The Effects of Single Versus Multiple Training Sessions on the Motor Skill Retention of Two Krav Maga Strike Techniques: in Women

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Abstract

Krav Maga (KM) self-defense system experts claim that KM techniques are based on natural body movements, learned rapidly, and improved with additional training. This study investigated the retention and further improvement with additional training of two KM strike techniques: straight punch and defensive kick, in untrained females. All participants received an initial 30-minute instruction session (AQ) taught by a certified KM instructor. Participants were divided into an intervention group (n=8), which received four additional training sessions; and a control group (n=8), which received no additional training. Kinematics and kinetics of punch and kick strikes were recorded at three timepoints: immediately after AQ, five days after AQ, and twelve days after AQ. Skill level obtained during AQ did not degrade in either group. Additional training did not improve skill level beyond that learned during AQ, suggesting increased practice time, or restructuring of training protocol may be required for further skill improvement.

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CHAPTER ONE

Introduction

The unique self-defense system of Krav Maga (KM) claims to produce logical and simplistic techniques based on movements that are natural for the human body to perform (Philippe, 2006). KM, literally meaning "contact combat" in Hebrew, is the official self-defense system for the Israeli military and security forces. Founded by Imrich Lichtenfeld, former chief instructor of the Tashal (Israeli army) in 1948, the KM instruction program was developed for soldiers as a 21-hour curriculum spread out over a one week training period where mechanics of knockout punches are learned in one hour and basic kicks in the next hour (Aviram, 2014). In 1964, a civilian form of KM was designed and implemented, giving ordinary citizens the confidence and capability to defend themselves, and perform small military missions (Lichtenfeld & Yanilov, 2001).

KM was developed through the amalgamation of selective techniques extracted from various martial arts such as Judo, Jujitsu, Aikido, Karate, and wrestling, with the idea of creating the most effective self-defense system. Furthermore, the KM techniques selected attempt to take advantage of physics to increase force application and optimize movement patterns. For example, gravity is used to increase impact force in kicks and punches by shifting the weight forward and slightly downward in the appropriate direction. In comparing KM to previous martial art forms, another distinguishing characteristic is its great emphasis on reaction time. Techniques are selected and practiced based on the body's natural movements in order to optimize this reaction time, instead of practicing complex slower maneuvers. Therefore, the KM program focuses on training progressions that lead to maximum movement efficiency and correct sequential execution. The maximum movement efficiency and correct sequential execution

develops into maximum speed and shift of mass in the direction of the attack, ultimately resulting in maximum force production possible by the performer (Aviram, 2014).

The physiological response to combat stress was considered when the KM program was first developed. Combat stress is defined as the perception of an imminent threat of serious personal injury or death where response time is minimal. Under combat stress, the decline of complex and fine motor skills occurs while gross motor skills are enhanced (Siddle, 1995). To be effective in stressful situations for a soldier, techniques targeted at using gross motor skills should be trained. Training these less complex gross motor skills increases the likelihood of acquiring new techniques as quickly as possible. KM techniques are premised on large body movements comprised of gross motor skills, potentially enabling KM to be learned quickly and practitioners to achieve a high level of proficiency rapidly (Boe, 2015). The putative rapid acquisition of KM techniques also lies in the teaching methods. The techniques are taught based on what the literature calls "accelerated learning", which is learning a novel technique in separate components (Boe, 2015). This accelerated learning process is suggested to enhance the ability to rapidly learn the self-defense techniques of KM. (Boe, 2015; National Research Council, 1988/91).

Today, KM caters to all types of audiences, however, the instructional time period for civilian KM has been adapted from the 21-hour intensive military curriculum (spread out over five days); and extended to multiple years of training. The process of rapidly training a military soldier in KM entirely within a 5-day period will be explored using the civilian population by teaching two techniques, the KM straight punch and defensive kick techniques, within one training session and later retesting to determine if the techniques are in fact retained with this minimal amount of practice administered. Biomechanical measures will be used to quantify

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movement patterns and striking capabilities to infer motor learning and retention, and skill

development of the two techniques.

CHAPTER TWO

Literature Review

2.1 Motor Learning

The acquisition and long-term retention of motor skills plays a central role in our day-to-day lives. Skills such as driving a car or playing tennis are all acquired through countless hours of repetitive practice. Motor skill learning can be referred to as the process by which movements are executed more rapidly and accurately with practice (Willingham, 1998) and eventually reach a relatively permanent change in performance (Schmidt & Wrisberg, 2008). Therefore, motor learning can be viewed as a critical process for the advancement from novice to expert performance (Schmidt, 2008).

Novel motor skills are usually learned slowly over multiple training sessions until performance reaches a near automatic and consistent level. Through many experimental learning models, skill acquisition initially develops relatively fast, for example great improvements in performance by the end a single training session; and afterwards more slowly, where additional improvements develop incrementally over multiple sessions of practice, until automaticity, defined as "without requiring attentional resources", is achieved (Doyon & Benali, 2005; Schmidt, 2008). Learning curves are often used to capture the progression of learning during repetitive practice over time (Chapman, 1919). In two classic studies by Bryan and Harter (1897/1899), the learning curves of new telegraphic operators learning Morse code was investigated over a 40-week period, in which participants exhibited both levels of improvement as well as plateaus as practice continued. Similarly, Franks and Wilberg (1982) examined the performance of a complex tracking task for ten days, with 105 trials per day. Results indicated continuous improvement between days one to four. Then, performance plateaued between days

five through seven. Afterwards, on day eight, performance began to improve again, and continued for the following two days. From these learning curves, the well documented "power law of practice" was developed.

The power law of practice can be observed in many domains such as mathematics (Gustin, 1985), music (Ericsson et al., 1993), and sport (Kalinowski, 1985; Monsaas, 1985). It states that learning occurs at a rapid rate at the onset of practice, and that this rate decreases as practice increases over time (Newell & Rosenbloom, 1981) (Figure 1). A good demonstration of a decreased rate of learning can be seen in Chapman's (1919) typewriting study, in which participants exhibited a positive acceleration in improvement in typing speed between 20 to 90 hours of practice, where typewriting speed ranged from about 55 to 215 words, respectively. Afterwards, during the remaining period of 90 to 180 hours of practice, typewriting speed ranged from only 215 to 265 words, respectively. Another classic experiment demonstrating the power law of practice is Crossman's (1959) cigar making study; examining the amount of time it took female cigar makers to produce one cigar as a function of how many cigars each worker had made since they started working. Results displayed that the majority of performance improvement occurred during the first two years, or after three million cigars were produced, and continued to show improvements after seven years of experience. After seven years of practice (about 10 million cigars produced), performance improvement increments were markedly smaller. Therefore, progressively more practice was necessary to produce further improvements in skill performance.

Power Law of Practice

Learning (y-axis)

Practice (x-axis)
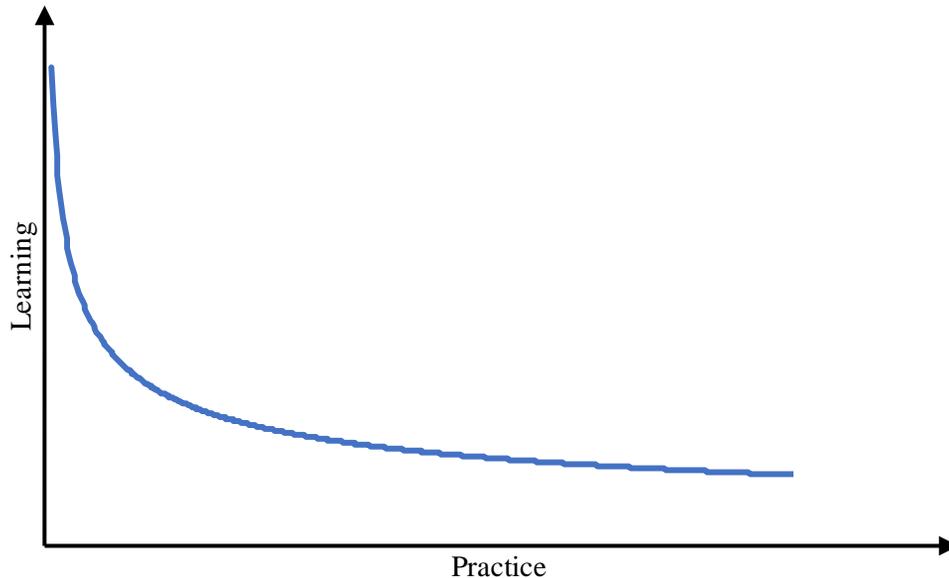
Figure 1. Power law of practice schematic demonstrating a rapid rate of learning at the onset of practice, and this rate of learning decreases as practice/training increases over time.

2.2 Training Methods

The mere constant repetition of a motor skill does not always improve performance. Again, as evidenced in the two classic Morse code studies, skill acquisition plateaus were reached, stunting further improvement in participants' performance, regardless of continual practice (Bryan & Harter, 1897/1899). However, through different and better training methods (Keller, 1958), as well as providing external rewards to participants, further levels of improvement can be achieved (Bryan & Harter, 1897/1899). Examples of different training methods can include using contextual interference (Goode & Magill, 1986; Pollatou et al., 1997), self-control training (Post et al., 2011; Chiviacowsky et al., 2008), and dyad training (Shea et al., 1999), as well as group training, the method by which most self-defense classes are taught (Brecklin, 2008). Therefore, restructuring the training protocol could overcome learning plateaus for further improvement.

Contextual interference is a learning effect where interference during practice is beneficial to skill learning. Contextual interference was first demonstrated by Shea and Morgan (1979) during

the learning of a motor task and was investigated by participants undergoing either a blocked or random practice schedule. The blocked practice schedule involved all practice trials of the first task to be completed before switching to the second task, and so on to the third task. In contrast, the random practice schedule involved a randomized order of practice trials for each task with the restriction that no more than two trials of any one task could be completed in succession. Shea and Morgan (1979) demonstrated that the blocked practice group resulted in a much faster rate of improvement on the task. However, the random practice group resulted in better retention performance on both retention tests (10 minutes and 10 days following the practice period); therefore, suggesting greater learning. The improved motor learning during random practice is thought to occur due to slower and more modest improvements in performance during practice. Since then, many studies have reported similar results, indicating that contextual interference, induced by a random practice schedule, facilitates improved motor learning of sport-related skills in badminton (Goode & Magill, 1986), baseball (Hall et al., 1994), basketball (Feghhi & Valizade, 2011), and volleyball (Bortoli et al., 1992); as well as in non-sport-related tasks such as foreign vocabulary learning (Schneider et al., 1998), and physical rehabilitation following stroke (Hanlon, 1996).

Usually, while practicing a novel skill, the instructor controls and prescribes the details of the training protocol for the learner. For example, the instructor will provide the instructions and decide the amount of feedback or demonstrations given, select which tasks are to be practiced, and decides the duration or number of trials performed during the practice session. In contrast, a self-controlled practice schedule allows the learner to control part of the practice conditions. Previous research has demonstrated a self-controlled practice schedule can enhance the effectiveness of motor learning and lead to better performance (Wulf et al, 2010). For example,

Post et al (2011) investigated participants learning to throw a dart using their non-preferred hand, in which the self-controlled training group decided when to stop practice. The control group (yoked) completed the same number of practice trials as their self-controlled counterpart. Results revealed that the self-control group was more accurate at dart throwing, suggesting a self-controlled amount of practice benefited the learning of a motor skill due to the learner being able to tailor the practice experience to their individual needs or preferences. In regards to performance feedback, participants who were provided feedback when requested during the practice of a sequential timing task demonstrated greater learning on a delayed transfer test, compared to those who had no influence on feedback frequency (Chiviacowsky & Wulf, 2002). These studies demonstrate self-control training gives the participant control over their own learning, leading to a more active and effortful role, as well as increased motivation for the participant (Chiviacowsky et al., 2008; Post et al., 2011).

Observational practice, or the method of learning through observing someone else's performance, is generally not as effective as participating in physical practice (Wulf et al., 2010). However, the combination of both observational and physical practice has been shown to be a superior practice method, compared to physical practice alone (Shebilske et al., 1992). In order to achieve the effects elicited by combining observational and physical practice, dyad training was developed. Dyad training occurs when two participants alternate between observing and physically practicing a motor task. Previous research has demonstrated that participants who practice in dyads perform similarly, or better than, participants who only perform physical practice, even though the dyad participants perform only half of the physical practice trials (Shebilske et al., 1992; Shea et al., 2000). Due to the observational learning component of dyad training, the learner gains the opportunity to extract additional important information related to

the task such as the appropriate coordination patterns, which may be missed during physical practice. The model or demonstration does not have to be from an expert performer; but instead, the observation of another learner can have a beneficial effect on learning (Adams, 1986). Furthermore, complex skills typically require rest between intervals of practice, especially when the skill is physically and/or cognitively demanding. The rest interval may offer the learner the opportunity to engage in different forms of processing, and at the same time provide relief from the demands of the task. Increased motivation may also occur due to competition arising between the two participants, as well as the setting of higher goals, or a loss of self-consciousness to perform the task as both participants are at the same stage of learning (Wulf et al., 2010). The findings reported by Shea et al. (1999), based on learning a stabilometer task, also suggested that physical practice, observation and dialog, such as suggestions or motivation, between learners can be combined in a single training protocol that enhances learning while simultaneously increasing efficiency because the two learners can practice in the amount of time typically required for one. Therefore, restructuring the training protocol can lead to continual improvements in performance.

2.3 Rate of Motor Learning

The speed at which a motor skill may be acquired is also related to the challenge level of the skill. Easier, or less complex skills, such as memorizing a 5-digit button combination can be considered fast learning because the person will reach the later stages of learning rapidly. In a study by Karni et al (1995), participants were given a sequential finger opposition task and after 10-20 minutes of practice, significant improvements in performance were evident, indicated by increased accuracy and movement speed. Furthermore, beyond three weeks of daily practice of

the same finger task, little change in performance was observed. Similarly, Van Mier et al. (1997) found significant improvements in performance after 10 minutes of practice for a novel maze-tracing task. These results suggest that some motor skills have the potential to reach high levels of proficiency within a short amount of practice; and that additional performance improvements require increasingly more time to achieve as training persists. In contrast, a slow learning or challenging skill, such as a complex dance routine or gymnastics skill, may take weeks, or even months to learn. For example, Williams et al. (2011) demonstrated that even after eight weeks of training the long swing gymnastics skill on the high bar, four out of the 13 novice participants were unable to perform the skill correctly. The above studies indicate that the rate of motor skill learning is very task specific, and that more complex tasks (whole body vs. single limb), appear to require more practice to be learned.

2.4 Motor Memory Consolidation: Offline Learning

Changes in skill performance can occur not only during training, referred to as "online", but also after training has ceased, which is referred to as "offline". The offline activity is very important because during this process, even during sleep, it can elicit further skill improvement and stabilization (Doyon et al., 2009; Shea et al., 2000; Malangré et al., 2014), which represents motor memory consolidation, or the intermediate stage between fast and slow learning (Schmidt, 2008; Doyon & Benali, 2005). Determining the appropriate time between training sessions to elicit motor memory consolidation has been a highly sought-after objective for many motor learning scientists and coaches. Research has demonstrated that distributed practice (i.e., fewer practice trials in shorter training sessions) produces faster learning compared to massed practice (i.e., many practice trials in longer training sessions) (Woodworth 1938). A classic example

study manipulated the spacing between practice sessions and was conducted by Baddeley & Longman (1978). They evaluated four groups of postal workers during a typing task used for mail sorting. Practice was differentiated as sessions lasting either one or two hours in duration and occurring once or twice a day; with the total amount of practice held constant (60 hours). Learning was most effective in the group given one hour per day for 60 days, and least effective in the group that trained for two 2-hour sessions a day for 15 days. Furthermore, distributing practice across more days demonstrated a greater maintenance of typing speed during one-month and nine-month retention intervals. Similarly, participants undergoing distributed practice (2 practice sessions each separated by 24 hours) were found to maintain performance levels better compared to massed practice (2 practice sessions on the same day) when learning both, a continuous dynamic balance task, as well as a key-press timing task (Shea et al., 2000). These results indicate that time after learning is beneficial to allow the process of consolidation to undergo its critical role and facilitate motor learning.

