $1450\text{N} \pm 290$ compared to a 3-inch power punch at $4.09\text{m/s} \pm 0.52$ and $790\text{N} \pm 130$. They concluded that although a 3-inch punch may not be as powerful, it is still a very good way to throw the opponent off balance and therefore practical in self-defense (Gulledge and Dapena, 2008).

Additionally, Wasik and Nowak (2015) analyzed two types of punches; traditional taekwondo straight punch versus a straight punch. They reported that the peak velocity of the taekwondo punch was greater than that of the straight punch, with peak velocities of $8.46\text{m/s} \pm 1.46$, and $5.34\text{m/s} \pm 0.32$, respectively. A tradeoff is demonstrated where a reverse punch takes less time to execute but reaches a lower peak velocity (Wasik and Nowak, 2015). In KM, quick movements are crucial and allow the defender to open up opportunities for the subsequent move (Levine and Whitman, 2007). Research suggests that a reverse punch and a traditional taekwondo punch achieve greater peak velocity compared to other punching techniques. However, a jab or a straight punch are shortest in duration and what KM experts use in their practice.

Measures Used to Assess Martial Arts: Kick

The front kick taught in variety of martial arts has been the subject of many biomechanical studies (Blum 1977; Sorenson et al., 1996; Falco et al. 2009). The front kick displays a proximo-distal coordination pattern where the final goal is to reach maximum velocity right before contact (Sorenson et al., 1996). Falco et al. (2009) looked at differences between novice ($n=16$) and advanced taekwondo practitioners ($n=15$, minimum of 4 years in training) and it was suggested that novice practitioners use their body weight more to increase force. The average impact force reported for the experts was at $1994\text{N} \pm 537$, and the average impact force reported for the novice practitioners was at $1477\text{N} \pm 679$ (Falco et al. 2009). These findings suggest that less experienced martial art practitioners can exert a relatively high impact force, perhaps by recognizing the fact that utilizing their body weight is as an effective way to increase force. Using one's own body weight is a common KM checkpoint taught in many striking techniques (Khan, 2004).

In a later study, Falco et al. (2011) investigated five different types of taekwondo kicks among 27 volunteers (14 advance, 13 intermediate). No difference was found in reaction time, but movement time was the shortest in duration for the front kick $0.46s \pm 0.095$. Falco et al. (2011) suggested, there was no difference in reaction time between common types of kicks and therefore, a defensive front kick that travels a short path would be a good approach for self-defense.

The effectiveness of KM training has not been addressed in the current research. Assessing the performance of KM training will further our understanding of novel skill acquisition in the context of self-defense and the effectiveness of techniques used by KM instructors in self-defense training.

2.0 Manuscript Introduction

Krav Maga was designed to be instructed to civilians in a relatively short period of time in order to defend against the fast-rising tensions in Europe in the late 1930s (Levine and Whitman, 2007; Khan 2004). Before the birth of KM, the founder, Imi Lichtenfeld, offered his help to communities by teaching self-defense techniques to any age group or sex. Therefore, expert practitioners believe that KM was originally designed to be accessible to many individuals regardless of age, gender, or fitness level. Moreover, some KM experts believe that even one training session has the potential to provide valuable skills that are advantageous in hand-to-hand combat (Levine and Whitman, 2007).

It is a common strategy in martial arts training programs to progress towards faster and stronger movements as the training advances (Walker 1975, Aviram 2014). In other words, faster and more powerful kicks/punches are considered a sign of improvement. Additionally, KM experts believe that the instructions and methods taught by the founder result in better performance described as fast and forceful (Levine and Whitman, 2007). KM instructors prefer to simplify the movements and break down the techniques into steps and what they call “checkpoints”. It is a common belief amongst the KM community that performing the checkpoints increases the power and reduces the movement time of a punch or kick (Aviram, 2014). Therefore, KM may provide a unique approach in self-defense training, perhaps by providing clear sets of instructions that are comprehensible to various population groups.

Although KM is offered in over 70 countries (IKMF, 2017), there seems to be very few mentions of the KM techniques, or the effectiveness of the training, in the current literature. The purpose of the current study is to further expand the current knowledge of KM and intensive self-defense training.

The following questions will be addressed in this thesis:

- 1) Do an individual's peak velocity and peak force increase with a single instructional session by an expert when compared to individual's baseline measures?
- 2) Does the performance of the checkpoints correlate with the peak velocity and the peak force?

It is hypothesized that

- 1) Instructions and training will result in an increase in peak velocity and peak force.
- 2) Successful performance of the checkpoints (i.e. following the KM instructions) will correlate with greater peak force and greater peak velocity.

3.0 Methods

To investigate the difference in performance of two KM techniques amongst novices, participants were tested before and five minutes after a 30-minute instructional session.

3.1 Participants

Seventeen healthy female participants (Age: 24.6, SD=3.4) were recruited through various methods such as posting ads, using the undergraduate research participation program (KURE), and by word of mouth. Participants were required to be in good general health with no history of injuries in the past year. Participants who had received any prior training in martial arts or had taken courses in self-defense were excluded. No other exclusion criteria were used. Approval of this study was provided by the Human Participants Review Sub-Committee, York University Ethics Review Board. All participants were informed about the nature of the study and the required clothing prior to their visit, and provided informed consent prior to initiating the experiment.

3.2 Equipment

A Vicon Motion capture system consisting of seven MXF40 Vicon cameras (Vicon Motion Systems Ltd., Oxford, UK), and Vicon Nexus (Vicon, Nexus version 1.8 2011) were used to collect data. Kinematic data were sampled at 100 Hz. A Vicon analog to digital converter was used to connect the Vicon system to a computer. Two force plates OR6-7 1k (AMTI, Watertown, MA, USA) with a MSA-6 amplifier were used to collect the ground reaction forces (Figure 1). The participants placed one foot on each plate when punching or kicking for the correct KM stance. To measure the impact force of the punch/kick applied by the participants, an AMTI MC3A-1000 force cube connected to an AMTI Gen5 amplifier was used. The AMTI manual retrieved from the company website (ATMI, 2017) indicated the force cube's maximum force capacity along the Z-axis at (1000) lbs. (4448 N), 500 lbs. (2224 N) along the X-axis, and 500 lbs. (2224 N) along the Y-axis. Analogue signals from the force cube and the force plates were sampled at 1000 Hz.

The force cube was mounted to a heavy and stable apparatus that was built using 15cm x 15cm cedar posts and metal fasteners (Figure 2). The force cube was rotated by 90 degrees in order to have the Z-axis face the participants and therefore was adjusted accordingly in the Nexus software (rotated along the X-axis). The force cube came with pre-existing mounting holes in its housing that were used to attach a 200x200 mm aluminum striking plate. The striking plate was padded with 12cm of high density foam to ensure participants were able to perform their subjective maximum effort without a high risk of injury.

Apparatus Setup

The force cube apparatus was adjusted according to the participant's height and preference of left vs right hand/foot. The height of the force cube was adjusted so that each participant punched at shoulder height and kicked at hip height. The force plates were positioned 20 cm apart to encourage the participant place the non-preferred foot forward for both punch and kick performances. The correct stance was recommended and further demonstrated by the KM instructor (Figure 2).



Figure 1. Force plate setup

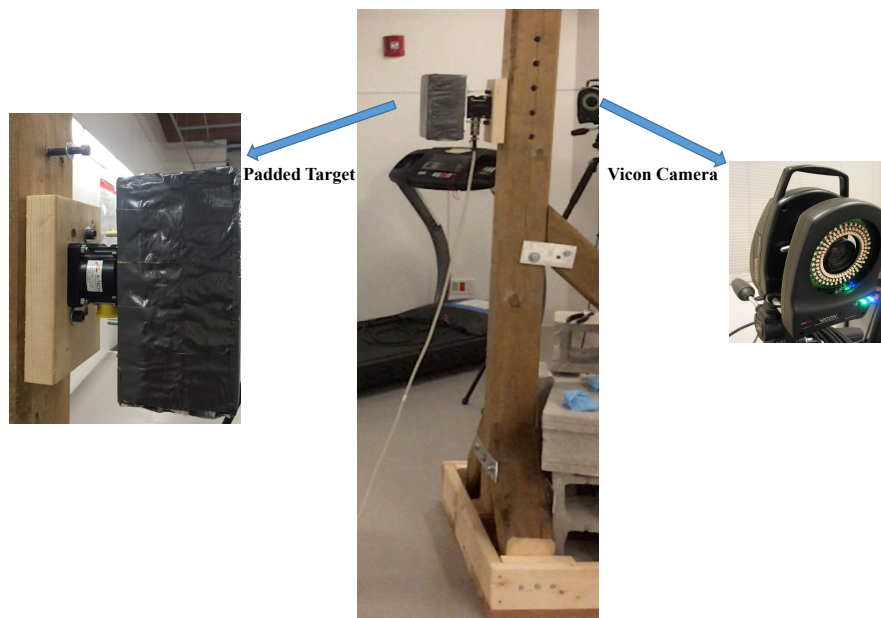


Figure 2. Force Cube Apparatus

3.3 Protocol

In order to reduce the number of false markers registered by the system due to reflected light from bright and reflective colours, the participants were asked to wear dark/matte colors. Additionally, they were asked to wear compression/fitted clothing to reduce the movements of the markers.

3.3.1 Warm up

Prior to any collection, participants were instructed through a warm up exercise and a functional stretching routine via a brief demonstration provided by one of the researchers. The warm up routine consisted of 20 jumping jacks. The stretching routine (standing) was as follows: hip flexion, leg swings, flexion and extension of the neck, and ankle and wrist circles.

3.3.2 Baseline Testing

Sixty reflective passive markers were placed on participants' body in accordance with Vicon marker recommendation guideline (Vicon, Oxford, UK). Double sided tape and transpore tape was used to further secure the markers (Figure 3).

Head:

- R L Anterior
- R L Posterior

Hand:

- R L 3rd Metacarpal
- R L 2nd Metacarpal
- R L 5th Metacarpal

Foot:

- R L Calcaneus
- R L medial Malleolus
- R L lateral Malleolus
- R L 1st Metatarsal
- R L 5th Metatarsal

**Torso:**

- Cervical 7
- Thoracic 10
- Xiphoid Process
- R L Lateral Deltoid
- R L Medial Deltoid
- R L Posterior Deltoid

Upper Arms:

- R L bicep
- R L humeral epicondyle
- R L Ulnar head
- R L Radial Styloid Process
- R L Ulnar Styloid Process

Hip:

- R L Iliac Crest
- R L Iliac Crest
- R L Anterior Superior Iliac Spine
- R L Posterior Superior Iliac Spine

Legs:

- R L Greater Trochanter
- R L Thigh
- R L Femoral Epicondyle
- R L Medial Epicondyle
- R L Fibula head
- R L Tibia head

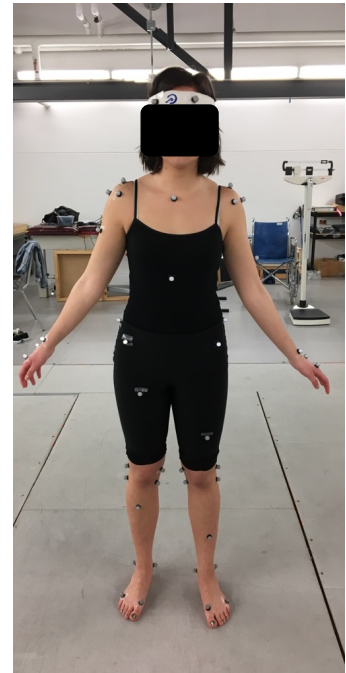


Figure 3: Marker setup

The participants were asked to stand quietly on one force plate, extend the arms into a T shape while the experimenter recorded a trial. This trial was used to create the T-pose model required by the Visual3D (C-motion Inc., Germantown, MD, USA) software for kinematic analysis. Moreover, the T-pose trial was used to determine the participant's weight and relative standing knee angle.

