3D ANALYSIS OF PUNCHING TECHNIQUE: REVERSE VS. LEAD

(GYAKU TSUKI VS. OI TSUKI)

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Master of Arts
in
Kinesiology

by
Douglas M. Gallaher
Fall 2013
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DEDICATION

This thesis is dedicated to the single biggest strength in my life, my soon to be wife Jennifer Gallaher. Throughout this process and others, she has been my rock and continues to love and support me as I walk the road of life. At the time this thesis was finished I had recently lost my good friend, Cortlan Lininger. With respect for him I accomplish a goal that he fully supported and encouraged me to attain. I leave this dedication with a Japanese idea I found moving while working on this project:

“Bunbu Ichi”

The pen and sword are one
ACKNOWLEDGMENTS

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ABSTRACT

3D ANALYSIS OF PUNCHING TECHNIQUE: REVERSE VS. LEAD

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by

Douglas M. Gallaher

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The purpose of the current study was to compare the kinematic variables of reverse and lead punching techniques. Fourteen male black belt karate practitioners were recruited. Each subject performed five reverse and five lead punches while measurements were taken for three-dimensional analysis. The analyses focused on the variable calculations for hip, shoulder, elbow, and wrist of the punching arm. The reverse punch had a peak resultant velocity (PRV) at the wrist of 5.63 ± 0.87 m/s, while the lead punch had 4.84 ± 0.84 m/s. Results indicated that there were significant differences in the peak resultant velocity at the wrist between the reverse and the lead techniques ($p < .01$). Action time for the lead punch was significantly faster than the reverse punch, 169 ± 31.1 ms compared to 213 ± 51.6 ms ($p < .05$). The linear displacements at the hip, shoulder, elbow, and wrist were all significantly greater in the reverse punch variation ($p < .05$). Action time was associated with peak resultant velocity (PRV) measured at the wrist in
the lead punch ($r = .55, p < .05$). PRV at hip, shoulder, and elbow was strongly
associated with PRV at the wrist in both techniques ($r = .74, p < .05; r = .68, p < .05;$
$r = .64, p < .05; r = .81, p < .05; r = .78, p < .05; r = .62, p < .05$). Range of motion at
the shoulder and hip was statistically associated with PRV at the wrist for the reverse
punch, while the shoulder and elbow were associated with the lead punch variation
($r = .54, p < .05; r = .7, p < .05; r = .47, p < .05; r = .33, p < .05$). Qualitative
observations were made concerning inter-joint coordination, balance, and range of
motion.
CHAPTER I

INTRODUCTION

The martial arts have attracted millions of participants worldwide. They have been practiced for self-defense, mental discipline, harmony of the body and mind, physical fitness, and sport competition. In the USA alone, somewhere between 2 and 10 million people participate in karate, judo, or another form of martial art (Cox, 1993; Nowjak-Raymer & Hill, 1996). In addition, mixed martial arts fighting is broadcast internationally to millions of spectators and in turn attracts attention to all martial arts programs and training (Fox, 2013). Most martial arts are hundreds of years old and are taught traditionally by apprenticeship. The difference among styles and technique is so great which leads to disagreement among experts in the field on what is proper form (Beasley, 2003; Mitchell, 1991; Nakayama, 1966). This often leads to practitioners seeking ways to enhance their performance for different purposes.

Most performers practice for one common purpose, competition, which has been arranged at local, regional, national, and international levels. During the competition, the performers use a combination of different techniques such as punching and kicking to score by making contact with the opponent’s body parts. Therefore, scientific data on martial art techniques are crucial for coaches and athletes in terms of effective training and practice. When assessing the offensive techniques that practitioners
possess, the hand or fist is a focal point. In traditional karate point sparring, called *kumite*, victory depends on many factors. And while scoring opportunities differ greatly speed is always a crucial factor. Punches delivered to the solar plexus are valid score criterion (National Karate Federation, USA Karate, 2012, p. 12).

Speed in competition is comprised of different components. This can include the time to react to offensive movements, the selection of an appropriate response, initiation of movement, and execution of the technique. Response selection is influenced by the contextual factors of the distance between fist and target and the dynamic distance between competitors. Although greater distances are associated with greater response times, they may enable a greater speed of the fist getting to the target.

The two most common punching techniques, *Gyaku tsuki* and *Oi tsuki*, are used in all karate tournaments in the United States (Figure 1). Figure 1 is a stylized drawing of the techniques intended to show foot positioning relative to the hand punching

*Figure 1*. Hand and foot positioning on left for *Oi tsuki*, and right for *Gyaku tsuki*.

and does not reflect mechanics of execution. The *Gyaku tsuki* is also referred to as the reverse punch because the hand that is punching is opposite the leg that is forward. This
variation employs a greater range of motion in the hips and a greater distance from the fist to the target by nature of its execution.

The *Oi tsuki*, or lead punch, is an alternative technique thrown by karate practitioners. The hand that is punching is on the same side as the leg that is forward, similar to a boxer’s straight jab. This type of punch can be thrown to the head or body and is a part of many offensive combinations. Use of the lead punch may diversify attacks and occupy the opponent’s attention providing more opportunities to score. Many times both punches are used by competitors in a tournament setting.