Consolidation of a motor memory has also been probed during the learning of a second motor task immediately after learning the first one. Brashers-Krug et al (1996) investigated the learning of two motor tasks separated by either a 4-hour break period or a no-break period. The motor tasks involved reaching movements to targets while interacting with a force-producing manipulandum. The findings from the study found that the consolidation of a motor skill was disrupted when a second motor task was learned immediately after the first; however, after a four-hour period between the tasks, the initial learning had consolidated. Similar results were found by Shadmehr and Brashers-Krug (1997), who reported that significant improvements in performance were found after a period of rest greater than four hours. Therefore, it is clear that

the passage of time during offline learning has an important contribution when learning and training motor skills.

2.5 Neural Mechanisms of Motor Learning

Technological and methodological advances in neuroimaging technology such as functional magnetic resonance imaging (fMRI) and positron emission tomography (PET), has enabled the investigation of the neural mechanisms involved in the learning of motor skills in humans. Based on fMRI imaging, the brain regions involved in the early learning stage of a motor skill are found to be controlled by neural networks encompassing the primary motor cortex (M1), dorsolateral prefrontal cortex (DLPFC), and pre supplementary motor area (preSMA) (Floyer-Lea & Matthews, 2005). These regions show a decrease in activation as learning progresses. In contrast, the premotor cortex (PMC), supplementary motor area (SMA), striatum, parietal regions, and the cerebellum, exhibits an increase in activation with learning (Floyer-Lea & Matthews, 2005; Ghilardi et al., 2000; Debas et al., 2010). Thus, learning is associated with differential area regulation of blood oxygenation level-dependent (BOLD) activity. The increase in activation is thought to portray recruitment of additional cortical substrates with repetitive practice (Poldrack, 2000). In contrast, decreases in activation indicate that the task can be carried out using less neuronal resources as fast learning occurs (Poldrack, 2000).

Performance improvements in later stages (slow) of motor learning usually develop at a slower rate compared to the earlier stages (fast) (Doyon & Benali, 2005). The amount of change and the time course of slow learning are task-dependent, and it is suggested that eventually performance becomes relatively permanent and automatic, which may result in less involvement of decision-making and attentional resources. Moreover, a smaller cost to the system at this stage

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will occur when interfered by a secondary task (Floyer-Lea & Matthews, 2005). Slow learning has been demonstrated to be associated with increased activation in M1, primary somatosensory cortex, putamen (Floyer-Lea & Matthews, 2005) and SMA (Lehéricy et al., 2005), as well as decreased activation in lobule VI of the cerebellum (Lehéricy et al., 2005). This indicates that progress from early to late stages of motor learning is depicted by the shift in fMRI activation from anterior to more posterior regions of the brain (Floyer-Lea & Matthews, 2005).

Aside from the alterations in brain activation levels during the process of learning a skill, grey and white matter structures also change. For example, Draganski et al. (2004) found that after three months of juggling training in novice jugglers, participants demonstrated an expansion in grey matter in the mid-temporal area of the brain compared to those who did not undergo the training. Similarly, after undergoing a six-week training period of juggling, Scholz et al. (2009) found evidence for training-related changes in white-matter structure.

The functional (activation levels) as well as structural (grey and white matter volume) changes within the brain during motor skill learning, as described above, occur due to the innate human ability of neural plasticity. Neural plasticity refers to the brain's ability to alter its existing structures and functions in response to experience, learning, training, or injury (Kolb & Whishaw, 1998; Ballantyne et al., 2009). The flexibility of the human brain to change allows us to be adaptable, acquire and retain new functions as well as recover from injury, if necessary. During motor skill learning, repeated exposure to an experience enables the relevant neurons to fire together and wire together; resulting in changes to motor and sensory cortices (Murphy & Corbett, 2009). The motor and sensory cortices are loosely organized into somatotopic functional maps, which exhibit use-dependent plasticity, or modification of the maps based on experience (Nudo et al., 1996). The motor maps reflect the coupling of muscles to specific motor cortex

neurons, while the sensory maps reflect the pairing of body parts to sensory cortex neurons. The motor maps facilitate both the learning and expression of movements; ultimately representing the motor engram, that is, the set of instructions to tell the body how to perform a specific movement (Monfils et al., 2005). The neural changes associated with neural plasticity are as follows: rewiring and remapping of neural circuits (Nudo et al., 1996), development of new synapses, strengthening of inter-neuronal connections (synaptogenesis) (Buonomano & Merzenich, 1998), dendrite remodeling (Hosp & Luft, 2011), axonal sprouting, and neurochemical production (Carmichael et al., 2017; Murphy & Corbett, 2009).

Investigating the brain structures of expert performers might provide the opportunity to assess the effects of long-term learning (Bengtsson et al, 2005). As experts demonstrate superior and optimized behaviour patterns compared to novices, differences in brain structure, specifically, the white matter, which is involved with the connectivity between specific brain regions, may reflect a "fine-tuning" of the connectivity. Roberts et al. (2012) investigated the behaviour and brain structure of healthy controls compared to a group of karate experts, using diffusion tensor imagining (DTI), force plates and a motion capture system. DTI measures the passive self-diffusion of water molecules and is used to calculate the level of fractional anisotropy (FA) in a voxel. The level of FA reflects changes in connectivity of a white matter pathway (Boorman et al., 2007). DTI results demonstrated significant differences, between groups, in the white matter of the cerebellar peduncles and M1; which are critical areas for the control of voluntary movement. The level of FA appeared to be less in the karate group compared to the novice group; suggesting a greater efficiency in particular white matter pathways, and a fine-tuning of connectivity. These differences in white matter are suggested to allow karate experts to synchronize the appropriate body segments in a highly repeatable and

accurate manner; which ultimately caused a higher peak impact force with target compared to novices. Furthermore, motor coordination and the amount of experience within the karate group were both associated with individual differences in white matter integrity in the cerebellum. Therefore, as evidenced above, motor learning initiates a set of neural mechanisms that alter not only the activation levels of the brain, but also, with prolonged practice, the brain structure and connectivity between different brain regions.

2.6 Evaluation of Learning: Retention Tests

Since motor skill performance is only an observable behaviour, inferring the amount of learning is difficult to assess because it cannot be directly observed (Magill, 2007). In motor learning experiments, two categories of measures are often used to describe behaviour. These include performance outcome measures and performance production measures. Performance outcome measures are those that indicate the result of performing a motor skill and are often depicted as performance curves. Outcome measures can include the speed, accuracy, distance, or time to complete the task (Magill, 2007). However, these measures do not describe the movements of the body that led to the observed outcome. In contrast, performance production measures describe how the body system moved before, during and after the skill. Examples include joint angles and velocities, displacement and acceleration of body segments, and muscle activity (i.e. electromyography, or EMG). Both performance outcome and production measures are used to quantify and compare performance values during a movement task.

In order to evaluate the motor learning of a movement task, retention tests are often employed (Magill, 2007). Retention may be defined as the persistence of proficiency for a skill after a period of no practice (Fischman, 1982). To administer a retention test in a motor skill

situation, the participant performs the learned skill after a period where there has been an absence of practice. In the literature, this period spans from as little as 5 minutes after practice (Weeks & Anderson, 2000) to as much as 10 years (Nourrit-Lucas et al., 2013). Afterwards, an assessment is made on the difference between the participant's performance level on the first practice day and that on the test day. If significant consistency and/or improvement are observed between the two time periods, then one can infer that a relatively permanent change in performance, and therefore learning has occurred (Magill, 2007).

Most studies in motor learning research typically measure short-term retention (post 24 hours) of novel motor skills (Shea et al. 2000; Brasher-Krug et al., 1996). In comparison, very few studies have investigated the long-term retention (Savion-Lemieux & Penhune, 2005; Lo et al., 2003; Nourrit-Lucas et al., 2013). Savion-Lemieux & Penhune (2005) assessed the effects of practice and length of delay on the learning and retention of a timed motor sequence task. The motor sequence task required participants to learn to recreate visual sequences by tapping in synchrony with a stimulus after performing one, three, or six blocks of practice over five consecutive days. Learning was evaluated by changes in accuracy, and percent response asynchrony; and results showed that the amount of practice had no effect on the learning and retention of the motor skill indicated by a retention test post four weeks after practice. Lo et al. (2003) investigated the retention of a 10-minute falls training session on reducing hand impact force in forward falls over a 3-month period. Findings demonstrated that the training session significantly reduced impact forces; however, participants from the control group performing only five falls spaced three weeks apart were also able to reduce impact force. These results suggest that participants taught themselves how to significantly reduce hand impact force during a forward fall with a minimal amount of experience.

Retention tests are a common tool used to analyze training effects under certain conditions. In the series of studies by Wulf et al (2007), the effects of attentional focus when practicing novel and experienced motor skills have been assessed by retention tests that occurred either one day after practice in golf, as well as one week after practice in volleyball and soccer. Retention tests in the literature have also been used to demonstrate what type of practice, blocked versus variable, is most conducive to improving a golf swing (Keogh & Hume, 2012).

2.7 Biomechanical Methods in Martial Arts/Self-Defense Research

Biomechanics is a sub-discipline of kinesiology and is defined as the study of the application of mechanics to biological systems. In the martial arts/self-defense literature, many studies using biomechanical methods have been conducted to analyze the performance of experts (Fernandes 2009; Dapena et al. 2008; Piorkowski, 2011; Groen et al., 2007), as well as to compare experts to amateur practitioners (Neto et al., 2008/2013; Pucsok et al., 2001; Estevan et al., 2011; Bertucco & Cesari, 2006). Predominant martial arts investigated have included Karate, Taekwondo, Kung Fu, boxing, Judo, Aikido, Shotokan and military self-defense. Kinematics and kinetics of offensive and defensive techniques are typically collected through the use of motion capture systems, accelerometers, EMG, force transducers and force plates (Fernandes et al., 2011).

Kinematics is the study of bodies in motion without regard to the forces that cause the motion; and is concerned with describing and quantifying the linear and angular positions of bodies and their time derivatives (Robertson, 2004). In the martial arts/self-defense literature, kinematic measurements are used to answer research questions such as who punches faster, what is the range of motion of the hip joint during a kick, or, how does an expert's movement pattern

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differ from an amateur's. Motion capture systems constitute a large majority of equipment typically used to collect kinematic data. Position data, usually obtained from passive or active markers affixed to a moving subject, are used to track body segments and joint angles in space; and are mathematically differentiated to produce velocity and acceleration data. Hand and foot velocities, as well as accelerations are commonly analyzed to compare techniques produced by expert and amateur practitioners. For example, Neto et al (2013) demonstrated significant correlations between years of experience and both peak hand acceleration and striking accuracy during a Kung Fu palm strike. Cheraghi et al, (2014) examined the lower body joint kinematics during a boxing punch and found that elite boxers utilize a lower leg drive from back foot to front foot to build momentum in the kinematic chain to assist in generating greater fist velocity. Estevan et al (2015) investigated the lower limb segment velocities (thigh, shank, and foot) during the execution of the Taekwondo roundhouse kick in experienced athletes. Investigators concluded that the roundhouse kick in taekwondo is performed in a proximal to distal segment movement pattern.

Kinetics refers to the study of the forces that cause the motion of bodies; and are generally recorded through the use of force transducers. Transducers convert one form of energy to another. Common force transducers used in biomechanics research are force plates, which convert a physical signal (i.e., force) into an electrical signal, usually voltage. Kinetic measurements are used in the martial arts/self-defense research to answer questions such as which type of punch produces a larger magnitude of impact force, or does martial arts training lead to improved balance control compared to healthy controls. Estevan et al. (2013) analyzed the effects of stance on Taekwondo kick performance using the ground reaction forces recorded from force plates. Similarly, Perrin et al. (2002) used a force plate to demonstrate that practicing

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Judo produces better static balance control compared to practicing dance. Vando et al. (2013) found that one week of high intensity karate training (14 hours) versus three hours of training induced a significant improvement in static body balance in preadolescent karate athletes indicated by a reduction in COP displacement and COP velocity. Through the use of a wall-mounted force plate, Gulledge and Dapena (2007) found that the power punch (close-range punch) was more effective at throwing an opponent off balance compared to a reverse punch (long-range punch).

Electromyography, or EMG, is the study of muscle electrical activity; and provides information about the control and execution of voluntary and reflexive movements (Robertson, 2004). Through the use of electrodes, placed mainly on the surface of the muscle, EMG is a valuable tool used to identify which muscles are activated and in which particular order. This sequencing of muscle activation can be used to analyze coordination patterns during particular movements (Cavanagh & Landa, 2013). For example, VencesBrito et al. (2011) reported distinct muscle activation patterns between experienced karate practitioners and naïve participants during the performance of a karate punch. Findings indicate that Karate experts produce peak muscle activity closer to contact with target in all agonist muscles of the arm and forearm compared to controls. Similarly, Neto and Magini (2008) used EMG to identify the coordination pattern during the Kung-Fu palm strike. As evidenced above, the majority of the studies in the martial arts/self-defense literature examine technique performance whether by experts, amateurs, or non-practitioners, but do not address skill acquisition.

2.8 Motor Learning in Martial Arts/Self-Defense Research

The primary goal of martial arts/self-defense training is to strengthen the capacity to defend oneself against potential attacks (Cummings, 1992; Brecklin, 2008). However,

determining the effects of a martial arts/self-defense training protocol on technique acquisition and/or retention can be extremely costly, both financially and in terms of time commitment. Therefore, the majority of studies investigating the training effects of learning martial arts/self-defense are conducted using surveys, questionnaires, and interviews (Brecklin, 2014; Nosanchuk, 1981). In a review by Brecklin (2008), the outcomes of women undergoing different self-defense training programs were evaluated. Results from the majority of the 20 studies evaluated indicate that completing self-defense classes have been shown to improve women's assertiveness, self-esteem, self-efficacy; and decrease anxiety, fear and helplessness when confronted by an opponent. However, it is important to note that the measures evaluated were psychological/attitudinal, with no measurement assessing the actual self-defense techniques of the participants.

Few studies in the literature have investigated the learning and retention by a non-practitioner performing a novel martial arts/self-defense technique (Burke et al., 2011; Weerdesteyn et al., 2008; Gomes, 2002). Burke et al (2011) reported that, among 15 participants without any prior martial arts experience, an average of 29 hours of training was required to learn 21 offensive and defensive techniques to proficiency. The 21 techniques were drawn from four martial arts: Aikido, Taekwondo, Shotokan and military hand-to-hand combat. The techniques were assessed based on a scoring system and reviewed by videotape to determine the proficiency levels.

Weerdesteyn et al (2008) taught sideways martial arts fall techniques to young adults without any prior martial arts experience during a 30-min training session and found that this short amount of training was able to substantially reduce hip impact forces by as much as 17%. Further, preliminary results provide some evidence for better retention of martial arts fall skills in inexperienced participants when instructed to do the fall technique weeks later. These results

demonstrate the idea that a short training period can be effective for novel skill acquisition and short-term retention in martial arts. Gomes et al (2002) found that the retention and transfer of a novel Judo technique was optimized under practice conditions similar to those of competition after only eight days of 30 practice trials per day. Together, these results suggest the potential for rapid acquisition of proficiency in performance of novel skills, as well as skill retention, in martial arts.