Participants were encouraged to perform up to five practice trials and once they reported that they were ready, they were instructed to punch the center (marked by a white X) as fast and as hard as they could without injuring their hand (Figure 4). No other instructions were given. Five trials were collected for the baseline punch. The same procedure was repeated to collect five trials for the baseline kick. The trials where participants stepped off the plate were repeated.

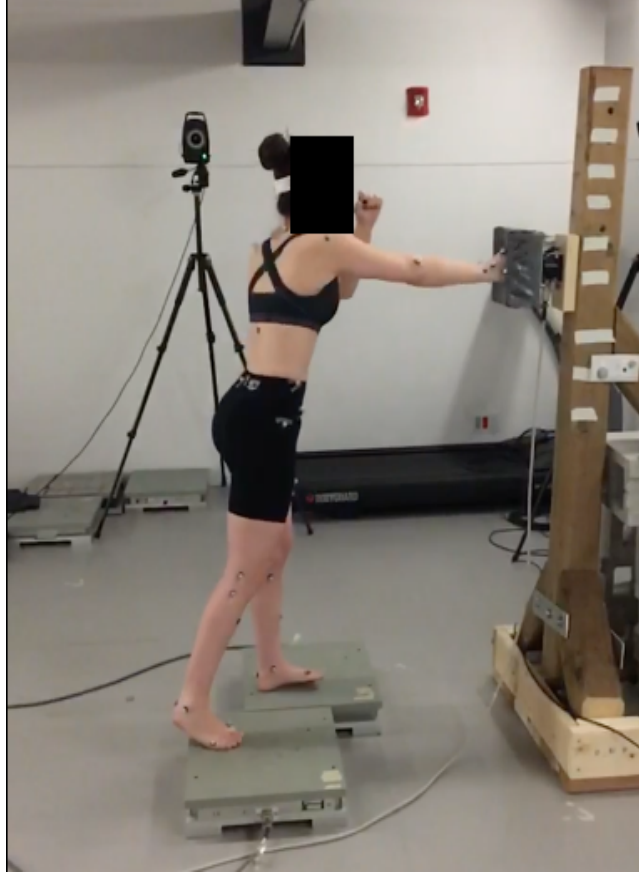


Figure 4. KM stance and experimental setup

3.3.3 Instruction/Training Procedure

All participants followed the same one-on-one training procedure and duration. The instructor spent five minutes, timed with a stopwatch, on each checkpoint for a total duration of fifteen minutes for punching (three checkpoints) and fifteen minutes for kicking (three checkpoints). The duration of training was chosen by observing two KM instructors during a pilot training. Moreover, they encouraged the participants to perform their best up to *five* repetitions at the end of each module in order to avoid fatigue.

A KM stance is a principle component of KM training and was repeated if needed throughout the instructional session. The stance requires the practitioner to flex the shoulders and elbows in order to bring hands to the same height as the neck; the dominant foot is stepped back; the feet are hip width apart and the knees are slightly bent in order to be balanced and agile. The

KM straight punch instructions include the following three checkpoints: 1. Straight (minimizing elbow abduction range); 2. Recoil (retracting the striking hand quickly to the starting position); and 3. Lean (pushing back on the dominant foot). The instructions given to all participants followed the same format and the checkpoints were taught in the same sequence. The KM defensive kick instructions included the following three checkpoints: 1. Knee high (preparing for the kick); 2. Knee extension (making contact with the target while pushing the target away); and 3. Lean (pushing back on the dominant foot).

Half of the participants began their training with punching instruction and the other half began with kicking instruction, in order to counterbalance the treatment. All participants were asked to sit on a stool and take a 5-minute break between punching and kicking instructional sessions.

3.3.4 Post-Instruction Testing

Once participants rested for five minutes after their instructional session, five trials of KM punch and KM kick were completed in the same manner as described above in Baseline Testing.

3.4 Data processing

The collected trials were labeled in the Nexus software before being exported and processed in the V3D software. Each participant's T-pose trial was used to create a model template that was applied to all trials performed by the participant. All raw data were filtered prior to any analysis.

3.4.1 Filtering

A residual analysis (Winter, 2005) was conducted to determine appropriate cutoff frequencies for each of the different types of signals; subsequently force plate signals were

filtered at 8 HZ; force cube signals were filtered at 25 HZ, and the kinematic data were filtered at 6 HZ. All data were filtered using a dual pass 2nd order Butterworth filter.

3.4.2 Events

The V3D software was used to identify specific movement driven events in the data of each trial. The events were used to highlight specific times within the data, which coincided with actions or occurrences associated with the KM movement. Key measures of interest were marked by the event itself or contained between two events. Anteroposterior (AP) shear force was used to select the *Start* and *End event* corresponding to the initiation and termination of the movement. The threshold set (mean of AP shear force in quiet standing +3 * SD) did not coincide with the hand movement visually. Therefore, the start of the KM punch was defined as the initiation of a posteriorly-directed shear force by the posterior lower limb (i.e., pushing backward on the ground to initiate a forward momentum of the body; Figure 5). The end of the KM punch was defined as the plateauing of the posteriorly-directed shear force at the end of the trial. All events were visually confirmed.

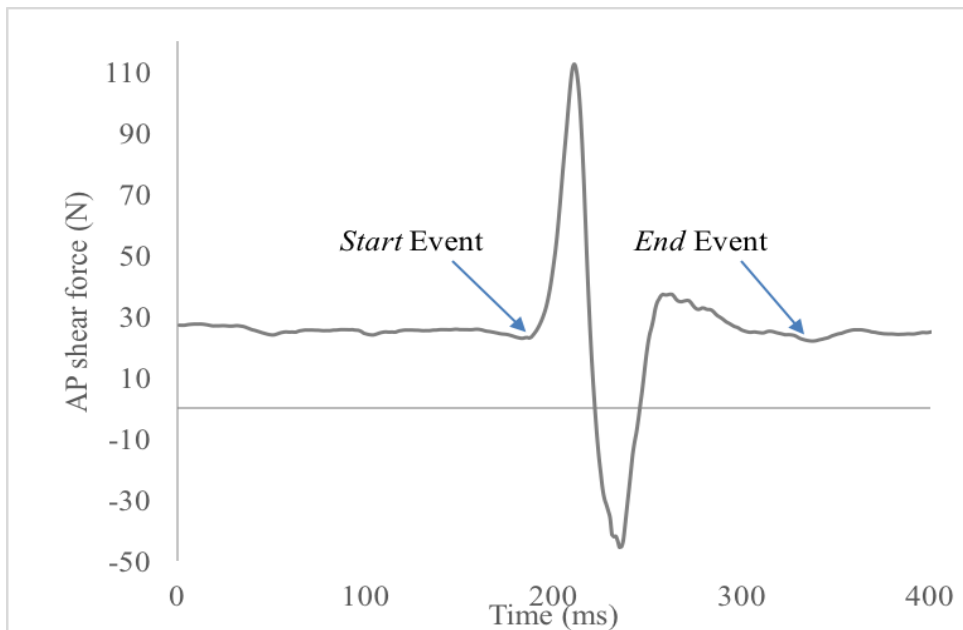


Figure 5: Anteroposterior (AP) shear force during a 4-second punch trial. *Start* and *End* events were marked using the AP shear force for punch and kick trials.

This study was designed to analyze the participants' maximum effort or peak force. The frame with the highest magnitude of force recorded by the force cube was marked as *Max F*. The same procedure was followed to create the *Start*, *End*, and *Max F* events for the kicking trials.

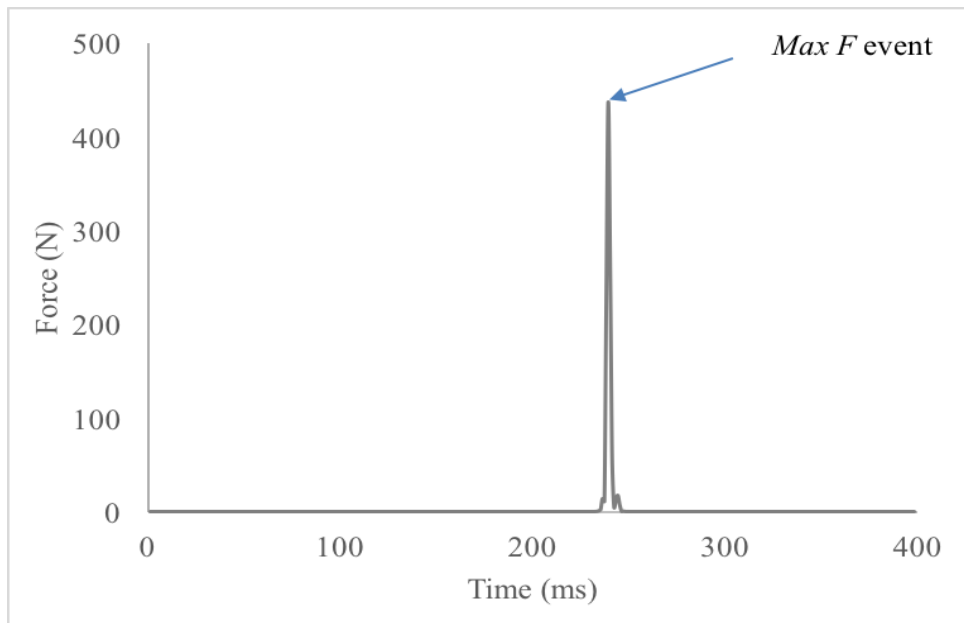


Figure 6: Peak force recorded by the force cube was used to mark the *Max F* event.

There were two categories of the measures investigated in this study. The first category, *performance* measures, analyzed the checkpoints taught by the KM instructor. The second category, *outcome* measures, analyzed the primary goals of each movement such as peak force and peak velocity. The KM checkpoints for punch, kick, and their respective dependent measure are discussed in the following section.

3.4.3 Punch Performance Measures

1. Shoulder abduction: Shoulder abduction range was quantified as the difference between maximum shoulder abduction angle between *Start* and *Max F* events, and the shoulder abduction angle at the *Start* event (Figure 7).

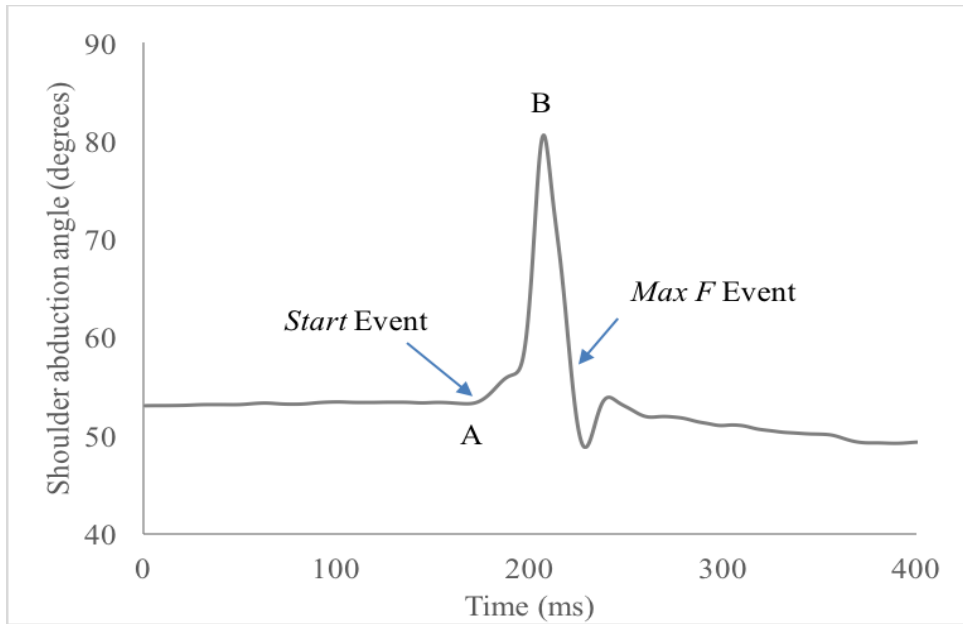


Figure 7: The shoulder angle at the starting position (A) was subtracted from the maximum shoulder abduction angle *Max F* event (B).