Regarding KM specifically, only one study has analyzed the teaching of KM principles and techniques to its participants in a rapid learning environment (Boe, 2015). However, that study did not measure the actual performance, learning or retention of the techniques practiced. That study (Boe, 2015) investigated the effects of an 8-hour training session with 43 Norwegian military officers and used pre- and post-intervention questionnaires to assess the effectiveness of the KM training on the officers' ability to function under stress. This study demonstrated positive effects towards the efficiency of the KM system and suggests that KM is a self-defense system that quickly establishes confidence as well as increased knowledge in close combat situations for those who practice it. Boe (2015) also proposed "the result of this study is promising as the search for the most effective close combat system is a never-ending process. Maybe Krav Maga can be the solution to this demanding process." (Boe, 2015, p. 6).

2.9 Krav Maga: Teaching Method

Proponents of the KM self-defense system suggest that techniques are learned rapidly due, in part, to the movements being natural for the human body, but also due to the teaching method implemented (Boe, 2015). Prior to performing a strike technique, a specific stance is adopted termed the "fighting stance" (Levine & Whitman, 2016). The fighting stance is as

follows: the practitioner stands with their feet hip-width apart in a staggered position, where the dominant foot is located posteriorly and the other foot is located anteriorly; the heel of the posteriorly located foot remains slightly elevated from the floor at all times; the hands are held up in front at chin height, while forming lose fists that are close together, and the elbows pointed downward to protect the sides of the body (Levin & Whitman 2014). The fighting stance suggests the dominant side of the body to be located posteriorly because, when attacked, the practitioner will be able to block with the forward (non-dominant) side, and then counterstrike using the more powerful (dominant) limb (Gershon Ben Kern, 2014).

Almost every KM technique is aimed at striking an opponent at what are known as "soft" locations, which are the most vulnerable. These locations include the eyes, throat, stomach, and groin area (Levine & Whitman, 2016; Kahn & Jacob, 2017). The training of strike techniques typically involves either striking a hand-held target, or striking the air. The teaching method utilized by KM experts and instructors when teaching novel strike techniques is termed accelerated learning (Boe, 2015), or more commonly referred to in motor learning research as the segmentation method (Wightman & Linter, 1985), which consists of deconstructing the technique into three separate components outlined by checkpoints (Levine & Whitman, 2016). A "checkpoint" defines the beginning and end of a component of the technique. The full technique is defined by the aggregation of the checkpoints. Once a KM technique is deconstructed into the three appropriate checkpoints, the first checkpoint is practiced, then the first checkpoint plus the second checkpoint together, and finally all three checkpoints are sequenced to create the entire technique. Two strike techniques, straight punch and defensive kick; will now be discussed to demonstrate how KM instructors break down KM techniques into checkpoints for learning.

The KM straight punch technique is broken down into three checkpoints: (1) **Straight** – the elbow is maintained tucked in close to the side of the body, pointed towards the ground and extends as the fist travels forward towards the target during the punch. The shoulder is adducted horizontally throughout the movement until contact with target is made. The first and second metacarpal knuckles of the fist contacts the target while externally rotated 45 degrees from horizontal and the first metacarpal knuckle is in line with the radius of the forearm (Levine & Whitman, 2016). The goal of this checkpoint is to minimize arm abduction between the beginning of the punch (as fist begins to move forward) and at contact with target (full extension of elbow joint). Maintenance of the elbow tucked in close to the side of the body is suggested to increase the delivery speed of the punch because it allows the fist to travel along the most direct and therefore shortest path towards the target; as opposed to doing a hook punch which has been reported to have the slowest delivery time compared to other boxing punches such as the jab or cross punch (Piorkowski et al., 2010). (2) **Recoil** – the fist is retracted immediately and rapidly after contact with target (Levine & Whitman, 2016). The goal of this checkpoint is to retract the striking fist as fast as possible so that either another fist strike can be delivered, or to evade a wrist grab from an opponent. (3) **Push** – the posteriorly located foot pushes forcefully backward, along the A/P axis, away from the target during the initiation of the punch (Aviram, 2014). The goal of this checkpoint is to generate the largest amount of force from the rear foot and leg in order to propel the mass and therefore the striking fist forward with greater velocity to produce a larger magnitude of impact force. As recently demonstrated in the literature, elite Boxers perform a similar leg drive during the beginning of the boxing straight punch. This leg drive has been found to build-up momentum in the kinematic chain, which subsequently increases fist velocity upon impact with target.

The KM defensive kick technique is broken down into three checkpoints: (1) **Knee lift** – the dorsi flexed foot and flexed knee of the kicking leg is lifted in front (anteriorly and vertically) (Levine & Whitman, 2016) of the participant as high and as close to the chest as possible, where the relative joint angle, created between the thigh and thorax segments, exhibits flexion at an angle occurring at a minimum of less than 90 degrees of flexion. The goal of this checkpoint is to "load" the striking leg by minimizing the space possible between the thigh and chest segments. (2) **Knee extension** – following knee lift, the leg and hip will extend forward and horizontally adducts until the sole of the foot makes contact with the target, with an emphasis on extension of the knee, while adducting horizontally before, during and after contact with target is made. The goal of this checkpoint is to extend the knee as much as possible in order to push the target as far away from the performer (delivering the strike) as possible (Levine & Whitman, 2016). (3) **Push** – the posteriorly located foot pushes forcefully backward, along the A/P axis, away from the target during the initiation of the kick. The goal of this checkpoint is to generate the largest amount of force from the rear foot and leg in order to drive the mass and striking foot forward with greater velocity to produce a larger magnitude of impact force; similarly, as in the KM straight punch technique.

The motor learning of KM techniques, such as the straight punch and defensive kick techniques, have yet to be investigated empirically. Furthermore, there is a lack of quantitative research associated with females in the martial arts/self-defense literature (Brecklin, 2008). Additionally, self-defense classes tend to focus on female practitioners (Curtis & Love, 2016). Therefore, a study is warranted to assess the rapid putative acquisition and retention of KM techniques claimed by KM experts, in novice women.

The purpose of the current study was to examine the learning of two KM techniques: straight punch, and defensive kick; in novice women who receive either a single training session, or multiple training sessions over the period of approximately one week. The motor skill retention of these techniques was assessed across three time points: post acquisition (PostAQ; immediately following the initial training session), retention 1 (RT1; five days after PostAQ), and retention 2 (RT2; 7 days after RT1). The following research questions were tested:

1. Would additional training sessions affect performance, defined in terms of a number of kinematic and kinetic measures, below, of the components of the straight punch technique?

2. Would additional training sessions affect performance, defined in terms of a number of kinematic and kinetic measures, below, of the components of the defensive kick technique?

I hypothesized that:

1. The performance of the straight punch would not differ between the PostAQ and RT1 sessions among the single-training session group, but would improve among the multiple-training session group; there would be no difference between the RT1 and RT2 sessions for either group.

2. The performance of the defensive kick would not differ between the PostAQ and RT1 sessions among the single-training session group, but would improve among the multiple-training session group; there would be no difference between the RT1 and RT2 sessions for either group.

CHAPTER THREE

MANUSCRIPT TO BE SUBMITTED:

The Effects of Single Versus Multiple Training Sessions on the Motor Skill Retention of two Krav Maga Strike Techniques: in Women

3.1 Introduction.

Experts of the Krav Maga (KM) self-defense system claim that KM technique is based on logical and simplistic movements that are 'natural' for the human body to perform, and are therefore believed to be learned quickly and retained (Philippe, 2006; Boe, 2015). KM is the official self-defense system for the Israeli military and was developed for soldiers as a 21-hour curriculum spread out over a five-day training period where mechanics of knockout punches are learned in one hour and basic kicks in the next hour (Aviram, 2014). KM was developed through the amalgamation of selective techniques extracted from various martial arts such as Judo, Jujitsu, Aikido, Karate, and wrestling, with the idea of creating the most effective self-defense system. In 1964, a civilian form of KM was designed and implemented, giving ordinary citizens the confidence and capability to defend themselves and to perform small military missions (Lichtenfeld & Yanilov, 2001). Today, KM caters to all types of audiences, however, the instructional time period for civilian KM has been adapted from the 21-hour intensive military curriculum (spread out over five days); and extended to multiple years of training. Nevertheless, the putative rapid skill acquisition and retention in regards to learning KM technique has yet to be investigated. Therefore, a study is warranted to evaluate such a claim.

In the martial arts/self-defense literature, many studies using biomechanical methods have been conducted to analyze the performance of experts (Fernandes 2009; Dapena et al. 2008;

Piorkowski, 2011; Groen et al., 2007), as well as to compare experts to amateur practitioners (Neto et al., 2008/2013; Pucsok et al., 2001; Estevan et al., 2011; Bertucco & Cesari, 2006). Predominant martial arts investigated have included Karate, Taekwondo, Kung Fu, boxing, Judo, Aikido, Shotokan and military self-defense. Kinematics and kinetics of offensive and defensive techniques are typically collected through motion capture systems, accelerometers, EMG, force transducers and force plates (Fernandes et al., 2011). The majority of studies in the martial arts/self-defense literature, has examined skilled performance whether by amateurs or experts, but do not address skill acquisition.

Few studies in the literature have investigated the learning and retention by a non-practitioner performing a novel martial arts/self-defense technique (Burke et al., 2011; Weerdesteyn, 2008; Gomes, 2002). Burke et al (2011) reported that, among 15 participants without any prior martial arts experience, an average 29 hours of training was required to learn 21 offensive and defensive techniques, drawn from Aikido, Taekwondo, Shotokan and military hand-to-hand combat, to proficiency. Weerdesteyn et al (2008) taught martial arts-based lateral-fall techniques to young adults without any prior martial arts experience during a 30-min training session and found that this short amount of training was able to substantially reduce hip impact forces by as much as 17%. Further, preliminary results provide some evidence for better retention of martial arts fall skills in inexperienced participants when instructed to do the fall technique weeks later. Gomes et al (2002) found that the retention and transfer of a novel Judo technique was optimized under practice conditions similar to those of competition after only 8 days of 30 practice trials per day. Together, these results demonstrate the idea that a short training period can be effective for novel skill acquisition and short-term retention in martial arts.

Regarding KM specifically, only one study has analyzed the teaching of KM principles and

techniques to its participants in a rapid learning environment (Boe, 2015). Results suggested that KM is a self-defense system that quickly establishes confidence as well as increased knowledge in close combat situations for those who practice it. However, that study did not measure the actual performance, learning or retention of the techniques practiced.

The purpose of the current study was to examine the learning of two KM techniques: straight punch, and defensive kick, among novice women who receive either a single training session, or multiple training sessions.

3.2 Methodology

3.2.1 Participants

Participants included 16 healthy female volunteers ($n = 16$; handedness: 15 right, 1 left) between the ages of 18 and 32 years old (mean ± standard deviation: 23 ± 3.7 years) recruited from the York University graduate and undergraduate student population. Participants read and signed an informed consent form prior to the commencement of any experimental set up procedures or data collection. The experimental protocols were approved by the Office of Research Ethics at York University and complied with the institutional guidelines for experimenting with human participants. Exclusion criteria included musculoskeletal injuries within the past six months that might affect the individual's ability to perform the required movements, and previous martial arts/self-defense experience; participants were asked to complete a questionnaire to provide this information (see Appendix A). Each participant was allocated at random to one of two groups, determined using paired randomization and a chance procedure (coin flip): Single Training (ST) or Multiple Training (MT). Information regarding participants' previous sport involvement, specifically in a competitive level capacity, was also

recorded through the questionnaire. "Competitive" was defined as anything beyond the recreational level. From the 16 participants recruited, nine had a competitive sport background.

3.2.2 Data Collection - Experimental Set-up and Equipment

All participants were asked to wear specific clothing provided by the experimenter, which included tight-fitting black shorts, a headband, and a tight-fitting black sleeveless shirt; participants were barefoot throughout the testing. The specified clothing is used to prevent any unwanted reflections that may be detected by the Vicon motion capture system during data collection. Prior to motion capture set-up, anthropometric measures were recorded (Appendix B). Participants completed a warm-up guided by the experimenter to minimize the risk of injury during testing. The duration of the warm-up was 10 minutes, and it consisted of jumping jacks, arm, wrist, neck and hip circles, shoulder and triceps stretches, leg swings and ankle circles. Sixty reflective markers, which were affixed to each participant (Appendix C) using double sided adhesive tape, allowed the camera system to capture and record the position of each marker and changes in position over time.

The Vicon motion capture system consisted of 7 infrared light emitting cameras (MX40, Vicon, Denver, CO, USA), which surrounded the participant, and software (Vicon Nexus, v. 1.6.1, 2011). Kinematic data were sampled at 100Hz (VencesBrito et al., 2011; Groen et al., 2007); camera strobe intensity was set to 1 and threshold to 0.5 to optimize the optical recording of the reflective markers. Two AMTI OR6-7-1000 force plates (AMTI, Watertown, MA, USA) and a single AMTI MC3A-1000 force cube (AMTI, Watertown, MA, USA) were placed within the kinematic capture volume and used to collect kinetic data at a sampling frequency of 1000Hz (Olsen, P., & Hopkins, W., 2003; Imamura et al., 2007). The two force plates were placed in a staggered position, with the rearward plate located on the preferred striking hand/foot of each

participant (e.g. for a right-handed participant, the rearward force plate was placed on the right side). The force cube was fastened securely to an adjustable wooden stand (Figure 2) and padded heavily with foam (9cm thick); this structure constituted the "striking apparatus", which participants either punched or kicked during each experimental trial. A small square target was placed at the center of the pad, and served as the target at which participants were asked to aim their strikes.
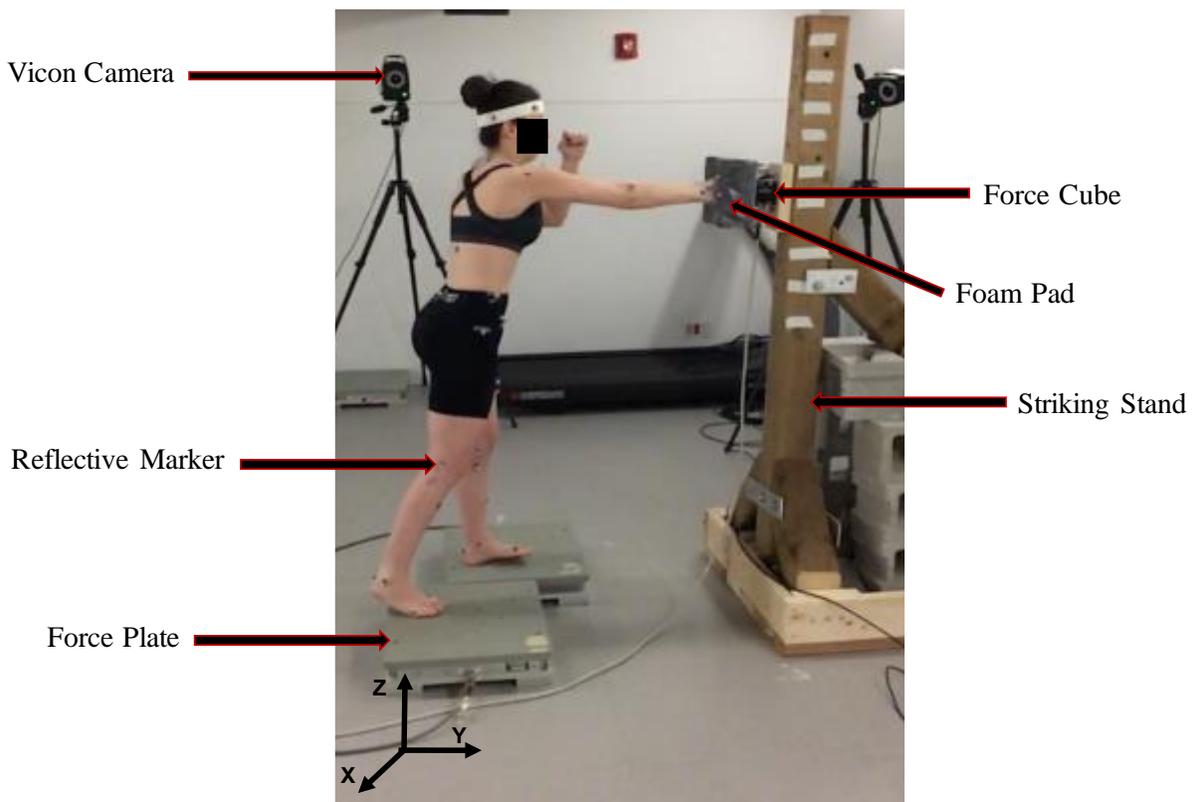
Figure 2. Equipment set-up: Reflective markers were affixed to each participant, which allowed the Vicon cameras to capture and record the position and change in position of each marker over time. The two force plates recorded ground reaction forces from both feet during strike movements. The force cube, padded with high-density foam, was mounted to the adjustable striking stand to record strike impact forces.

The surface of the force cube was positioned and oriented in the Vicon system software to represent the dimensions of the padded target (length 21cm x height 20cm x thickness of 10.8cm). The striking height of the target was adjusted based on the height of each participant, in which the punch height was positioned at shoulder height to simulate a strike targeted at the

throat (Levine & Whitman, 2016); and the kicking height was positioned at naval/hip-level to simulate a strike targeted to the body center of mass. The data collection system was started and stopped for each strike trial. Prior to data collection, a static standing trial was recorded for five seconds, during which participants stood fully erect (legs straight, upright posture with no forward trunk flexion or hyperextension) on both force plates (one foot on each) with arms held abducted at the shoulders to the sides of the body.

All kinematic and kinetic data were expressed in the right-handed orthogonal inertial reference frame. The Y-axis represented the anterior-posterior direction, perpendicular to the force cube, with positive being oriented to the anterior direction. The X-axis represented the medial-lateral direction parallel to the force cube, with positive being oriented to the right direction. The Z-axis represented the vertical direction, perpendicular to the force plate, with positive being oriented to the upwards direction (Gulledge & Dapena, 2008). Joint rotation about the Y-axis represented abduction/adduction, joint rotation about the X-axis represented flexion/extension, and joint rotation about the Z-axis represented longitudinal rotation. The primary measures of interest included: 1) peak impact force (N), 2) peak hand/foot velocity (m/s), 3) peak anterior/posterior (A/P) ground reaction force (GRF) (N), and 4) shoulder abduction, thigh-thorax flexion, and knee extension joint angular displacements (degrees).

3.2.3 Procedure

Instruction and post-acquisition testing: All participants from both groups entered the learning phase where proper fighting stance was taught and participants received segmentation training (Wightman & Linter, 1985) of the KM straight punch and defensive kick techniques based on three checkpoints from each technique, provided by an expert KM practitioner (Professor Olivier Birot). A checkpoint defines the beginning and end of a component of the

technique. The full technique is defined by the aggregation of the checkpoints. The participants'

initial position and posture was the same for both the straight punch and defensive kick

techniques: the participants stood with their feet in a staggered position, the heel of the back foot

remained slightly elevated from the floor at all times; the hands were held up in front at chin

height, while forming loose fists that are close together, and the elbows pointed downwards

(Figure 3). The three checkpoints for the KM straight punch and defensive kick techniques are

outlined in table 1. Time allotted for learning each checkpoint during the initial instruction

session (AQ) was 5 minutes. Therefore, 15 minutes of learning time occurred for each technique,

making the total learning time to amount to 30 minutes during AQ.

Immediately after AQ, all participants performed five trials of both the straight punch and

defensive kick techniques (PostAQ). The only instruction given was to perform the strikes as

powerfully, quickly and accurately as possible to the center of the target.
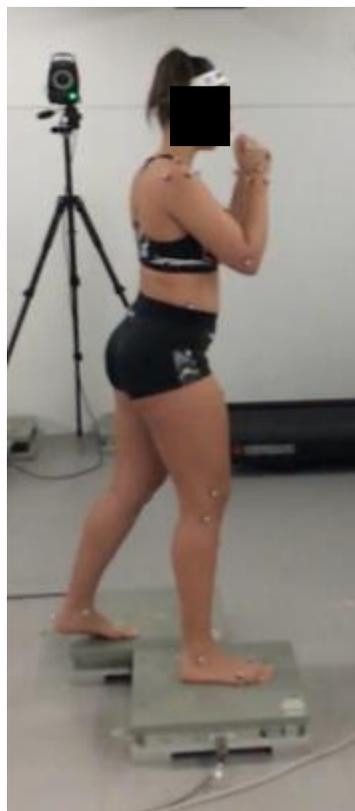

Figure 3. Fighting stance.

Table 1. Checkpoints of the Krav Maga techniques

Straight Punch Technique	
Checkpoint:	Movement Description
(1) Straight	The elbow is maintained tucked in close to the side of the body, pointed towards the ground and extends as the fist travels forward towards the target during the punch. The shoulder is adducted horizontally throughout the movement until contact with target is made. The first and second metacarpal knuckles of the fist contact the target while externally rotated 45 degrees from horizontal and the first metacarpal knuckle is in line with the radius of the forearm.
(2) Recoil	The fist is retracted immediately and rapidly after contact with target.
(3) Push	The posterior foot pushes forcefully backward, along the A/P axis, away from the target during the initiation of the punch.
Defensive Kick Technique	
Checkpoint:	Movement Description
(1) Knee Lift	The dorsi flexed foot and flexed knee of the kicking leg is lifted in front (anteriorly and vertically) of the participant as high and as close to the chest as possible, where the relative joint angle, created between the thigh and thorax segments, exhibits flexion at an angle occurring at a minimum of less than 90 degrees of flexion.
(2) Knee Extension	The leg and hip is extended forward and horizontally adducted until the sole of the foot makes contact with the target, with an emphasis on extension of the knee, while adducted horizontally before, during and after contact with target is made.
(3) Push	The posterior foot pushes forcefully backward, along the A/P axis, away from the target during the initiation of the kick.

Training for the MT group: The same method (segmentation) and amount of time (30 mins) as was used in the learning phase was utilized as practice for the techniques on training days for MT. Practice included punching and kicking a hand-held target as well as the air. Instruction and training was provided and monitored by the expert practitioner. An outline of the sequence of study and lab procedures is provided in Figure 4.
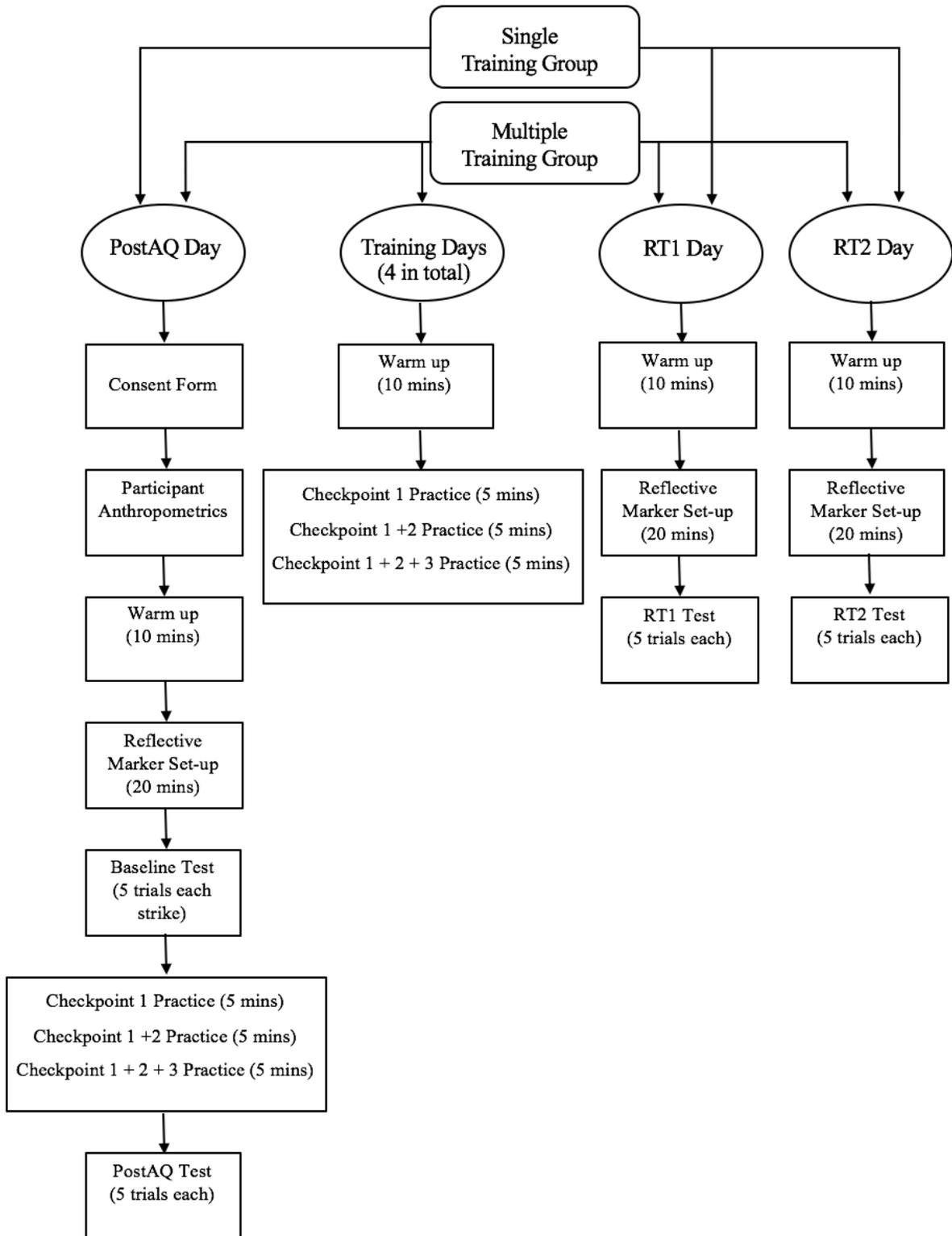
Figure 4. Sequence of study and lab procedures. PostAQ = post acquisition assessment immediately after initial training session, RT1 = retention 1 assessment five days after PostAQ, RT2 = retention 2 assessment one week after RT1.

After PostAQ, the ST group received no further training and was instructed not to practice the techniques for the remainder of the study. The MT group completed four additional daily practice sessions, focusing on both the straight punch and defensive kick techniques. The expert practitioner supervised each practice session, and provided additional instruction, as needed. Each session lasted 30 minutes. On day 5, all participants completed the testing protocol again (RT1). After RT1, all participants were instructed to not practice the KM techniques. On day 12, all participants again completed the testing protocol (RT2) (Table 2). During each testing session, participants were allowed to rest as much as desired in order to mitigate any fatigue effects.

Table 2. Study Timeline

|	Day:	1	2	3	4	5	6	7	8	9	10	11	12
Group Type:	Multiple Training	Post AQ	T	T	T	T/RT1	NT	NT	NT	NT	NT	NT	RT2
	Single Training	Post AQ	NT	NT	NT	NT/RT1	NT	NT	NT	NT	NT	NT	RT2

MT = multiple training, ST = single training, PostAQ = post acquisition, RT1 = retention test 1, RT2 = retention test 2 T = training session NT = no-training session.

3.2.4 Data Processing

Processing Raw Data

All raw data were filtered in Visual 3D (C-motion, USA) using a 4th order low pass, Butterworth filter (Kim et al., 2009; Piorkowski et al., 2011; Neto et al., 2013; Groen et al., 2007). A residual analysis approach was used to determine a filtering cutoff frequency for kinematic data of 7Hz; the residual analysis was conducted using the position data during a fist punch for the third metacarpal marker, which were collected during pilot testing (Piorkowski et al., 2011). The third metacarpal marker was used as it was considered the fastest moving marker during the punch strike. The residual analysis examined the difference between the raw and

filtered data over a range of cutoff frequencies (Wells & Winter, 1980), and quantified the signal content that remains when the filtered data is subtracted from the raw data (Robertson, 2004). After filtering all marker position data, body segments (Figure 5) were created based on the marker position data. From the body segments, joint angles of interest were created and defined as the orientation of one segment relative to another segment.
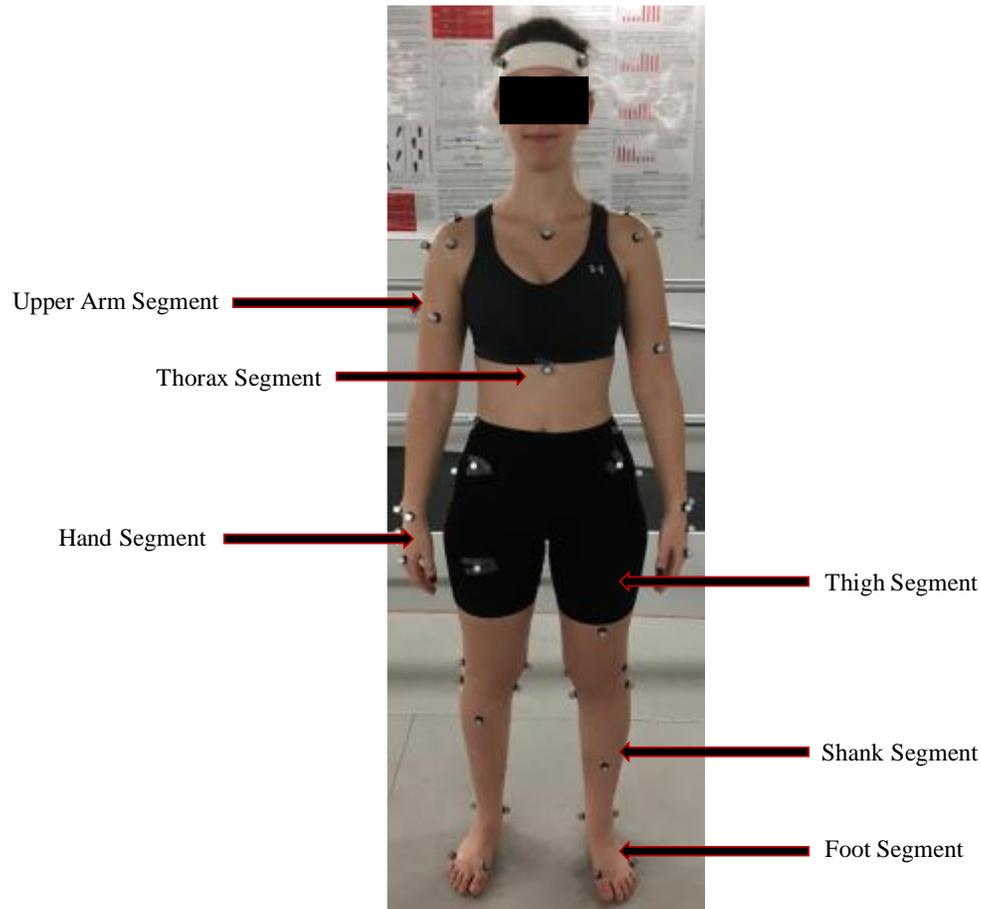

Figure 5. Participant segments used for component metric measures.

The cutoff frequency for force cube data was 27Hz. This was determined using two analyses: 1) A residual analysis of strike reaction force on force cube from pilot data yielded a cutoff of 36Hz; 2) To ensure that the force cube on the stand did not pick up any additional frequencies that may have developed from the stand imposing its own vibrations into the signal, a residual analysis was performed on a force plate placed on the ground. This force plate was

padded with the same thickness of foam that padded the force cube and was punched (i.e., the punch was delivered in the downward direction, as the force plate was located on the floor). The residual analysis yielded a frequency cutoff of 27Hz. From these two analyses a cutoff frequency of 27Hz was selected for the force cube data. Force plate data from both force plates were filtered at 7Hz determined by a residual analysis of the GRF along the anterior-posterior axis of the rearward force plate during a punch strike trial.