2. Recoil: Recoil velocity was quantified as the peak hand velocity between *Max F* and *End* event (Figure 8).

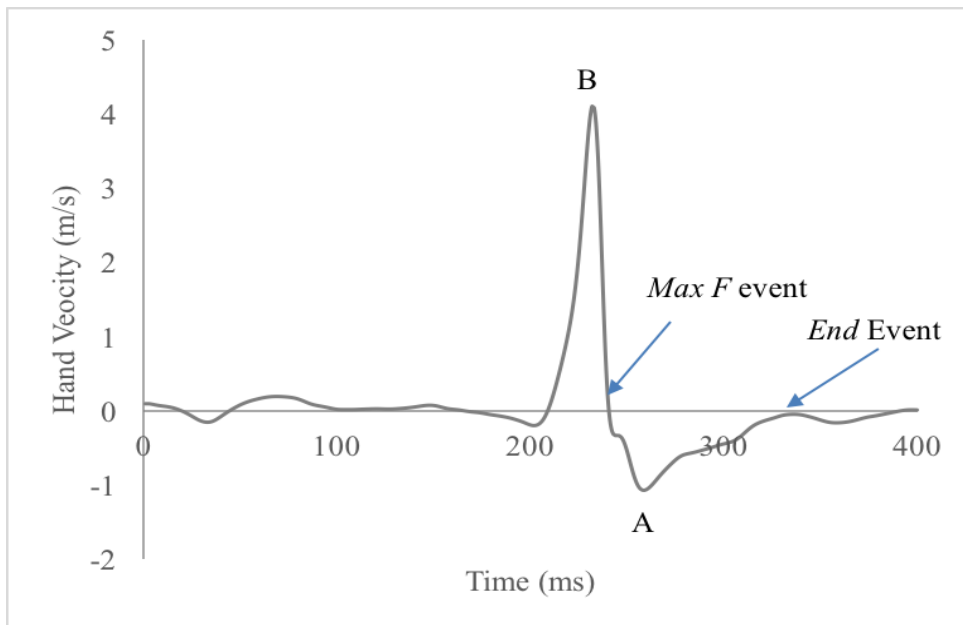


Figure 8: The peak velocity (absolute) between the *Max F* event and *End* event, (A), was used to measure the recoil velocity.

- Lean: AP shear force range was quantified as the difference between the value of AP shear force at the *Start* event and the maximum AP shear force between *Start* and *Max F* event (Figure 9).

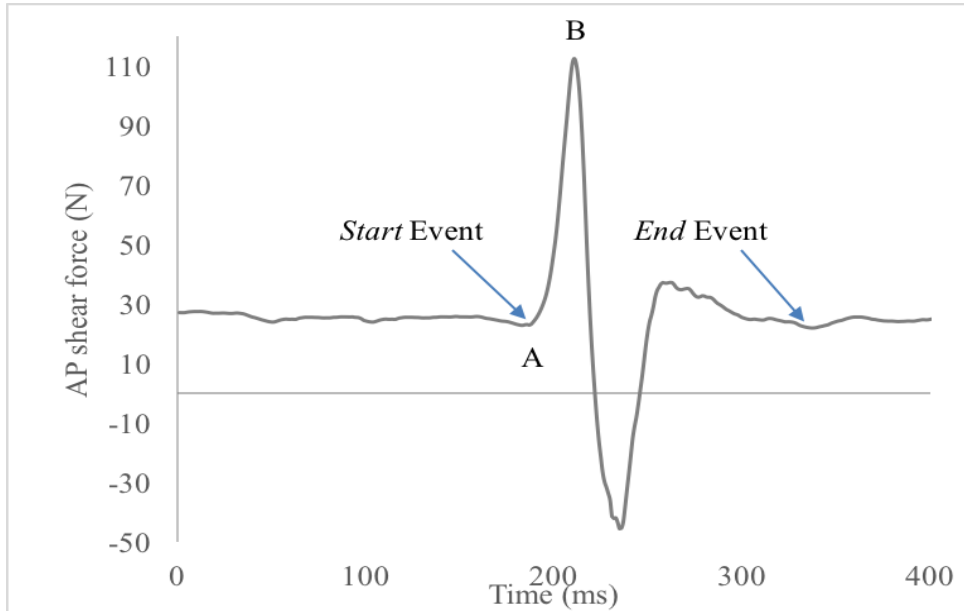


Figure 9: AP shear force at the *Start* event (A) was subtracted from the maximum AP shear force between *Start* and *Max F* event (B).

Table 1: Summary of Punch performance measures for each checkpoint

Checkpoint	Dependent Measure	V3D events
1) Straight	Shoulder abduction range	<i>Start, Max F</i>
2) Recoil	Peak hand velocity	<i>Max F, End</i>
3) Lean	AP shear range	<i>Start, Max F</i>

3.4.4 Punch Outcome Measures

- Peak impact force: Peak force was defined as the maximum force recorded along y-axis of the force cube (Figure 6).
- Peak hand velocity: Peak hand velocity was quantified as the peak velocity between *Start* event and *Max F* event (Figure 8, marked as “B”).

3.4.5 Kick Performance Measures

1. Knee high: Hip flexion angle was quantified as the maximum flexion angle between upper torso and thigh between the *Start* and the *End event* (Figure 10).

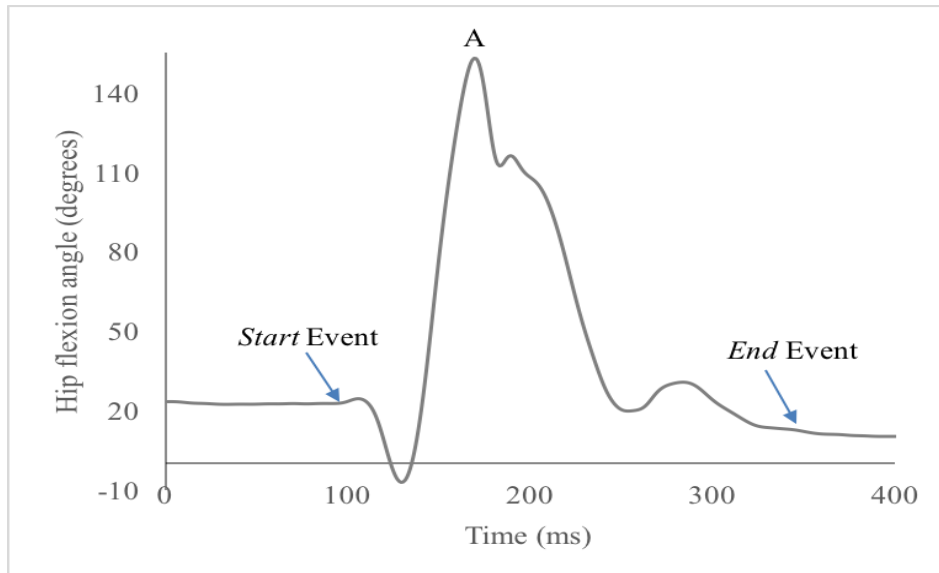


Figure 10: The maximum hip flexion angle (A) between the *Start* and *End* event was used for knee high checkpoint.

2. Knee extension: Knee extension angle was quantified as the knee angle at the *Max F* event. The participant's standing knee angle (T-pose) was used to normalize the knee angles. For instance, knee angle at *Max F* event of a participant with 170 degrees standing knee angle would be adjusted by increasing the angle by 10 degrees (Figure 11).

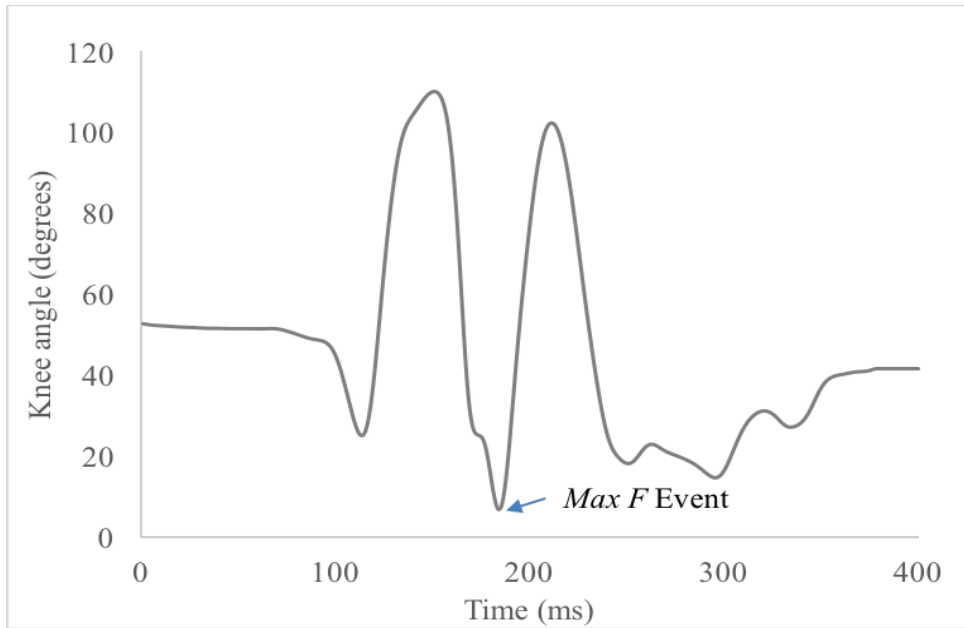


Figure 11: The knee extension angle at *Max F* event.

3. Lean: The lean checkpoint was quantified as the difference between the maximum AP shear force between *Start* and *Max F* events, and the AP shear force at the *Start* event (Figure 12).

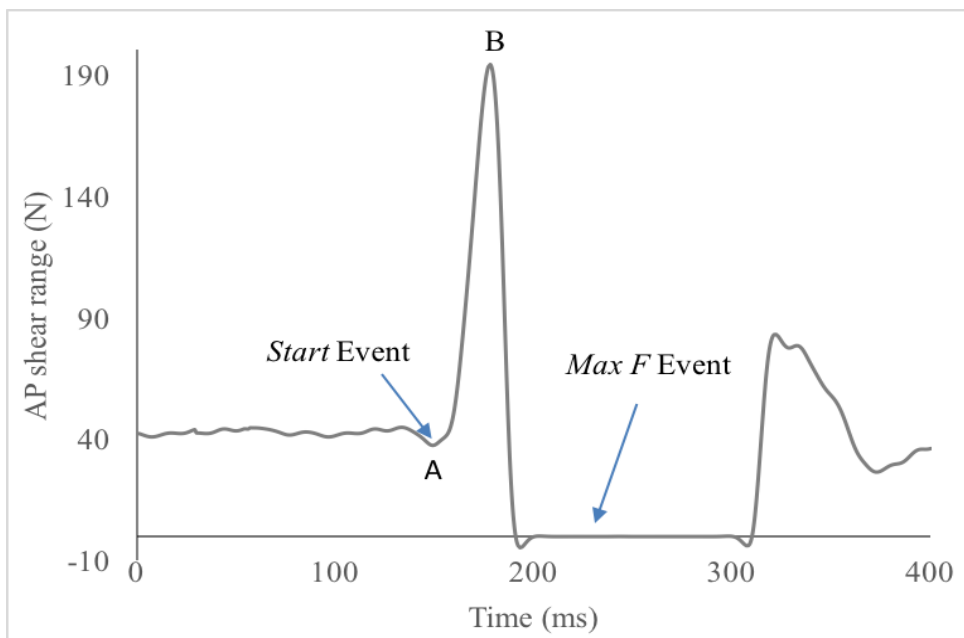


Figure 12: The AP shear force at *Start* event (A) was subtracted from the maximum AP shear force between *Start* and *Max F* event (B).