Quantifying Strike Technique Performance

To quantify the performance of the KM techniques, the strikes were divided into one kinetic and two kinematic components outlined by events (Figures 6 and 7) (Estevan et al., 2011). An event is an occurrence of interest that correlates to a particular action in time; events were created in the data using the Visual 3D program. The components, and the outlined events, used to evaluate the performance of both the straight punch and defensive kick techniques are displayed in Appendix D; as well as graphically in Figures 8 to 13. For demonstration purposes, the signals used for each corresponding component in Figures 8 to 13 were normalized to 100% of the movement trial, in which 0% represented 0.5 seconds prior to IN and 100% represented END. The selection of 0.5 seconds was used as the start of movement trial (0%) in order to capture a static posture prior to initiation of strike movement, as it became clear that the GRF production sometimes preceded both the foot and hand movements; and was therefore selected for visual purposes only. After collecting and processing all component measures of interest for each strike technique, an assessment of the difference between PostAQ and RT performance values of these components was conducted to determine consistency of the components in the techniques, and therefore technique performance.
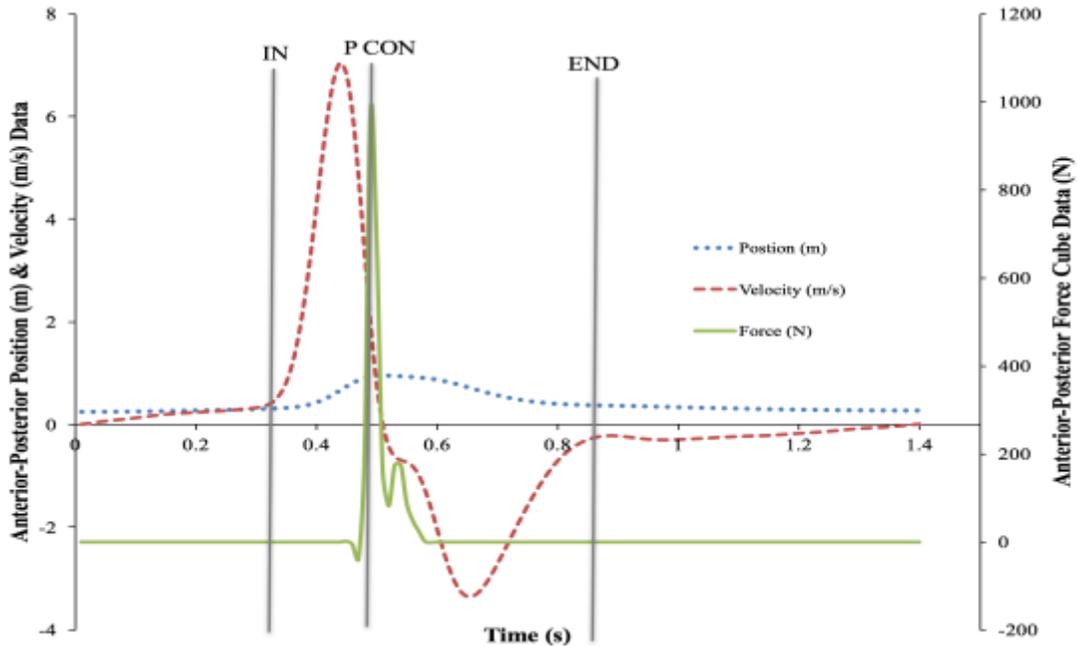
Figure 6. Punch position signal (blue dotted line), velocity signal (red dashed line), and force signal (green straight line) of hand in the anterior-posterior direction with events (IN = initiation of hand movement, P CON = peak force during contact with target, END = end of punch recoil).
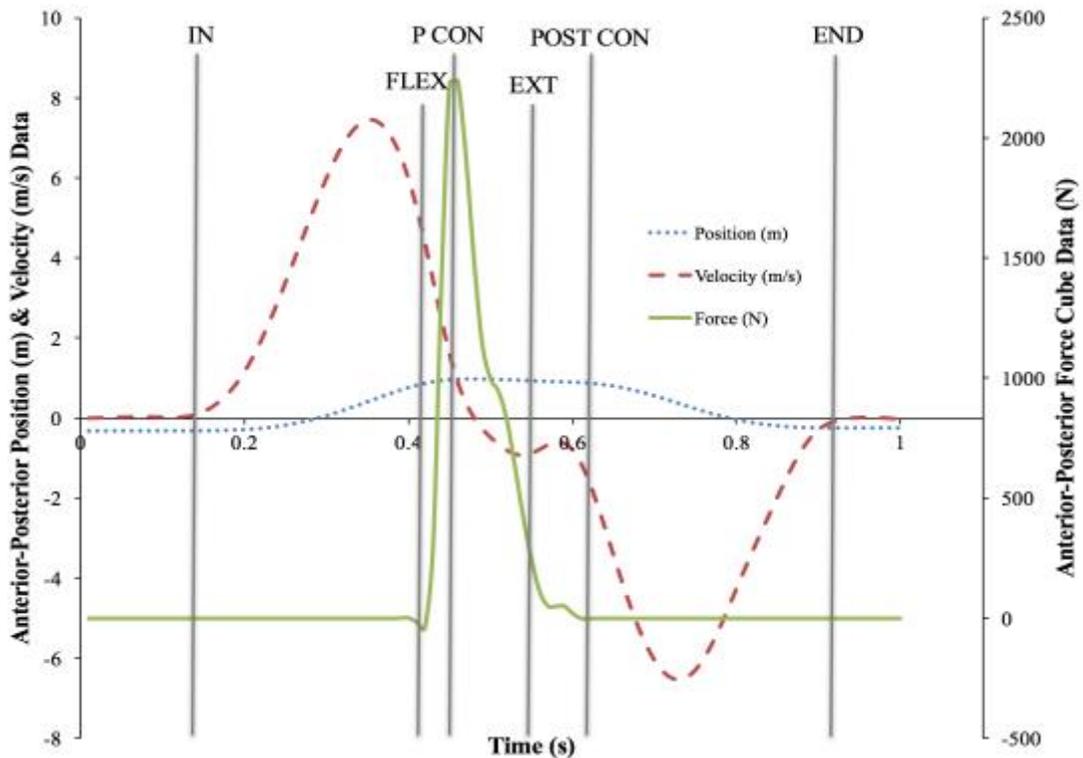

Figure 7. Kick position signal (blue dotted line), velocity signal (red dashed line), and force signal (green straight line) of the foot in the anterior-posterior direction with events (IN = initiation of foot movement, P CON = peak force during contact with target, FLEX = maximum thigh-thorax flexion, EXT = maximum knee extension, POST

CON = end of foot contact, END = end of kick). FLEX and EXT events are included for demonstration purposes and are based on information found in later figures (Figures 10 & 11).
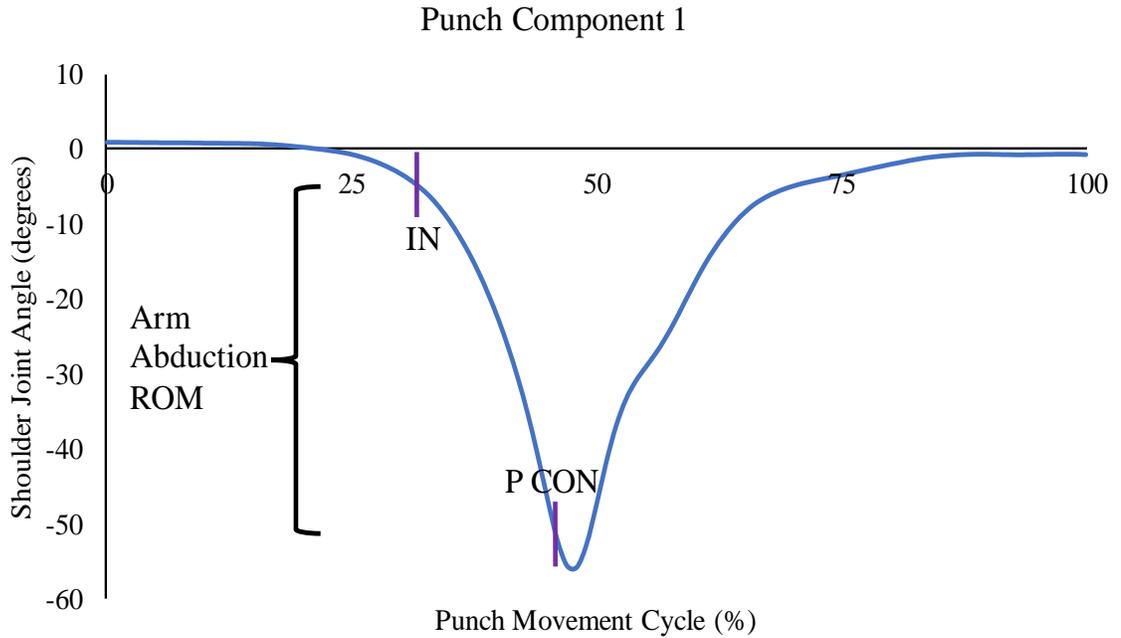
Punch Component 1

Figure 8. Representative plot of punch component 1, arm abduction ROM between the upper arm and thorax segments, calculated between IN and P CON events. Signal normalized to 100% of punch movement between start of trial, selected at 0.5 seconds before IN, and END (100%).
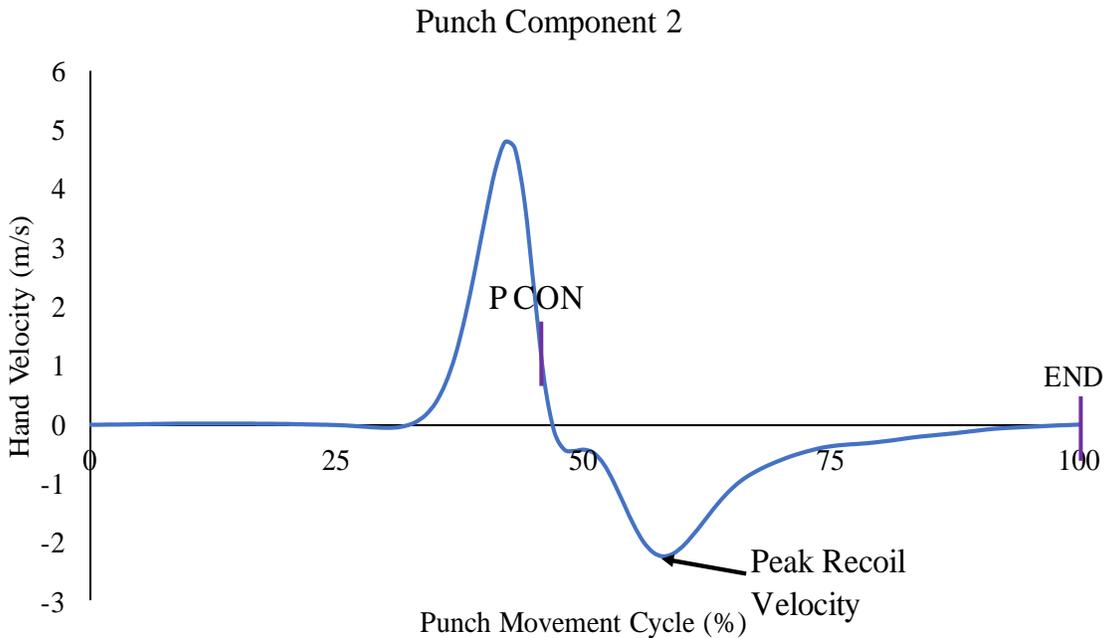
Punch Component 2

Figure 9. Representative plot of punch component 2, peak recoil velocity of the striking hand selected between P CON and END events. Signal normalized to 100% of punch movement between start of trial, selected at 0.5 seconds before IN, and END (100%).
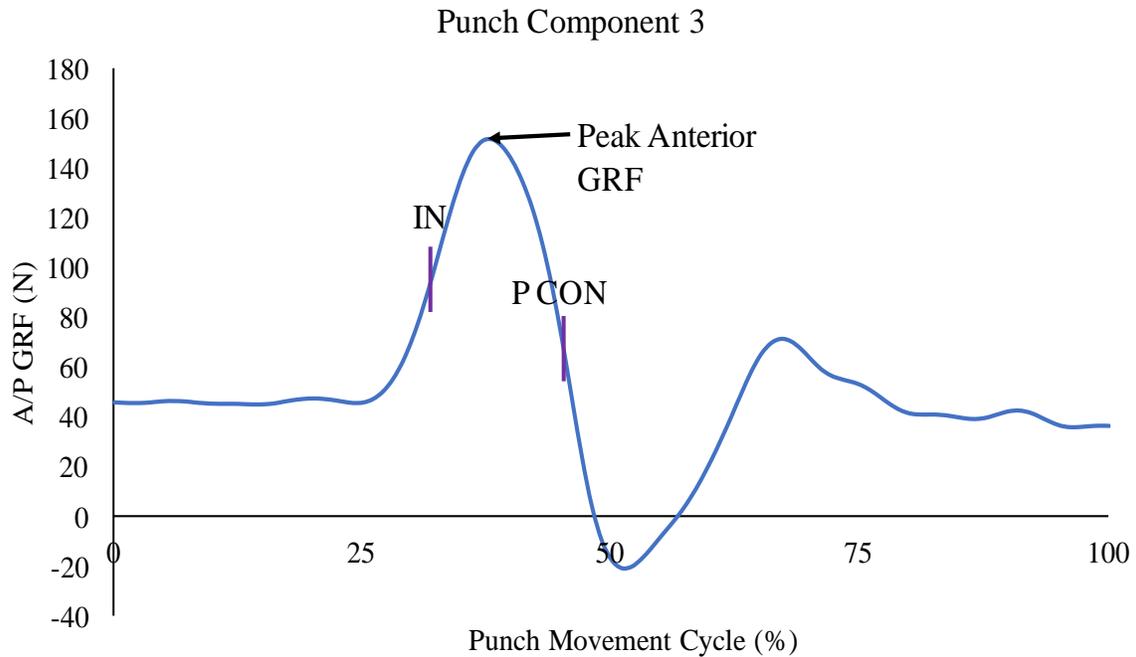
Figure 10. Representative plot of punch component 3, peak anterior GRF, calculated between IN and P CON events. Signal normalized to 100% of punch movement between start of trial, selected at 0.5 seconds before IN, and END (100%).
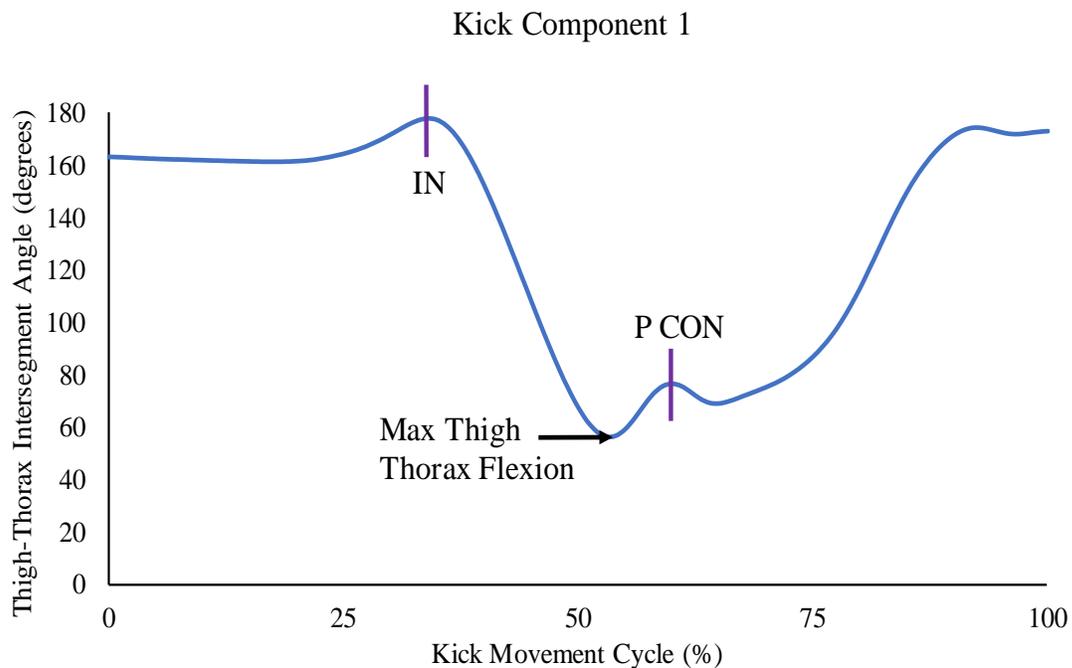
Figure 11. Representative plot of kick component 1, maximum thigh-thorax flexion angle, calculated between IN and P CON events. Signal normalized to 100% of kick movement between start of trial, selected at 0.5 seconds before IN, and END (100%).
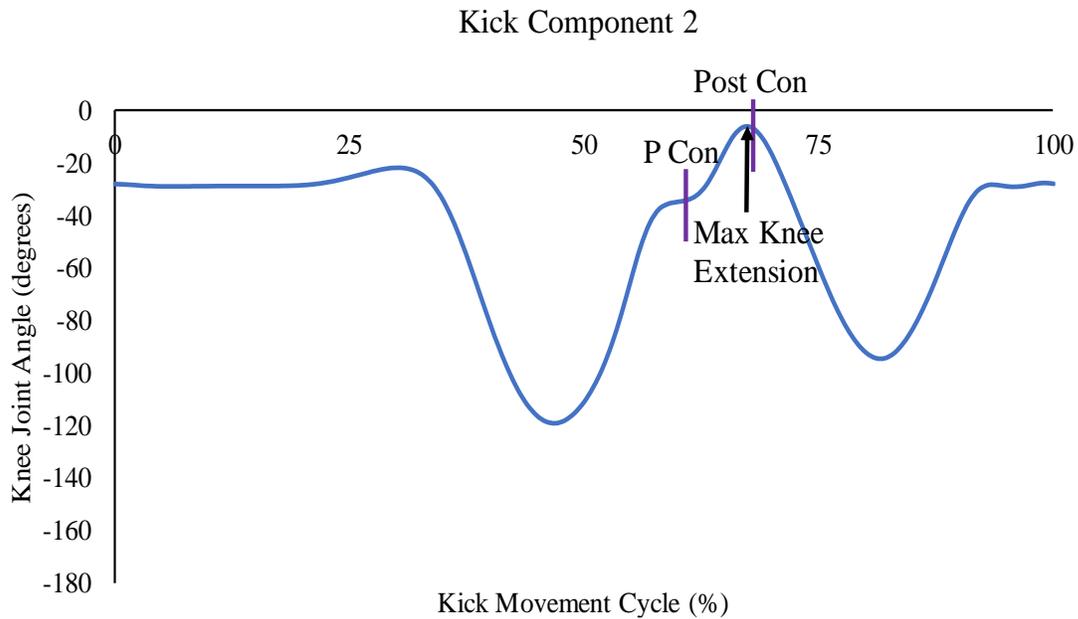
Kick Component 2

Figure 12. Representative plot of kick component 2, maximum knee extension angle, calculated between P CON and POST CON events. to 100% of kick movement between start of trial, selected at 0.5 seconds before IN, and END (100%).
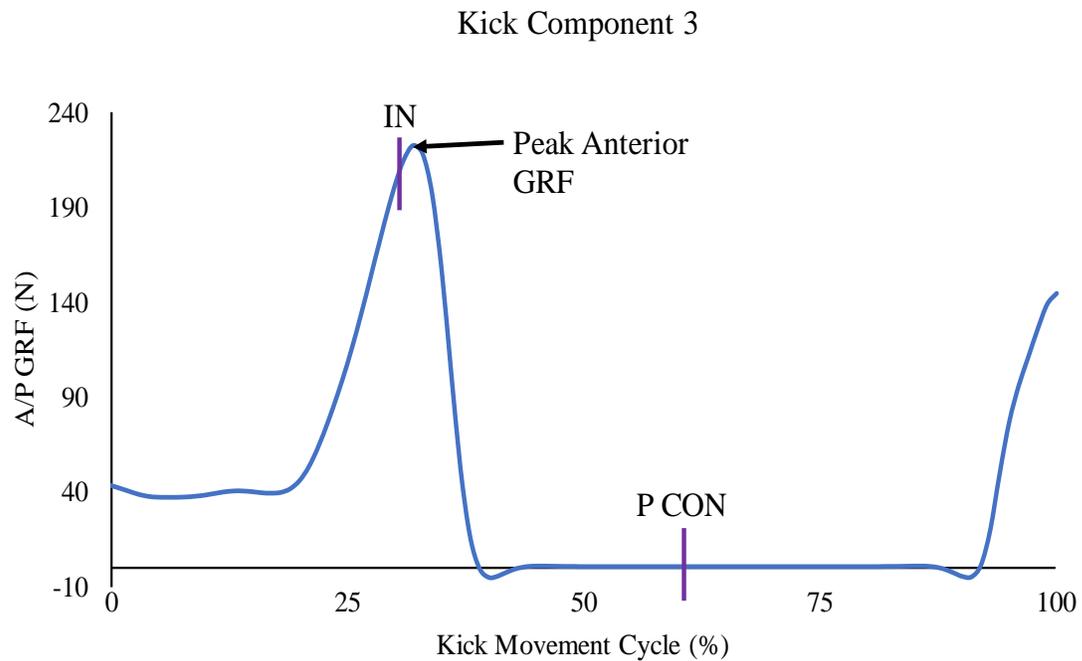
Kick Component 3


Figure 13. Representative plot of kick component 3, peak anterior GRF, calculated between IN and P CON events. to 100% of kick movement between start of trial, selected at 0.5 seconds before IN, and END (100%).

3.2.5. Statistical Analysis

All statistical analysis was performed using JMP 9 (The SAS Institute, Cary, North Carolina USA). The statistical method used was a mixed, repeated-measures 2 (GROUP) x 3 (TIMEPOINT) analysis of variance (ANOVA) (Table 5) for each component of both Krav Maga techniques, totaling 6 ANOVA tests (Punch: arm abduction ROM, peak retraction velocity, and peak A/P GRF; kick: maximum thigh-thorax flexion angle, maximum knee extension angle, and peak A/P GRF). The factor GROUP consisted of two levels: single training/multiple training. The factor TIMEPOINT consisted of three levels: PostAQ/RT1/RT2.

Normality was assessed visually by plotting the distribution of the data in a histogram. Normality was also assed quantitatively using the Shapiro-Wilk W Test for Goodness of fit (indicating $p < 0.05$ is not normally distributed). Non-Gaussian distributions were corrected using a log transform for positively skewed data, or a square-root transform for negatively skewed data.

Component metric performance for each strike technique was analyzed to find differences among components of each technique between groups and across timepoints, in order to determine maintenance or improvement in checkpoint performance.

Results were statistically significant at $p < 0.05$.

3.3 Results

3.3.1 Straight Punch Component Performance Analyses

No significant interaction effect of Group and Timepoint [$F_{(2, 28)} = 1.998$, $p = 0.154$], main effect of Group [$F_{(1, 14)} = 0.451$, $p = 0.513$], or main effect of Time [$F_{(2, 28)} = 0.387$, $p = 0.683$] was found for arm abduction angle ROM (Component 1) (Figure 14). No significant interaction effect of Group and Timepoint [$F_{(2, 28)} = 0.0409$, $p = 0.96$], main effect of Group

[F(1, 14) = 0.984, p = 0.338], or main effect of Time [F(2, 28) = 0.733, p = 0.489] was found for

peak recoil velocity (Component 2) (Figure 15). No significant interaction effect of Group and

Time [F(2, 28) = 2.03, p = 0.150], main effect of Group [F(1, 14) = 1.533, p = 0.236], or main

effect of Timepoint [F(2, 28) = 2.495, p = 0.101] was found for peak anterior GRF (Component

3) (Figure 16).
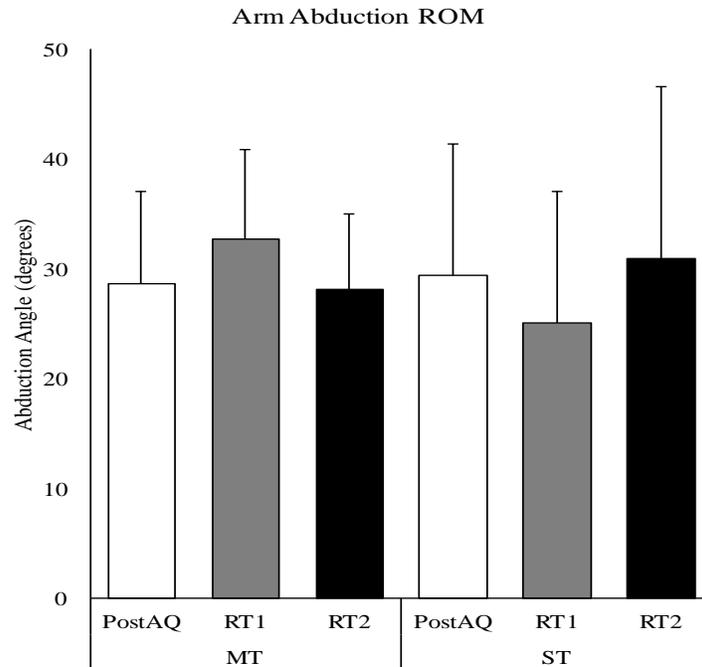
Figure 14. Mean arm abduction angle ROM for each Group at each Timepoint for punch component 1. Error bars represent standard deviation. PostAQ = post acquisition assessment immediately after initial training session, RT1 = retention 1 assessment five days after PostAQ, RT2 = retention 2 assessment one week after RT1, MT = multiple training session group ST = single training session group.

Peak Recoil Velocity
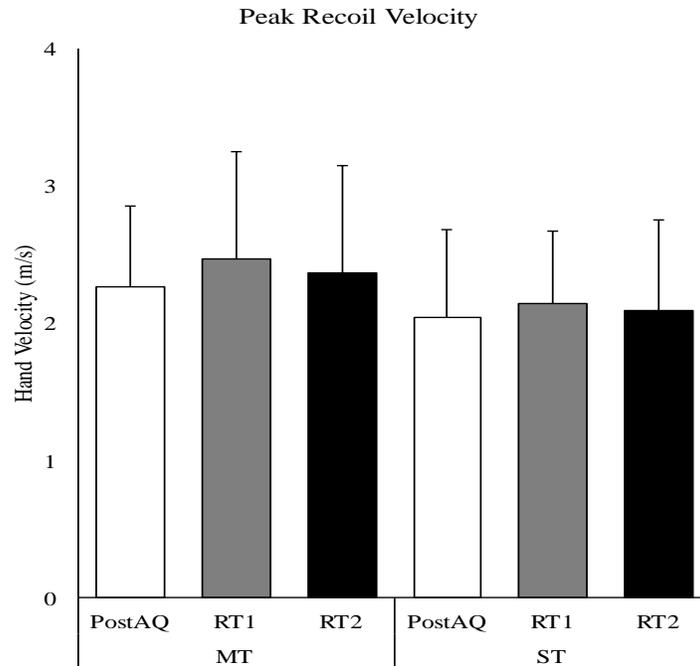
Figure 15. Mean peak fist recoil velocity for each Group at each Timepoint for punch component 2. Error bars represent standard deviation. Mean values were changed from negative to positive. PostAQ = post acquisition assessment immediately after initial training session, RT1 = retention 1 assessment five days after PostAQ, RT2 = retention 2 assessment one week after RT1, MT = multiple training session group ST = single training session group.
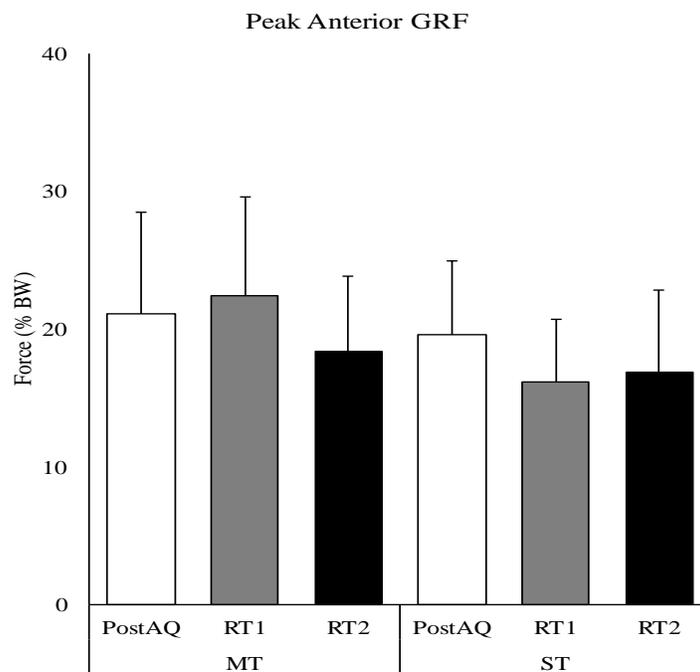
Peak Anterior GRF

Figure 16. Mean peak anterior GRF normalized to % BW for each Group at each Timepoint for punch component 3. Error bars represent standard deviation. PostAQ = post acquisition assessment immediately after initial training session, RT1 = retention 1 assessment five days after PostAQ, RT2 = retention 2 assessment one week after RT1, MT = multiple training session group ST = single training session group.

3.3.2 Defensive Kick Component Performance Analyses

No significant interaction effect of Group and Timepoint [$F_{(2, 28)} = 0.716$, $p = 0.497$], main effect of Group [$F_{(1, 14)} = 0.391$, $p = 0.542$], or main effect of Timepoint [$F_{(2, 28)} = 0.278$, $p = 0.759$], was found for maximum thigh-thorax flexion angle (Component1) (Figure 17). No significant interaction effect of Group and Timepoint [$F_{(2, 28)} = 0.903$, $p = 0.417$], main effect of Group [$F_{(1, 14)} = 0.534$, $p = 0.477$], or main effect of Timepoint: [$F_{(2, 28)} = 0.429$, $p = 0.655$] was found for maximum knee extension angle (Component 2) (Figure 18). Though there was no significant Timepoint difference, a 25.1% decrease in knee extension angle was found among participants within the multiple training group between PostAQ (24.29 ± 9.40 degrees) and RT1 (18.20 ± 11.52 degrees). A similar decrease in knee extension angle (22.7%) was also observed in the single training group between RT1 (24.43 ± 10.54 degrees) and RT2 (18.89 ± 11.18 degrees), which cannot be explained by training because they received no training. No significant interaction effect of Group and Timepoint [$F_{(2, 28)} = 0.675$, $p = 0.517$], main effect of Group [$F_{(1, 14)} = 0.102$, $p = 0.754$], or main effect of Timepoint: [$F_{(2, 28)} = 0.473$, $p = 0.628$] was found for peak A/P GRF (Component 3) (Figure 19).
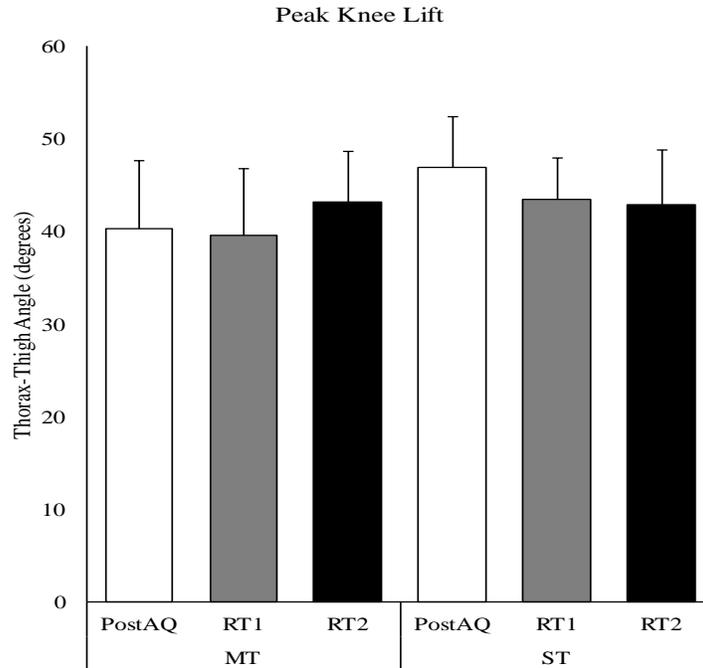
Figure 17. Mean maximum thigh-thorax for each Group at each Timepoint for kick component 1. Error bars represent standard deviation. PostAQ = post acquisition assessment immediately after initial training session, RT1 = retention 1 assessment five days after PostAQ, RT2 = retention 2 assessment one week after RT1, MT = multiple training session group ST = single training session group.
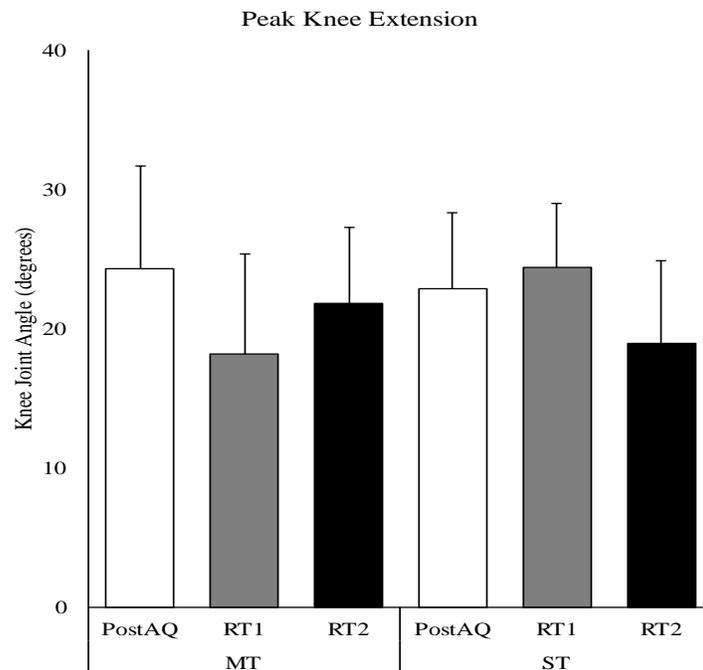