Table 2: Kick performance measures

Checkpoint	Dependent Measure	Corresponding events
1) Knee High	Hip flexion angle	<i>Start, End</i>
2) Knee Extension	Knee extension angle	<i>Max F</i>
3) Lean	AP shear range	<i>Start, Max F</i>

3.4.6 Kick Outcome Measures

1. Peak impact force: Peak force was defined as the maximum value recorded along y-axis of the force cube (Figure 6).
2. Peak foot velocity: Peak foot velocity was quantified as the peak velocity between *Start* event and *Max F* (Figure 8).

3.5 Statistical Analysis

The average value of five trials before and five trials after for each participant, for each dependent measure, was used to perform a paired t-test (JMP, version 13, SAS Institute INC., Cary, NC). The p-value was set at 0.05 for statistical significance.

If a given outcome measure (e.g., peak force or peak velocity) was found to be significantly different after instruction, a secondary set of analyses was performed to further investigate the correlation between the *outcome* measure and the *performance* measures. The significantly different *outcome* measure was plotted against the significantly different *performance* measure and a fitted regression line was used to describe this correlation.

4.0 Results

The results of the statistical analyses only support the hypotheses in the kick measures. The punch force showed no difference in the Post-instructional testing. Although some metrics changed significantly in Post-instructional testing, some measures showed no significant change.

Punch: The punch analysis showed significant changes in the following measures: recoil velocity ($t=3.72$, $df=16$, $p=0.002$), AP shear force ($t=3.66$, $df=16$, $p=0.002$), and peak velocity ($t=2.57$, $df=16$, $p=0.02$). Shoulder abduction range ($t=0.3$, $df=16$, $p=0.77$) and peak force ($t=1.29$, $df=16$, $p=0.22$) showed no significant change in Post-instructional testing.

Table 3: Dependent measure values

Performance measure		Outcome measure	
Baseline	Post-instruction	Baseline	Post-instruction
<i>Shoulder Range (Degrees)</i>		<i>Peak Force (N)</i>	
27.4±2.67	26.61±2.29	432±40	463±32
<i>Recoil Velocity (m/s) Significant</i>		<i>Peak Velocity (m/s) Significant</i>	
1.71±0.11	2.21±0.14	4.92±0.21	5.33±0.15
<i>AP shear range (N) Significant</i>			
65.9±5	87.3±7.7		

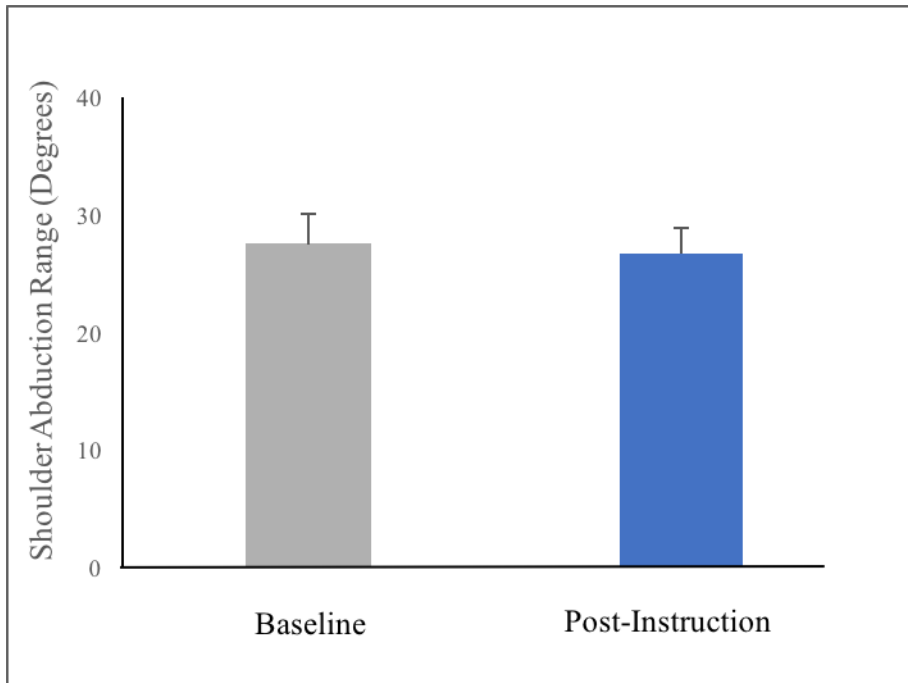


Figure 13: Shoulder abduction range was not statistically different in Post-instructional testing ($p=0.77$).

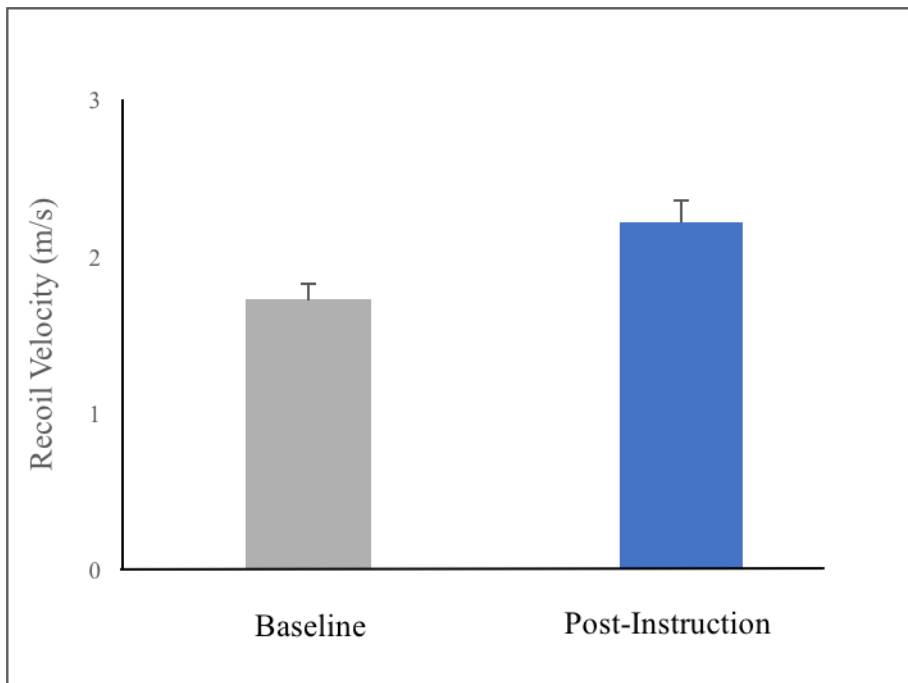


Figure 14: Recoil velocity was significantly increased by 21% after instruction, compared with baseline performance ($p=0.002$).

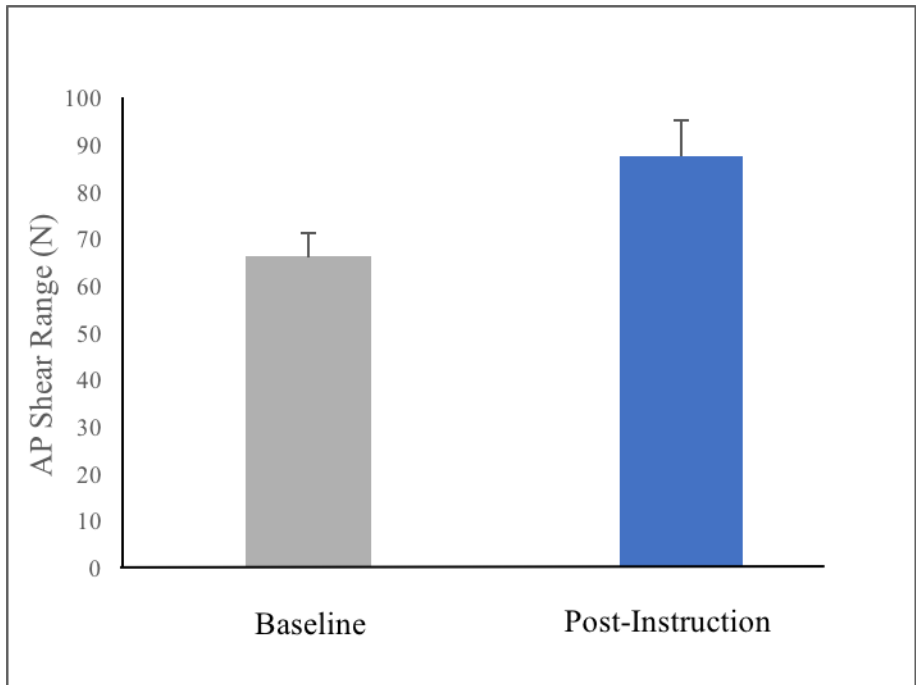


Figure 15: AP shear force range was significantly increased by 33% after instruction, compared with baseline performance ($p=0.002$).

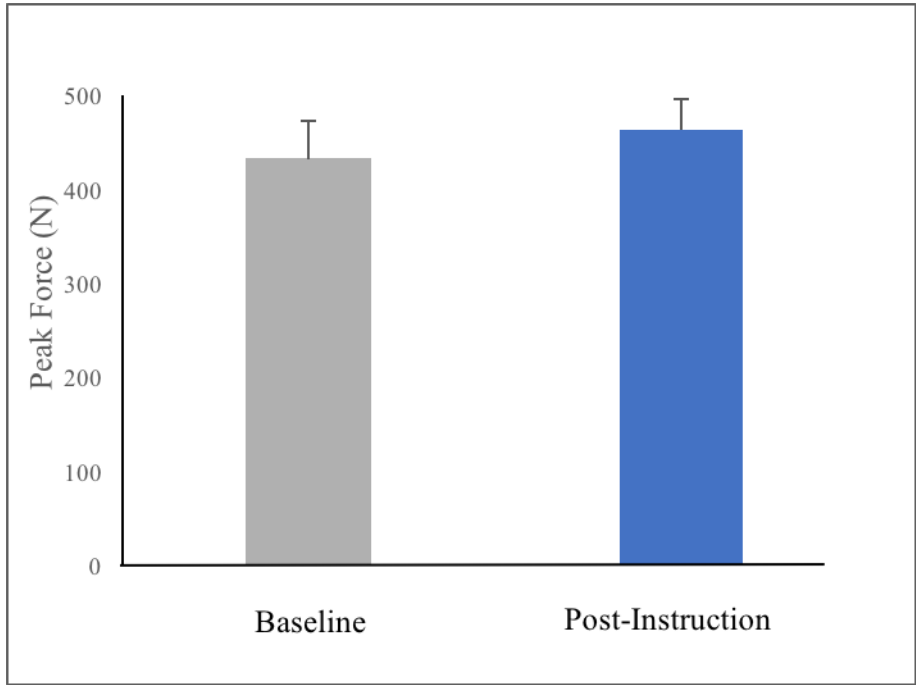


Figure 16: Peak force during punching was not significantly different after instructions, compared with baseline performance ($p=0.22$).

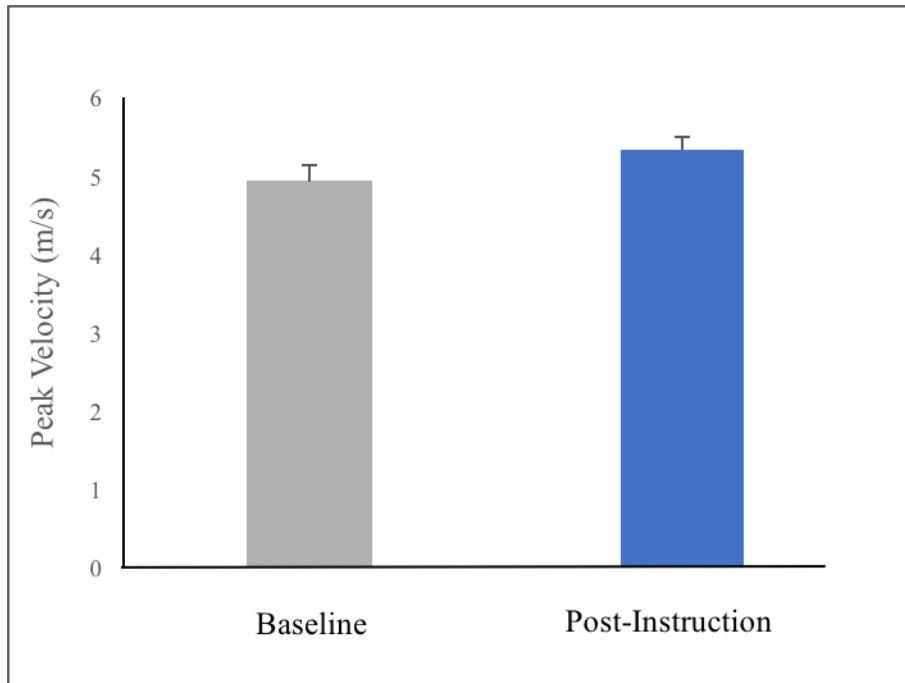


Figure 17: Peak hand velocity during punching was increased by 8% when compared with baseline performance ($p=0.02$).

Kick: The kick performance showed significant changes in two of the *performance* measures:

AP shear range ($t=3.5$, $df=16$, $p=0.003$) and hip flexion angle ($t=2.32$, $df=16$, $p=0.03$; no significant change was observed in the knee extension angle ($t=1.22$, $df=16$, $p=0.24$). Both *outcome* measures, peak force ($t=6.06$, $df=16$, $p=0.001$) and peak velocity ($t=4.85$, $df=16$, $p=0.001$) showed a significant change when compared to baseline measures.

Table 4: Kick measure values

Performance measure		Outcome measure	
Baseline	Post-instruction	Baseline	Post-instruction
<i>Hip Flexion</i> (Degrees) Significant		<i>Peak Force</i> (N) Significant	
119.9±3.4	128.1±2.8	867±82	1231±114
<i>Knee Extension</i> (Degrees)		<i>Peak Velocity</i> (m/s) Significant	
138.2±2.02	141.4±2.06	4.5±0.13	5.25±0.13
<i>AP Shear Range</i> (N) Significant			
95.1±10.1	132.8±13.11		

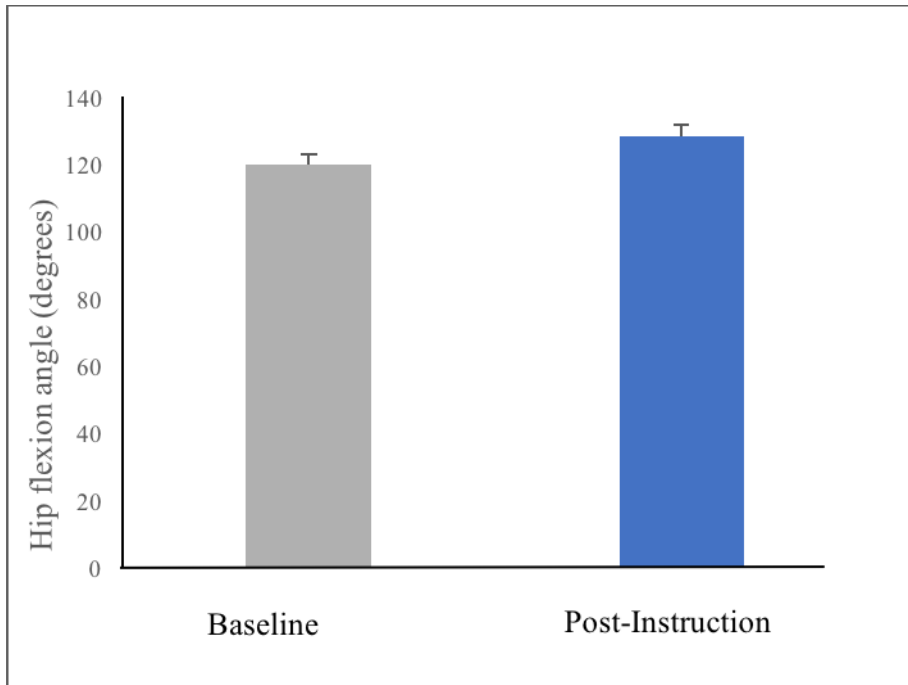


Figure 18: Hip flexion angle was increased by 6% when compared with baseline performance ($p=0.03$).

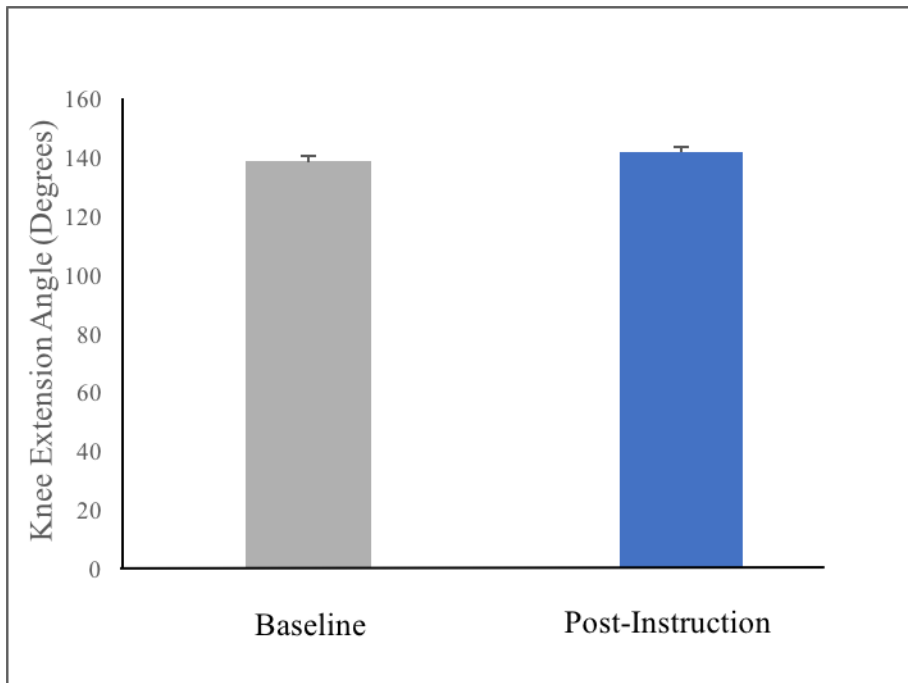


Figure 19: Knee extension angle was not significantly increased after instruction, compared with baseline testing. ($p=0.24$).

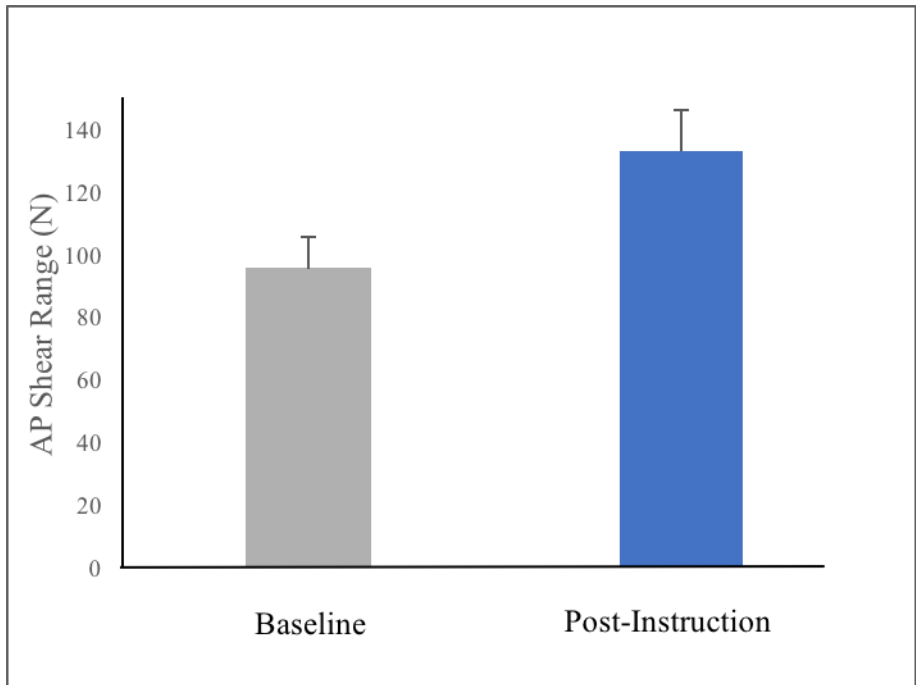


Figure 20: AP shear range change was significantly increased by 40% after instruction, when compared to baseline testing ($p=0.003$).

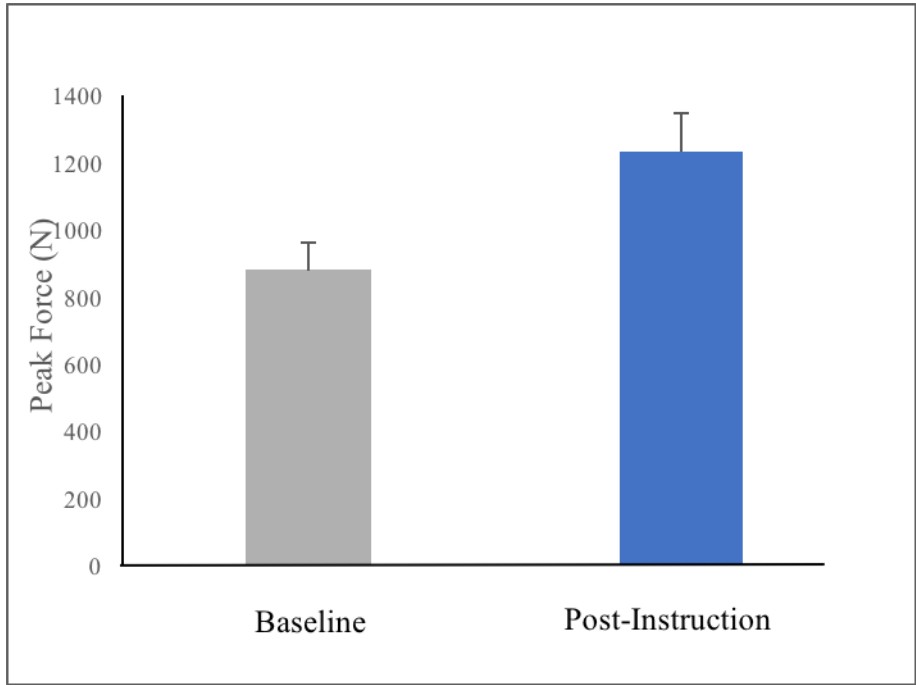


Figure 21: Peak force was significantly increased by 42% after instruction, when compared to baseline testing ($p=0.001$).