Figure 18. Mean maximum knee extension for each Group at each Timepoint for kick component 2. Error bars represent standard deviation. Mean values were changed from negative to positive. PostAQ = post acquisition assessment immediately after initial training session, RT1 = retention 1 assessment five days after PostAQ, RT2 = retention 2 assessment one week after RT1, MT = multiple training session group ST = single training session group.
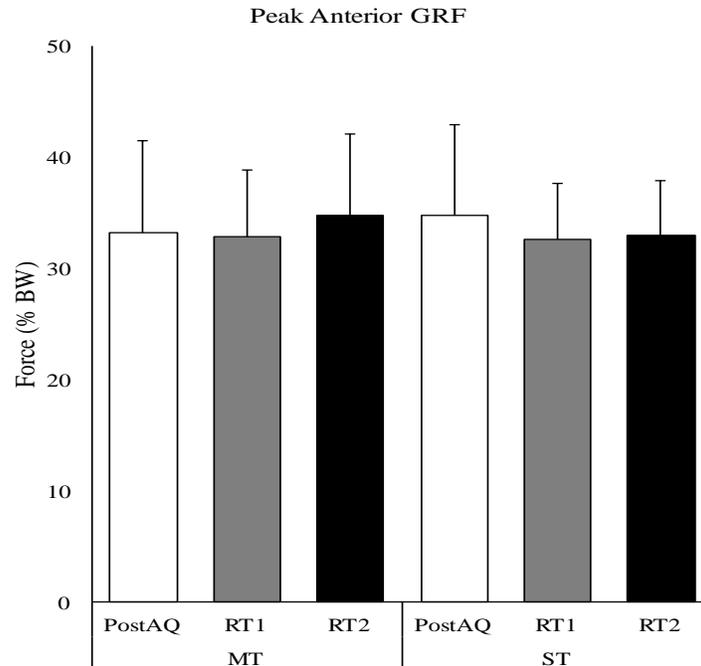
Figure 19. Mean peak anterior GRF for each Group at each Timepoint for kick component 3. Error bars represent standard deviation. PostAQ = post acquisition assessment immediately after initial training session, RT1 = retention 1 assessment five days after PostAQ, RT2 = retention 2 assessment one week after RT1, MT = multiple training session group ST = single training session group.

3.4 Discussion

This study posed the following research questions: 1) Would additional training sessions affect performance, defined in terms of a number of kinematic and kinetic measures, below, of the components of the straight punch technique? 2) Would additional training sessions affect performance, defined in terms of a number of kinematic and kinetic measures, below, of the components of the defensive kick technique? It was hypothesized that: 1): The performance of the straight punch would not differ between the PostAQ and RT1 sessions among the single-training session group, but would improve among the multiple-training session group; there would be no difference between the RT1 and RT2 sessions for either group. 2): The performance of the defensive kick would not differ between the PostAQ and RT1 sessions among the single-training session group, but would improve among the multiple-training session group; there would be no difference between the RT1 and RT2 sessions for either group.

The hypotheses were partially supported, but only in the sense that there were no differences in performance among the ST group participants between the three testing sessions. This is not surprising, of course, given that these participants were instructed not to practice the movements between testing sessions and they received no additional training after the initial training session. More surprising, however, was the absence of change in the performance of the participants in the MT group, all of whom received multiple training and instructional sessions.

Results for each component of the KM straight punch and defensive kick techniques indicate that performance after a single training session did not differ between PostAQ and RT1, or between RT1 and RT2; confirming the first and second hypotheses for ST and demonstrating the maintenance of strike technique performance. Results for each component of the KM straight punch and defensive kick techniques indicate that performance after multiple training sessions did not differ between PostAQ and RT1, as well as between RT1 and RT2. These findings suggest that further practice, described as an additional four training sessions, had no further effect on performance improvement for skill acquisition as well as skill retention, refuting the first and second hypotheses for the straight punch and defensive kick techniques for MT. Based on unpublished data from our lab, two out of the three components for the straight punch technique, as well as one out of the three components for the defensive kick technique has been demonstrated to be learned after an initial KM instruction session (AQ). Therefore, learning did occur, however, whatever skill that was obtained after AQ was not improved by multiple training sessions, as evidenced by MT. Furthermore, the skill obtained after AQ was also not degraded over time by not training, as demonstrated by ST.

Multiple Training Group

Although the MT group performed additional training sessions, performance did not change. A number of factors might have contributed to the lack of change in performance, including practice time, the structure of the training and practice sessions, and practice intensity (or time between practice sessions).

Practice time: It is speculated that perhaps not enough practice was provided, when participants were provided only 15 minutes per strike technique. Therefore, maybe more training is required; or not enough intensity during training was provided, to stimulate skill level improvement. The well documented power law of practice may be at work with present findings, which states that learning occurs at a rapid rate at the onset of practice, as indicated by unpublished data from our lab, however this rate decreases as practice increases over time (Newell, 1981; Chapman, 1919). A good demonstration of a decreased rate of learning can be seen in Chapman's (1919) typewriting study, in which participants exhibited a positive acceleration in improvement in typing speed between 20 to 90 hours of practice, where typewriting speed ranged from about 55 to 215 words respectively. Afterwards, during the remaining period of 90 to 180 hours of practice, typewriting speed ranged from only 215 to 265, respectively. In the current study, perhaps the skill level of participants improved rapidly with the first instructional session, as participants learned the basic movements and expectations of performance. It is possible that performance levels did not change with subsequent training because not enough training time was provided. Therefore, a plateau in learning the KM techniques may have been reached and more practice may be necessary for further improvements. However, as evidenced by Bryan and Harter (1897, 1899), mere repetition of a motor skill does not always lead to improved performance. Often times, different and better

training methods need to be implemented in order to achieve further performance improvements (Keller 1958).

Structure of training and practice sessions: The lack of performance improvement in the MT group may have been caused by the need to restructure the training protocol, after the initial instruction session. Restructuring the training protocol during periods of skill acquisition may allow for additional improvements in performance once a plateau is reached, as speculated for the MT group. Research has demonstrated that high contextual interference, stimulated by randomly alternating between tasks for each trial during training, results in enhanced motor skill retention, as opposed to a blocked schedule in which all trials from one task are practiced before moving on to the next task (Goode & Magill, 1986; Pollatou et al., 1997). In the current study, a blocked training approach was used, in which the KM punch was practiced entirely before moving on to the KM kick. Alternating between punch and kick trials during practice sessions may stimulate further improvements in technique performance after the initial training session in MT.

Usually, martial arts/self-defense training sessions are performed in a group, in which participants are paired for technique practice (Brecklin, 2008). For example, one partner will hold a target while the other partner practices the strike technique, and afterwards, participants will switch. Previous research has demonstrated that dyad training, or training participants in a pair, has greater learning outcomes, compared to training individually. The idea of dyad training is that learners experience additional processing through observational learning during rest intervals. This combination of observational learning and physical practice allows the observer to extract additional information about the task, such as appropriate coordination patterns, which may be missed during physical practice alone (Shebilske et al., 1992). Recent research has also

revealed that the model in which the learner observes does not need to be from an expert performer (Adams, 1986). Furthermore, increased motivation has also been found during dyad training, due to the stimulation of a competition between participants during training (Wulf et al., 2010). Therefore, including a dyad training approach in the current study's training protocol may be a viable method for the improvement in technique performance following the first instruction session in the MT group.

Related to the structure of training and practice sessions, self-determination of practice schedules, in which the participant is able to have control over some practice conditions during a session, has also been shown to lead to greater performance during motor skill learning (Wulf et al, 2010). Self-controlled training gives the participant control over their own learning, as opposed to an instructor, leading to a more active role and increased motivation for the participant (Chiviacowsky et al., 2008; Post et al., 2011). During the KM training sessions, the instructor had complete control over the amount of time allotted for each checkpoint as outlined by the training protocol. This highly structured and instructor-control training protocol may have been beneficial during the initial instruction session, however, as participants in the MT group continued training throughout the study, perhaps they felt "forced" into a given practice schedule and volume of practice, or alternatively, they desired additional trials of practice. For example, Post et al. (2011) demonstrated that participants deciding when to stop practice, compared to participants with no influence on practice amount, performed with greater accuracy when learning dart throwing, using the non-preferred hand. These results suggested a self-controlled amount of practice benefited the learning of a motor skill due to the learner being able to tailor the practice experience to their individual needs or preferences. Therefore, as speculated in the MT group, the learner may have required a practice session tailored to their individual needs,

including either an increased or decreased amount of practice trials, in order to stimulate further performance improvement.

Practice intensity: Selecting the appropriate amount of time between practice sessions can produce greater motor learning. Research has demonstrated that distributed practice (i.e., fewer practice trials in shorter training sessions) produces faster learning compared to massed practice (i.e., many practice trials in longer training sessions) (Woodworth, 1938). Furthermore, participants undergoing distributed practice (2 practice sessions, separated by 24 hours) were found to maintain performance levels better compared to massed practice (2 practice sessions on the same day) when learning a continuous dynamic balance task (Shea et al., 2000). These results suggested that time after learning is beneficial to allow the process of motor memory consolidation to undergo its critical role and facilitate motor learning. The training protocol used in the current study for MT was a massed practice approach, in which participants practiced both strike techniques, immediately after one another, during the same practice session; as well as undergoing a practice session on each subsequent day during the five-day training period. Therefore, it can be speculated that the massed practice approach resulted in less motor learning compared to what a distributed practice approach may offer. Brashers-Krug et al (1996) investigated the learning of two motor tasks separated by either a 4-hour break period or a no-break period and found that the consolidation of a motor skill was disrupted when a second motor task was learned immediately after the first. However, after a four-hour period between the tasks, the initial learning had consolidated. Perhaps learning the straight punch technique and then taking a break, after which, the defensive kick technique is practiced can stimulate greater learning. Additionally, perhaps spacing the practice sessions across more days (i.e., spacing practice sessions with 48 hours between each session as opposed to 24 hours as done in the

current study) can elicit greater learning by allowing the process of motor memory consolidation to take place, through the passage of time, without disruption.

Single Training Group

The findings for the ST group suggested that skill level did not degrade, for a period of up to 12 days, with no additional training. The speculation for this finding is that perhaps the notion of 'natural movements' in KM training is a good one, and that the simplicity of learning and performing the movements allows for a basic level of skill to be obtained quickly and retained relatively permanently. Weerdesteyn et al. (2008) demonstrated that teaching martial arts falls techniques to naïve participants in a brief 30min instruction session had a significant effect in reducing hip impact forces with the ground. Additionally, Weerdesteyn et al. (2008) suggested that when inexperienced fallers were asked to do the martial arts fall technique a few weeks after training, they displayed correct performance (based on observation). This finding is in line with the results obtained in ST, demonstrating that martial arts/self-defense techniques appear to be premised on training movements that are 'natural' for the human body to obtain quickly and retain relatively permanently, similar to KM techniques.

Another possible contributing factor to explain the maintenance in skill level demonstrated in ST is "offline" learning. Offline learning is the process during which training has ceased, and yet changes in skill performance can occur. During offline learning, the passage of time can elicit further skill improvement and stabilization (Doyon et al., 2009; Shea et al., 2000) through motor memory consolidation. Lo et al. (2003) investigated the retention of a 10-minute falls training session on reducing hand impact force in forward falls over a 3-month period. Findings demonstrated that the training session resulted in significantly reduced impact forces; however, participants from the control group performing only five falls spaced three weeks apart were also

able to reduce impact force by the same amount as the training group. These results suggested that: 1) participants taught themselves how to significantly reduce hand impact force during a forward fall with a minimal amount of experience; and 2) consolidation of the forward fall technique with the passage of time, demonstrating "learning without practice" (Brashers-Krug et al., 1996). The passage of time, as evidenced by Lo et al. (2003), appears to strengthen the motor memory of a novel motor skill. These results may explain the retention of skill level in both KM techniques exhibited by ST.

Experts of the Krav Maga (KM) self-defense system claim that KM technique is based on logical and simplistic movements that are 'natural' for the human body to perform, and are therefore believed to be learned quickly and retained (Philippe, 2006; Boe, 2015). Clearly, people can and do learn KM. However, this study did not capture and demonstrate such learning, perhaps due to the reasons discussed earlier. An outcome of this study is the new knowledge that such minimal training is not adequate to stimulate the ongoing learning of KM techniques, beyond that which occurs with the very first session. Going forward, practitioners of KM may consider using these other theories of motor learning, such as contextual interference or distributed practice, in their own teaching methods; which can then be tested in the future.

CHAPTER FOUR

General Discussion

The motor learning of martial arts/self-defense techniques in novice performers has yet to be thoroughly investigated. A number of studies have examined the performance of various martial arts/self-defense techniques performed by experts and/or amateurs; demonstrating improved performance with prolonged practice (across many years) in both performance production and performance outcomes measures. Furthermore, structural changes in the brain have also been reported to explain the effects of prolonged practice on motor skill performance (Roberts et al., 2012). Improved performance with practice has been marked by increased striking limb velocities and accelerations (Cheraghi et al., 2014), impact forces (Gulledge & Dapena, 2007), accuracy (Neto et al., 2013), and greater repeatability of coordination patterns (VencesBrito et al., 2011). Therefore, the performance of various martial arts/self-defense techniques have been well documented, however, there is a lack of literature demonstrating the actual learning of novel martial arts/self-defense techniques in novice performers (Gomes, 2012; Burke et al., 2011; Weerdesteyn et al., 2008).