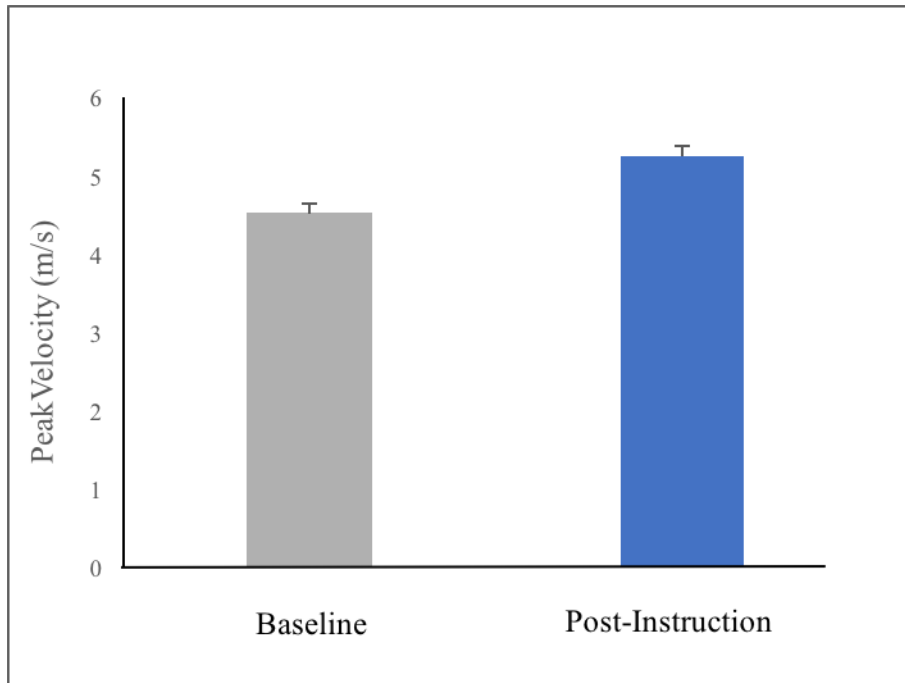


Figure 22: Peak foot velocity was significantly increased by 17% after instruction, when compared to baseline testing ($p=0.001$).

Kick: The kick performance displayed a 42% increase in force after the instructional session. AP shear range (*performance measure*), and peak velocity (*outcome measure*) also showed to be significantly different in the Post-instructional testing. The AP shear force displayed a positive moderate correlation with the peak force ($R^2 = 0.58$) (Figure 23). AP shear force did not show a correlation with velocity ($R^2 = 0.07$) (Figure 24).

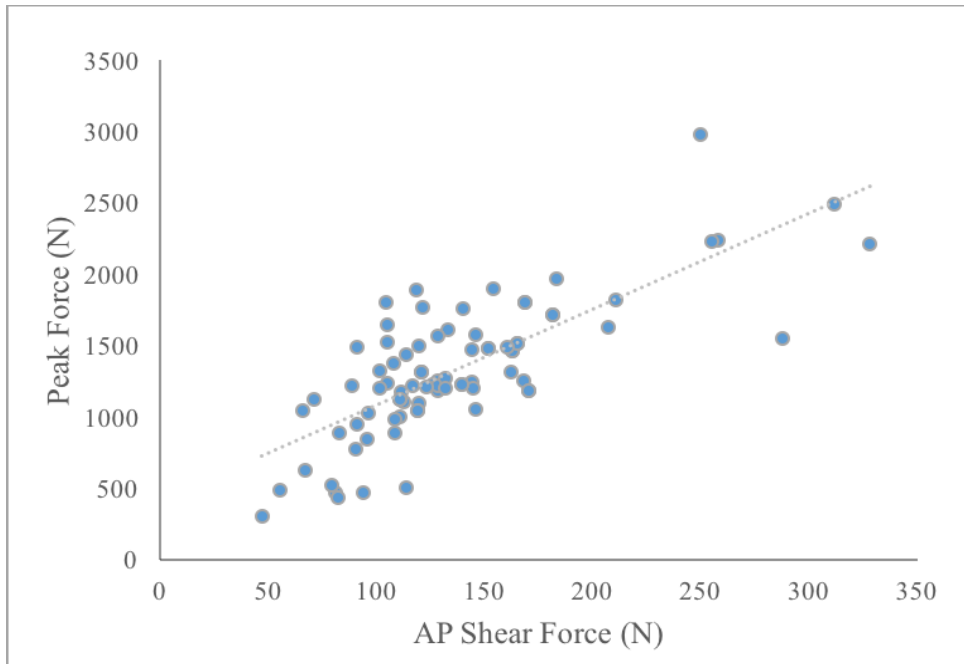


Figure 23: A moderate positive correlation ($r^2=0.58$) was found between change in AP shear force and peak force, during kicking.

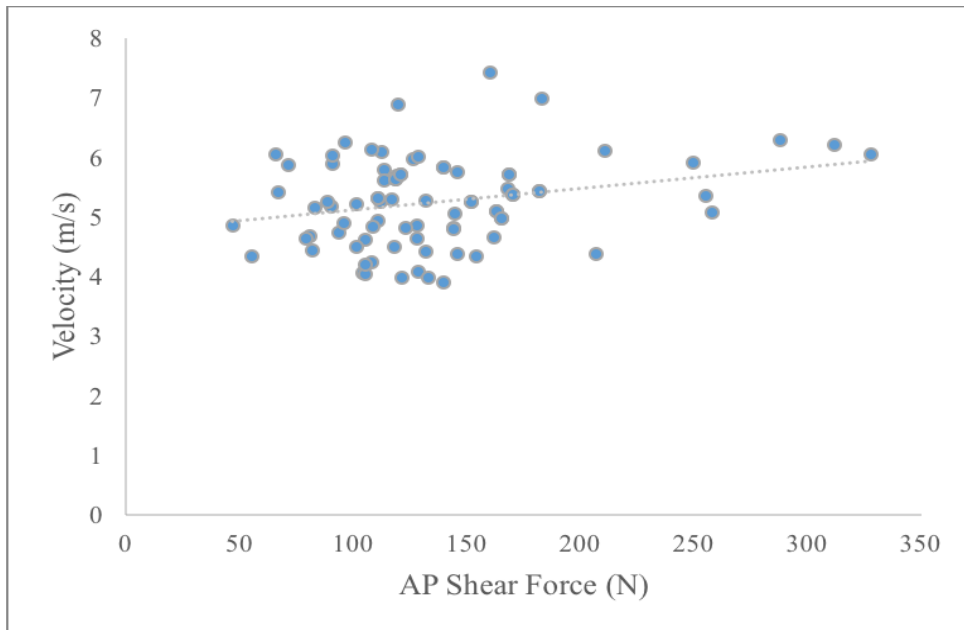


Figure 24: No correlation was found between AP shear range and velocity during kicking ($R^2 = 0.07$).

5.0 Discussion

It was hypothesized that the peak velocity and the peak force of the KM kick and punch would increase with a 30-minute instructional session. Moreover, the successful performance of

the checkpoints was hypothesized to correlate with greater peak velocity and peak force; in other words, applying the checkpoints would help the participant to punch harder and faster. The t-test results demonstrated partial support for the hypotheses. The kick velocity and the kick force both demonstrated a significant increase in Post-instructional testing. Participants increased the peak force by 42%, from 867 N (\pm 330) in Pre-Instruction to 1231 N (\pm 455) in Post-instruction. Peak foot velocity was increased from 4.50 m/s to 5.25 m/s, a 17% increase. These findings reveal that the KM instructions assisted the participants to increase the force significantly. This is consistent with KM claim that the KM kick checkpoints increase power.

The knee extension checkpoints showed no statistical difference when compared to baseline testing. Changes in the hip flexion angle and AP shear force, on the other hand, proved to be significant. The hip flexion and the and knee extension instructions break down the KM defensive kick into the “preparation” and “execute” components and perhaps make it easier to instruct to novice populations. It is possible that the fixed position of the equipment impeded the performance of the knee extension checkpoint from changing significantly. This study demonstrates a correlation between applying the kick checkpoints, and an increase in kick force and kick velocity. Correlation analysis showed a moderate relationship between the AP shear range and peak force. Not surprisingly, the highest AP shear range values recorded were correlated with the highest force recorded (Figure 23).

Additionally, one of our participants with over 10 years of training in gymnastics was able to kick at an average of 2428N (\pm 325) in Post-instructional testing compared to 1514N (\pm 206) in baseline. The participant was able to reach a maximum value of 2974N in one of her trials. Although she demonstrated a very powerful kick in her Pre-Instructional testing, she continued to demonstrate an additional 60% increase in peak Force, possibly as a result of

applying the KM techniques. This suggests that KM instructions is advantageous to both the novice and athletic population.

These data did not show a significant change in the punch peak force but a significant 8% increase in peak velocity. Although the changes in peak force was not significant, data suggests that the participants were able to maintain the same force as they punched in a shorter duration. The significant changes in the velocity of the hand moving in both directions suggest that the movement was performed in a shorter duration. Peak force was increased from 432N to 463N (not significant); peak velocity was increased from 4.92m/s to 5.33m/s, recoil velocity was reduced from 2.21m/s to 1.71m/s. This reduction in movement time is consistent with KM instructional goals.

Overall, KM instructional session resulted in an increase in kick force (42%) and kick velocity (17%). Although punch force was not increased significantly, the punch duration was most likely reduced due to an increase in punch velocity (8%) and recoil velocity (21%). Therefore, a 30-minute KM instructional session showed to improve the performance of two techniques in a group of novice volunteers with no experience in martial arts or self defense.

The amount of time required to observe significant changes in performance as a result of practice is somewhat dependent on the nature of the task (Schmidt, 2006). Most martial arts approaches take many years to master and new research suggests that the skills learned may not prepare the practitioners for hostile situations (Angleman et al., 2014); therefore, a new approach may be more effective. The data suggest that a short instructional session such KM training can be an effective way to instruct certain skills or certain aspects of a more complex skill.

Moreover, these findings suggest that the participants illustrate early characteristics of learning after a short set of instructions. The results could be valuable to many population group

who simply do not have the resources for long training modules. The findings suggest that even one training session can demonstrate improvements in certain skills.

5.1 Study Limitations

The apparatus built for this study was designed to mount the force cube in a fixed position to reduce error in the signal recorded by the force cube. Therefore, it is possible that some participants experienced soreness in their hand or fatigue but failed to report it.

Future Directions

The current study demonstrated a large change in the kick force (42% increase) but no significant change in the punch force. Range of motion studies amongst healthy population report a higher hip and knee flexion angles for the female population (Sousie et al. 2011). It is possible that this difference in flexibility may offer novice female population an advantage in some movements, such as the front kick. Future sex-related studies should explore whether one sex demonstrates an advantage in a given striking method, and whether self-defense approaches should be modified and have different focuses to suit both sexes better.

6.0 Appendices

Appendix A: Peak Force Change

Table 5: Peak force difference before and after the instructional session. The table on the left represents the % change in punch peak force when compared with Post-instructional testing. Table on the left represents the kick performance. Data is sorted from largest difference to the smallest difference.