It is suggested that the primary goal of martial arts/self-defense training is to strengthen the capacity to defend oneself against potential attacks (Cummings, 1992; Brecklin, 2008). Therefore, knowledge pertaining to the motor learning of novel martial arts/self-defense techniques will help develop our understanding for the selection and utilization of appropriate training methods for effective skill development. The implication of this knowledge is to expedite the learning of novel techniques and therefore increase the rate of learning. Currently, the majority of studies that have investigated the training effects of learning martial arts/self-defense have been conducted using surveys, questionnaires, and interviews (Brecklin, 2014;

Nosanchuk, 1981; Boe, 2015). This is largely due to the costs, both financially and in terms of time commitment, associated with conducting motor learning research. Results from these studies have indicated that benefits can be gained from performing martial arts/self-defense training, however, these results have been predominately limited to participants' psychological/attitudinal changes in response to training, as opposed to the actual performance of techniques learned. For example, increased self-esteem and assertiveness, as well as decreased anxiety, fear and helplessness, when confronted by an opponent, have been noted after performing self-defense training (Brecklin, 2014; Boe, 2015). Therefore, the current study was aimed at providing quantitative data on the actual learning of novel motor skills in the domain of martial arts/self-defense research.

The current results suggest that, following a single instruction session, performance did not diminish over the following 12 days for the no-training group. These finding are suggested to support the role of offline learning during the consolidation of a motor skill with the passage of time (Doyon et al., 2009; Shea et al., 2000). Previous research has demonstrated that the passage of time is critical for the consolidation of motor skills. For example, Lo et al. (2003) examined the retention of a 10-minute falls training session on reducing hand impact force in forward falls over a 3-month period. Findings demonstrated that the training session significantly reduced impact forces; however, participants from the control group performing only five falls spaced three weeks apart were also able to reduce impact force. These results suggest that the forward fall technique was consolidated with the passage of time due to offline learning. Malangré et al. (2014) investigated the effects of sleep-related offline learning during the learning of a novel complex arm movement task. Findings demonstrate that a night of sleep elicited performance improvement beyond that achieved at the end of the initial training session. The passage of time,

as evidenced by the above studies, appears to strengthen the motor memory of a novel motor skill, which therefore may explain the maintenance in skill level after a single instruction session, as demonstrated by the current study.

That performance did not improve with additional training for the training group appears to support the notion that mere constant repetitive practice of a motor skill does not always improve performance or, the power law of practice relationship between practice amount and skill level improvement may be at work. Research has demonstrated that different and better training methods can lead to further improvements in performance levels (Keller, 1958). Therefore, restructuring of the current study's training protocol may lead to further improvements in skill level with additional training. Previous research has revealed that dyad training, or training participants in a pair, has greater learning outcomes, compared to participants training individually. The premise behind dyad training is that learners undergo additional processing through observational learning during rest intervals. The process of observational learning alone is not as effective as physical practice, however, combining both observational with physical practice has been found to be superior to physical practice alone (Shebilske et al., 1992). These added benefits are due to the observer being able to extract additional information about the task such as appropriate coordination patterns and task demands, which may be missed during through physical practice alone. Recent research has also found that the model observed does not need to be from an expert performer (Adams, 1986). Dyad training has also been proven to be more efficient, in terms of time commitment, because two participants are able to be trained in the same amount of time as it would take to train one participant (Shea et al., 1999). Finally, dyad training has also been found to increase motivation by stimulating a competition between participants; and can further increase participation by

removing self-consciousness to perform the task as participants can relate to one another because they are considered to be at the same stage of learning (Wulf et al., 2010). Martial arts/self-defense techniques are typically taught in a group setting (Brecklin, 2008), however, practitioners are often paired for practice. For example, one partner may hold the target in which the other partner will strike, and thereafter, participants will switch. Future studies may consider adopting a dyad training protocol when conducting self-defense/martial arts motor learning research.

Based on previous literature, learning a second task immediately after learning a first task has been demonstrated to disrupt the consolidation of motor skills (Brashers-Krug et al., 1996). However, after a four-hour break period between tasks, the initial learning was found to be consolidated. Based on the results of the current study, it is speculated that learning the two strike techniques, one immediately after the second, may have caused a disruption in the consolidation process. Savon-Lemieux and Penhune (2004) showed that the amount of practice did not affect the learning of a timed motor sequence task, but rather the distribution of practice over several days was the most important factor affecting retention. These results suggest that the passage of time is crucial for maximum benefits of practice to be gained, due to the delay in time allowing for consolidation to take place. Therefore, KM instructors, as well as instructors in other disciplines such as sport, may consider spacing techniques out over more time when teaching novel movement patterns.

Additional training strategies often used in motor learning are contextual interference and self-control practice. Contextual interference, induced by a random practice schedule, has been demonstrated to facilitate improved motor learning in sport related (Goode & Magill, 1986; Hall et al., 1994) and non-sport related skills (Schneider et al., 1998; Hanlon, 1996). Perhaps using a

training protocol that altered between the two strike techniques, would provide greater motor learning during practice. The self-control practice approach has demonstrated improved motor learning due to the learner being able to tailor the practice experience to their individual needs or preferences. Since the instructor controlled the training protocol in the current study, participants were not given the opportunity to perform the amount of trials they may deem necessary. Previous research has demonstrated that when participants had control over selecting the number of practice trials to perform during non-dominant hand dart throwing, motor learning was greater compared to yoked participants (Post et al., 2011). Similarly, greater motor learning was found when participants had control over the frequency of feedback, during the learning of a non-dominant hand bean bag toss, compared to yoked participants (Chiviacowsky et al., 2008). The benefits associated with learner's control over the frequency of feedback is related to the comparison between the learner's intrinsic feedback to the external feedback provided by the instructor. This feedback comparison, when requested, is suggested to attach "meaning" to the intrinsic feedback; becoming interpretable and more effective for future performance (Chiviacowsky et al., 2008).

The power law of practice is suggested to explain the results of the current study in regards to the lack of skill improvement found after additional training sessions were performed. As evidenced by previous research, progressively more training is required for further improvements in skill level. For example, Chapman (1919) demonstrated that typewriting speed improved rapidly between 20 to 90 hours of practice; however, as training continued, modest changes in improvement were evident between 90 to 180 hours of practice. Similarly, Crossman (1959) examined cigar-making speed as a function of the number of cigars each worker had made since they started working. Results demonstrated that the majority of performance improvement took

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place during the first two years of experience, and that performance continued to improve for up to seven years. However, after seven years of practice, performance improvements were distinctly smaller. The power law of practice, in concordance with "deliberate practice theory" has also been suggested in the development of expertise from early childhood to adulthood in sports such as swimming (Kalinowski, 1985) and tennis (Monsaas, 1985), as well as in music (Ericsson et al., 1993) indicating that early specialization in sport, increased practice time, as well as deliberate practice are necessary factors to achieve expert level performance. Deliberate practice is defined as any training activity that is performed with a specific purpose of increasing performance, requiring cognitive and/or physical effort, and is relevant to promoting skill development (Ericsson et al., 1993). Going back to the results of the current study, perhaps participants did not improve with additional training due to two factors: 1) the four additional training sessions did not provide enough practice to induce skill improvement in the strike techniques; and/or, 2) the training sessions were not intense enough in terms of following the criteria outlined by deliberate practice theory. Instructors and learners should consider that motor skill development can involve a shift towards deliberate practice, which may be accomplished by utilizing the training methods described above, but still requires many hours of practice to improve performance.

4.1 Conclusion

The current study examined the motor skill retention of two KM self-defense strike techniques: straight punch and defensive kick under two training conditions. One training group received an initial single training session; and the other group received four additional training sessions. Results for both strike techniques demonstrated that there was no significant difference undergoing either single or multiple training sessions for improved skill acquisition or retention.

These results suggest that the skill level obtained following an initial instruction session can be retained for up to 12 days; and that additional training did not improve skill level. It is speculated that the additional training sessions did not provide enough learning to achieve further improvements in technique performance after the initial training session. Perhaps two weeks or even a month of additional training would be required to stimulate an improvement in performance. Alternatively, perhaps a restructuring of the training protocol may have been necessary following the initial instruction session to produce further improvement in technique performance. For example, increasing contextual interference by alternating between punch and kick trials during the training sessions could increase performance as opposed to the blocked training schedule used in this study. Additional suggestions include dyad training, self-controlled training, as well as providing a greater passage of time for offline learning. An outcome of this study is the new knowledge that such minimal training is not adequate to stimulate the learning of KM techniques. Therefore, KM instructors should consider using other training methods, such as those listed above, in their own pedagogy.

4.2 Limitations

A clear limitation is the immovability of the striking target. Although the target was heavily padded with foam, the target remained static during impact trials. This rigidity of the target may have altered the development of skilled movement, as participants might have slowed their movements in an effort to reduce impact forces and thus reduce the risk of injury, deliberately or otherwise. Although participants were instructed to strike as hard as possible, they might not have done so. Going forward, the striking target may be placed on a pneumatic piston so that it may act as a shock absorber when the impact force is applied. When the participant applies a force, the piston would retract by sliding backwards to attenuate the forces that may

cause damage to body structures. The sample selected for the current study included healthy young female adults. Therefore, a second limitation is the generalizability of the present findings to other age groups, as well as to the male population.

4.3 Future Areas of Study

Future areas of study for the motor learning of KM techniques will be the addition of other aspects involved in a real-world self-defense situation. For example, in a real-world situation, the effects of stress when encountered by a life-threatening situation, such as an opponent, can cause motor performance to decline. Furthermore, the reaction time of the techniques practiced should also be investigated due to the necessity of reacting quickly to increase the chances of successfully defusing a dangerous situation. This may be accomplished by imposing a stimulus, visual or auditory, in an experimental protocol, in which participants must react and perform the technique as quickly as possible; as opposed to the current study's protocol in which participants were allowed to execute when prepared. The use of EMG recording should also be implemented in future studies to capture the sequencing of muscle activation in order to identify the specific segment movement patterns before and after the training protocol. The determination of sex as well as age differences in learning KM strike techniques should also be investigated. Furthermore, to address the relatively limited amount of training that participants received, the effects of a semester-long (i.e., four month) training protocol on the learning and performance of KM techniques should also be investigated.

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Appendices

Appendix A: Participant screening form

Study Name: The Effects of Single Versus Multiple Training Sessions on the Motor Skill Retention of Two Krav Maga Strike Techniques

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 or lbs): _____

Phone number: _____   E-mail: _____

Screening Questions

1) Do you have any previous martial arts/self-defense experience?   □ Yes   □ No
   If yes, describe. (i.e. Karate, Kung Fu?)
   _____

2) Are you generally in good health?   □ Yes   □ No

3) Do you have any diagnosed serious or chronic conditions?   □ Yes   □ No
   If yes, describe. (i.e., thyroid, metabolic disease?)
   _____

4) Do you have any diagnosed cardiovascular conditions?
   If yes, describe. (i.e., high blood pressure, heart attack, blood clots?)   □ Yes   □ No
   _____

5) Do you have any diagnosed neurological disorders?
   If yes, describe. (i.e., stroke, Parkinson's or Huntington's disease, diagnosed vertigo) □ Yes   □ No
   _____

6) Do you have any diagnosed musculoskeletal conditions?
   If yes, describe. (i.e., arthritis?)   □ Yes   □ No
   _____

7) Have you had any injury, pain or surgery in the previous 6 months on your wrist,   □ Yes   □ No
   elbow, shoulder ankle, knee, hip or low back?
   If yes, describe. (i.e., ACL tear, joint dislocation?)
   _____

8) Competitive sport background (Competitive defined as beyond the recreational
   level). If yes, list sport(s). (i.e., soccer, dance)   □ Yes   □ No
   _____

For any question above in which you answered "Yes", will the condition(s) described □ Yes   □ No

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?   □ Yes   □ No

Eligible to participate   □ Yes   □ No
Principle investigator initials: _____

Appendix B: Participant anthropometrics table

Name		
Age		
Mass (kg)		
Height (m)		
Trunk depth (cm)		
Leg Length (cm)		
Knee Width (cm)		
Ankle Width (cm)		
Shoulder Offset (cm)		
Wrist Width (cm)		
Hand Width (cm)		
Elbow width (cm)		

Appendix C: Full body marker set template.

Right Foot:	Left Foot:
• R heel • R 1st metatarsal • R 5th metatarsal	• L heel • L 1st metatarsal • L 5th metatarsal
Right Lower Leg:	Left Lower Leg:
• R fibular head • R medial epicondyle (tibia) • R shank • R lateral malleolus • R medial malleolus	• L fibular head • L medial epicondyle (tibia) • L shank • L lateral malleolus • L medial malleolus
Right Upper Leg:	Left Upper Leg:
• R greater trochanter • R thigh • R lateral femoral epicondyle • R medial femoral epicondyle	• L greater trochanter • L thigh • L lateral femoral epicondyle • L medial femoral epicondyle
Right Upper Arm:	Left Upper Arm:
• R lateral epicondyle (humerus) • R bicep • R acromion • R anterior deltoid • R medial deltoid • R posterior deltoid	• L lateral epicondyle (humerus) • L bicep • L acromion • L anterior deltoid • L medial deltoid • L posterior deltoid
Right Forearm:	Left Forearm:
• R radial styloid process • R ulnar styloid process	• L radial styloid process • L ulnar styloid process
Right Hand:	Left Hand:
• R 2nd metacarpal • R 3rd metacarpal • R 5th metacarpal	• L 2nd metacarpal • L 3rd metacarpal • L 5th metacarpal
Hip:	Trunk:
• R posterior superior iliac spine • L posterior superior iliac spine • R anterior superior iliac spine • L anterior superior iliac spine • R iliac crest • L Iliac crest	• T10 • C7 • Manubrium • Xiphoid process
Head:	
• Right back head • Right front head • Left back head • Left front head	

Appendix D: Components of the Krav Maga techniques outlined by events

Straight Punch Technique		Defensive Kick Technique	
Component 1:	Arm abduction	Component 1:	Thigh-thorax flexion
Event 1: IN	Initiation of hand movement indicated by first instance of positive hand velocity in the anterior-posterior direction towards the target.	Event 1: IN	Initiation of foot movement indicated by first instance of positive foot velocity in the anterior-posterior direction towards the target.
Event 2: P CON	Peak contact with target indicated by peak force on force cube in the anterior-posterior direction.	Event 2: FLEX	Smallest thigh-thorax flexion angle formed between the initiation of the kick to contact with target
		Event 3: P CON	Peak contact with target indicated by peak spike in force on the force cube in the anterior-posterior direction.
Measure:	Amount of arm abduction about the shoulder joint in degrees between events IN and CON	Measure:	Maximum thigh-thorax flexion about the thigh-thorax joint in degrees between events IN and CON.
Component 2:	Peak retraction velocity	Component 2:	Knee extension
Event 1: P CON	Peak contact with target indicated by peak force on force cube in the anterior-posterior direction.	Event 1: P CON	Peak contact with target indicated by peak spike in force on the force cube in the anterior-posterior direction.
Event 2: END	End of punch recoil indicated when the hand stops moving back towards the body in the anterior-posterior direction.	Event 2: EXT	Will represent knee angle at the time of maximum knee extension between P CON and POST CON.
		Event 3: POST CON	End of foot contact with target indicted by zero impact reaction force on the force cube in the anterior-posterior direction.
Measure:	Peak velocity value of fist retraction between events P CON and END.	Measure:	Greatest extension angle about the knee joint in degrees between events P CON and POST CON.
Component 3:	Anterior GRF	Component 3:	Anterior GRF
Event 1: IN	Initiation of hand movement indicated by first instance of positive hand velocity in the anterior-posterior direction towards the target.	Event 1: IN	Initiation of foot movement indicated by first instance of positive foot velocity in the anterior-posterior direction towards the target.
Event 2: P CON	Peak contact with target indicated by peak force on force cube in the anterior-posterior direction.	Event 2: P CON	Peak contact with target indicated by peak spike in force on the force cube in the anterior-posterior direction.
Measure:	Peak anterior GRF.	Measure:	Peak anterior GRF.