Participant	Force difference %
S1	99.60
S2	30.41
S3	24.09
S4	23.24
S5	17.67
S6	16.03
S7	9.99
S8	5.08
S9	4.44
S10	1.00
S11	0.81
S12	-1.65
S13	-7.29
S14	-9.05
S15	-9.57
S16	-14.04
S17	-25.74

Participant	Force difference %
S1	132.88
S2	98.72
S3	97.18
S4	85.01
S5	60.39
S6	51.56
S7	49.60
S8	46.78
S9	45.43
S10	40.01
S11	33.20
S12	31.16
S13	26.77
S14	21.69
S15	21.25
S16	4.87
S17	-20.25

Appendix B: Group Values for Punch Measures

The group average is highlighted in black.

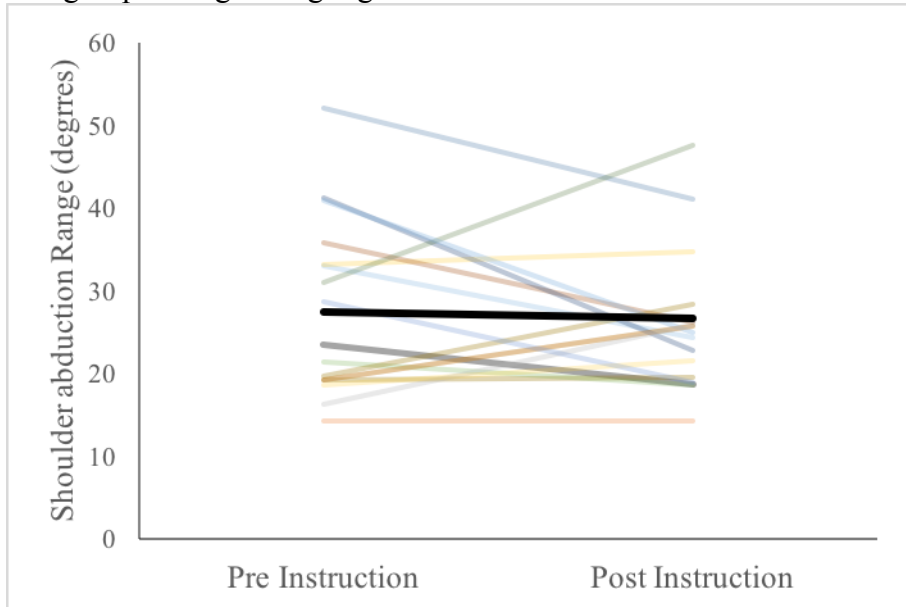


Figure 24: Group values for shoulder abduction angle ($t=0.23$, $df=32$, $p=0.82$).

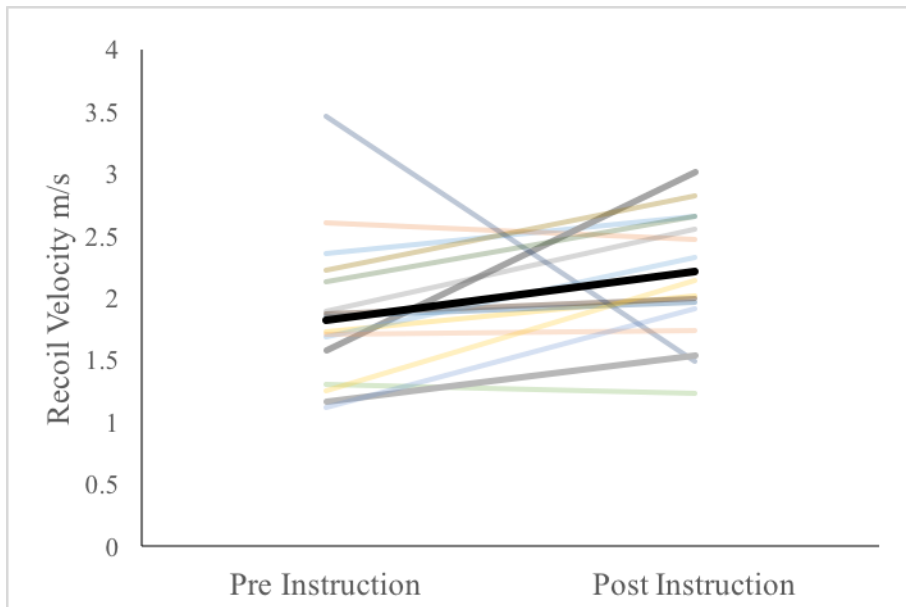


Figure 25: Group values for punch recoil velocity. Recoil velocity was increased by 21% in Post-instructional testing ($t=2.95$, $df=32$, $p=0.006$).

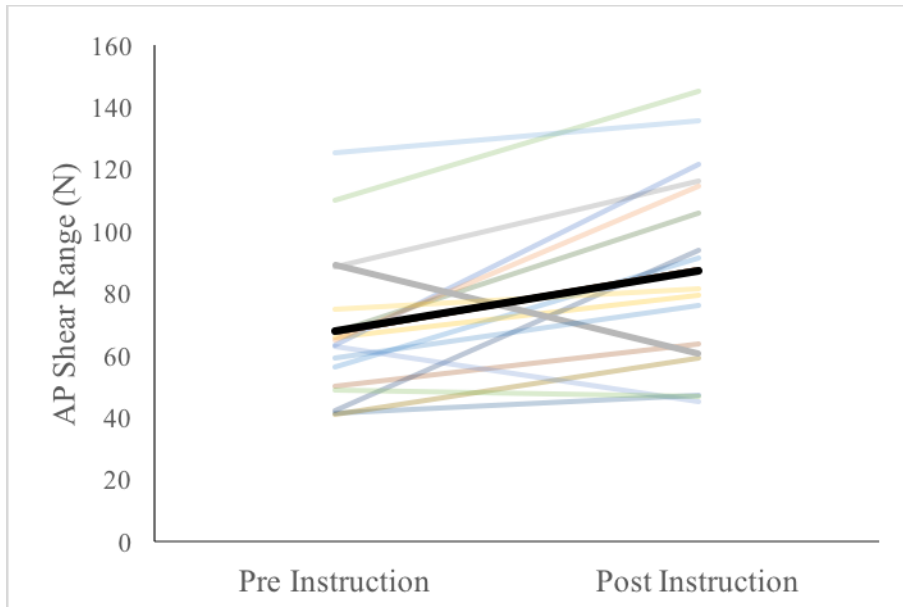


Figure 26: Group values for punch AP shear range. AP shear range was increased by 33% in Post-instructional testing ($t=2.35$, $df=32$, $p=0.025$).

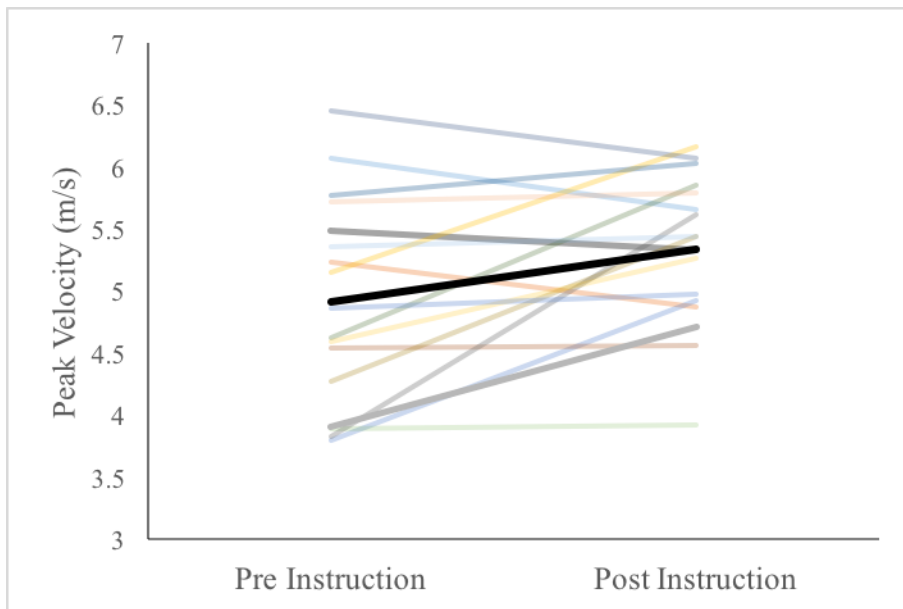


Figure 27: Group values for punch peak velocity ($t=1.68$, $df=32$, $p=0.10$).

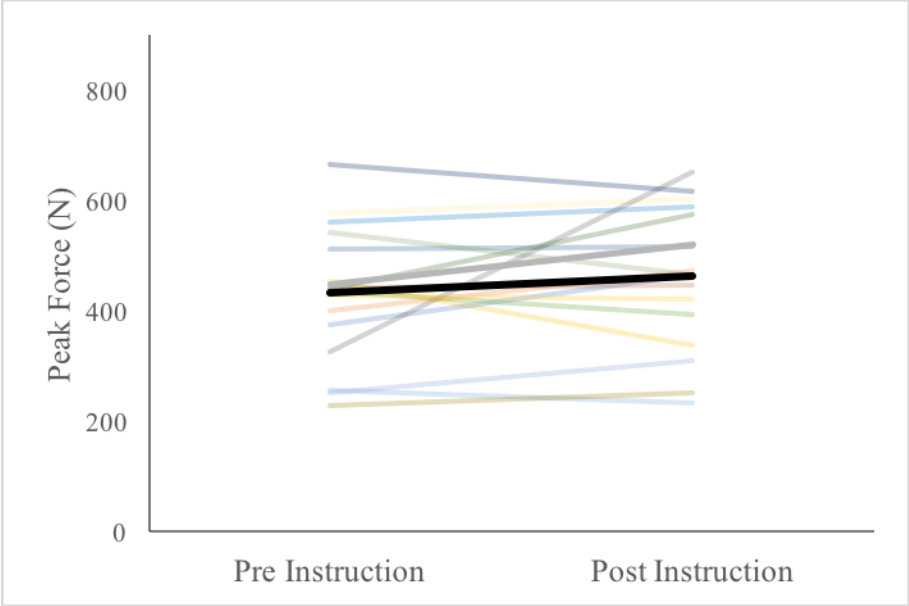


Figure 28: Group values for punch peak force ($t=0.73$, $p=0.47$, $df=32$).

Appendix C: Group Values for Kick Measures

The group average is highlighted in black.

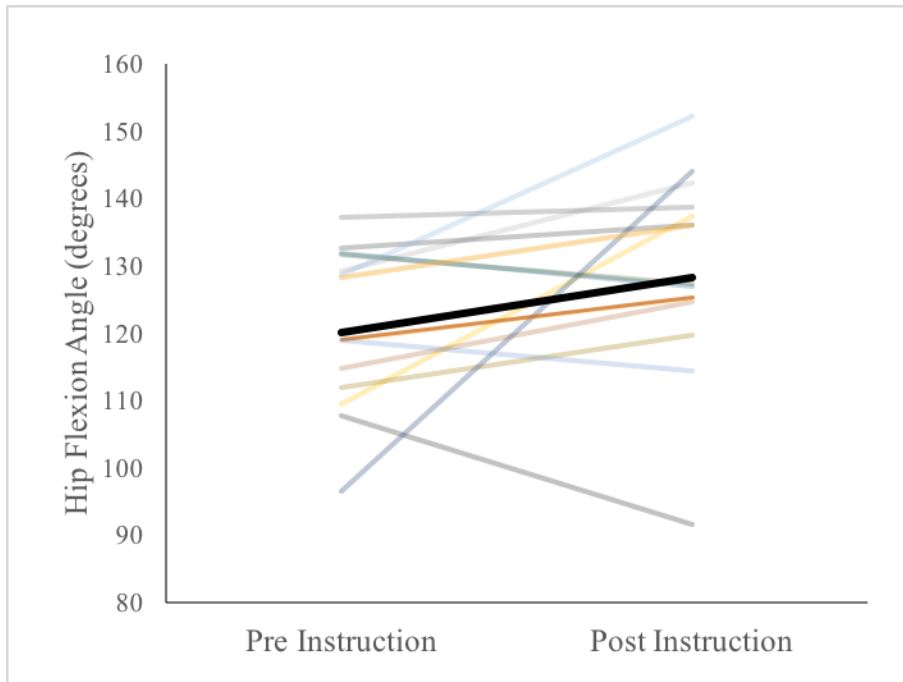


Figure 29: Group values for hip flexion angle. ($t=1.85$, $df=32$, $p=0.08$).

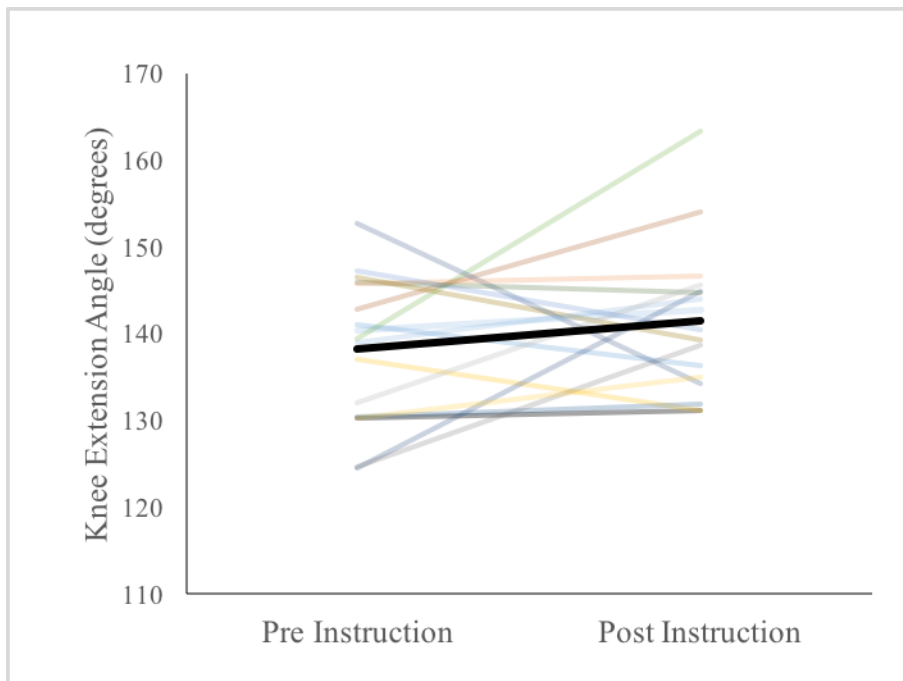


Figure 30: Group values for knee extension angle ($t=1.11$, $df=32$, $p=0.13$).

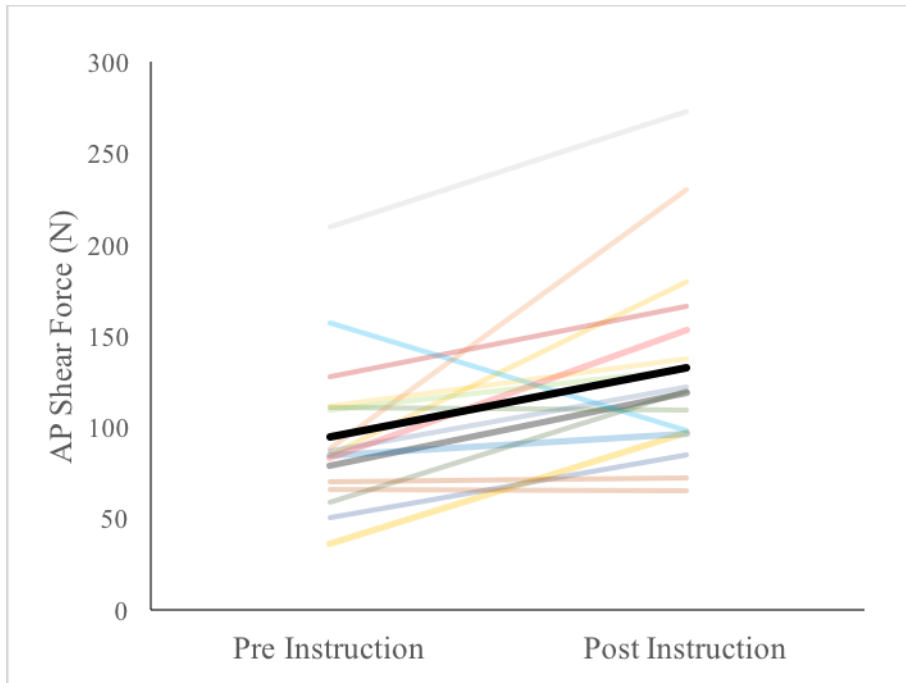


Figure 31: AP shear range was increased by 40% in Post-instructional testing ($t=2.25$, $p=0.03$, $df=32$).

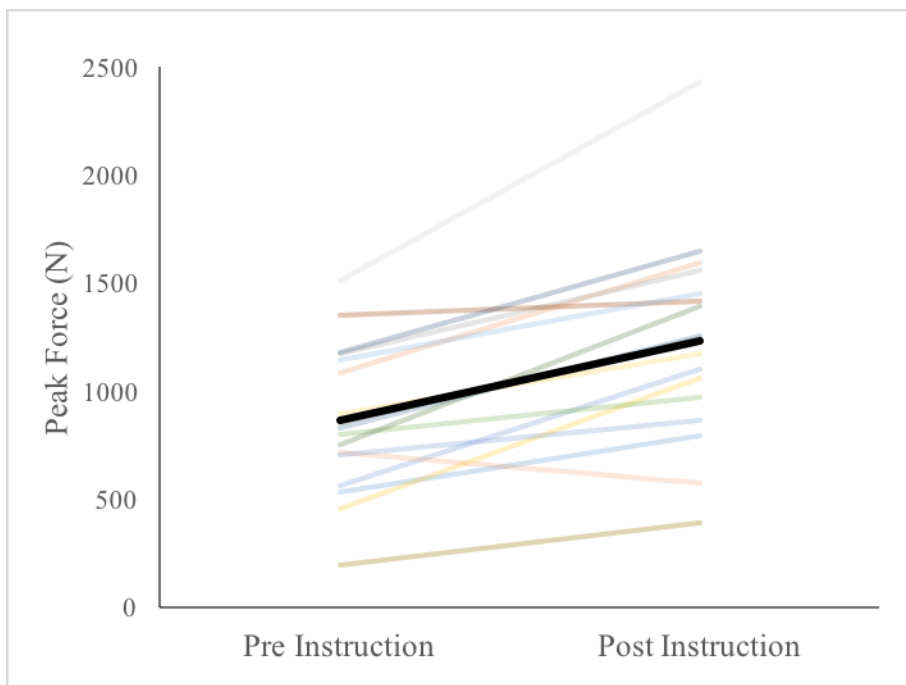


Figure 32: Group values for kick peak force. Peak force was increased by 42% in Post-instructional testing ($t=2.59$, $p=0.007$, $df=32$).

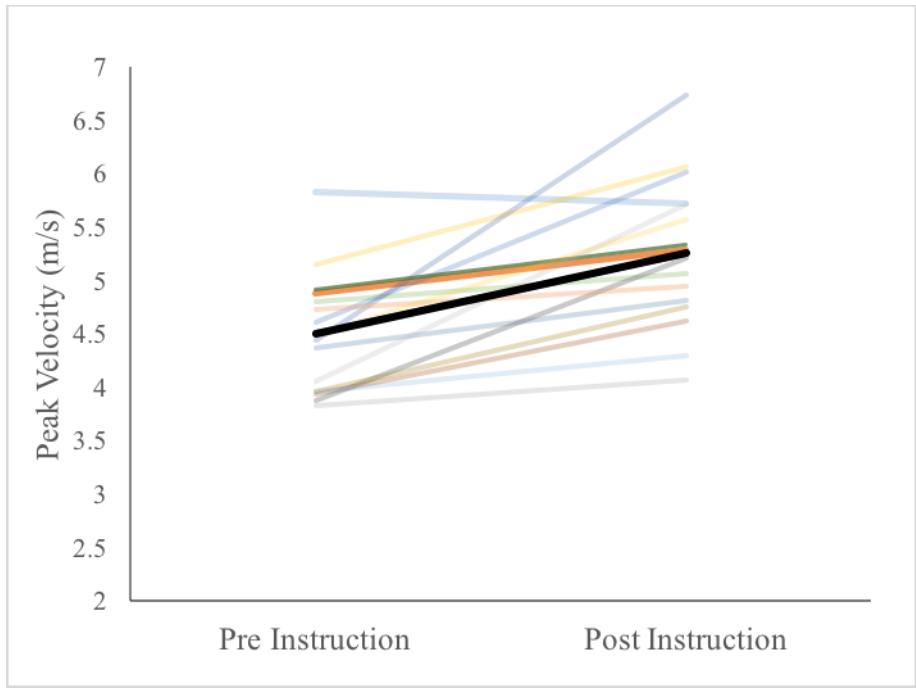


Figure 33: Group values for kick peak velocity. Peak velocity was increased by 17% in Post-instructional testing ($t=3.54$, $p=0.001$, $df=32$).

Appendix D: Participant Screening Form

Study Name: Effects of a One-day Krav Maga Training: Early Stages of Skill Acquisition of a Krav Maga Kick and Punch

This study, under the direction of Dr. William Gage & Dr. Olivier Birot and conducted by Vincenzo Di Bacco & Mehran Taherzadeh at York University, will require that you meet certain eligibility criteria about your age, martial arts/self-defense experience and health status.

Participant information

Name: _____ Age: _____

Gender: _____

Height (cm or inches): _____ Weight (Kg): _____

Phone number: _____ E-mail: _____

Screening Questions

1. 1) Do you have any previous martial arts/self-defense experience? If yes, describe. (i.e. Karate, Kung Fu?) _____
2. 2) Are you generally in good health?
3. 3) Do you have any diagnosed serious or chronic conditions? If yes, describe. (i.e., thyroid, metabolic disease?) _____
4. 4) Do you have any diagnosed cardiovascular conditions? If yes, describe. (i.e., high blood pressure, heart attack, blood clots?) _____
5. 5) Do you have any diagnosed neurological disorders? If yes, describe. (i.e., stroke, Parkinson's or Huntington's disease, diagnosed vertigo?) _____
6. 6) Do you have any diagnosed musculoskeletal conditions? If yes, describe. (i.e., arthritis?) _____
7. 7) Have you had any injury, pain or surgery in the previous 6 months on your wrist, elbow, shoulder ankle, knee, hip or low back? If yes, describe. (i.e., ACL tear, joint dislocation?) _____
8. 8) Competitive sport background (Competitive defined as beyond the recreational level). If yes, list sport(s). (i.e., soccer, dance) _____

For any question above in which you answered "Yes", will the condition(s) described by that question affect your ability to participate and complete this study?

If yes, indicate the question number(s).

Do you know of any reason why you should not participate? Eligible to participate

Principle investigator initials: _____

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