Training advice for these punching techniques is minimal and sometimes conflicting. For example, Beasley (2003), in 40 years of competition, found the reverse punch to be one of the most effective in scoring. However, Nakayama (1966) believed the lead punch to have more devastating force behind it than any other punching motion. This is important because vigorous application is one of the six criteria required for scoring in the USA National Karate Federation tournament rules (National Karate Federation, USA Karate, 2012, p. 12). In practical terms, vigorous application is understood to mean the speed of the technique, so that judges can perceive the force that was developed through that speed. Not only the speed of the punching hand itself is important, but also the movement time of each technique. However, the kinematic differences between the two techniques remain inconclusive, especially the association among the kinematic variables and the result of punching techniques.

Much is known about the history of both punching techniques in karate and there are books that describe their performance. Previous research has addressed performance and competition quantitatively (Gulledge & Dapena, 2007; Yoshihuku,
Ikegami, & Sakurai, 1987). Peak velocities at the wrist were measured in the 6 to 8 m/s range (Cesari & Bertucco, 2008; Chiu & Shiang, 2000; Hofmann, Witte, & Emmermacher, 2008; Nakayama, 1966; Whiting, Gregor, & Finerman, 1988; Yoshihuku et al., 1987). Although similar findings were revealed in previous studies, the implications and application of these findings remain ambiguous due to the limitations of the research methods and design. The first limitation is that all linear kinematic variables were obtained in the horizontal direction from a two-dimensional plane (Chiu & Shiang, 2000; Gulledge & Dapena, 2007; Shibayama & Fukashiro, 1997). However, the punching techniques in Karate depend on the linear distance and speed (resultant direction in three-dimensional space) to score. Furthermore, there are limited studies focused on the investigation of the cause of observed performance. Another limitation that resulted in similar findings may be due to the small homogenous groups of elite level participants (Hofmann et al., 2008; VencesBrito, Ferreria, Cortes, Fernandes, & Pezarat-Correia, 2011).

Aside from the mentioned speed studies, range of motion and coordination of body segments has not been reported on for martial arts punching techniques (Costelloe, Kingman, & Dyson, 2002). Specifically, hip displacements and any correlations between peak velocity and other factors are lacking. Qualitative observations of center of mass, balance, and range of motion are near impossible in a 2D setting due to the frame of reference (Gulledge & Dapena, 2007). With all the quantitative data available, there is still a very small amount of information on qualitative performance (Cesari & Bertucco, 2008; Costelloe et al., 2002; Gulledge & Depena, 2007).
What athletes and coaches could benefit from involves qualitative description of punching motions. Of specific interest displacement of the hips and changing foot positioning may reveal interesting findings. The punch motion is presented in multiple disciplines and possible implications may be of interest to other groups and help encourage the use of biomechanical description. Coaches and athletes need to know what they can modify and how that will affect competition performance.

Correct distance and good timing are interrelated scoring criteria. They are described in the rules as the precise distance from the opponent to deliver the technique and the proper timing for it to have the greatest potential effect (National Karate Federation, USA Karate, 2012, p. 14). In other words, hitting a scoring area as the opponent is retreating or the full extension of a punch too far from a scoring area will not satisfy the criteria. Also, the timing of the attack must reveal this potential, a punch from both competitors landing simultaneously is not score worthy. Other criteria required for valid scoring include form, attitude, and focus. These are accomplished as long as competitors are properly performing the techniques. Therefore, speed and distance become the deciding factors and the easiest to discern visually for judges.

How tournament coaches should be training their athletes becomes a pertinent question. Understanding more about these variations of punch, in a biomechanical sense, will help all martial artists whether they compete or not.

Statement of the Problem

This study was performed to expand the body of knowledge on the biomechanics of the reverse and lead punches. The first objective was to evaluate the
techniques with respect to the kinematic variables relevant to the punch: speed of motion, temporal values, and range of motion. The second objective was to determine whether one variation had a significantly faster resultant velocity measured at the wrist. The last objective was to examine the association between the peak resultant velocity at the wrist and selected variables.

Hypotheses

1. Temporal variables
   a. Reaction time between techniques is similar.
   b. Action time will be shorter for the lead punch technique.
   c. Total movement time will be shorter for the lead punch technique.

2. Peak resultant velocity
   a. The reverse punch will have a greater peak resultant velocity measured at all markers.

3. Resultant linear displacement
   a. The reverse punch technique will have a significantly greater linear range of motion at all markers.

4. Correlations between outcome of performance and selected variables.
   a. Age and experience will have a significant correlation with the peak resultant velocity at the wrist.
   b. Temporal variables will have a significant association with peak resultant velocity at the wrist.
c. Peak resultant velocity at other markers will have a significant association with peak resultant velocity at the wrist.

d. Resultant linear displacement at other markers will have a significant association with peak resultant velocity at the wrist.

Purpose

Due to the small body of research on the biomechanics of both punch techniques and disagreements among experts, this study was conducted to provide both quantitative and qualitative analysis on both reverse and lead punching technique performed in karate. The first purpose was to compare the differences of selected kinematic variables between the two techniques. Additionally, the association between kinematic variables and peak resultant velocity at the wrist were examined in each technique. The second purpose was to present a qualitative analysis for both punching techniques to provide crucial cues for coaches and athletes to enhance the training and performance efficiently.

Limitations

The limitations of the study were:

1. Relative strength, speed, and neuromuscular activation time of the subjects was not known.

2. An assumption, based on rank, was made as to the competency of technique performance by the subjects.

3. Only trials that had all marker data available were selected for analysis.

4. A visual stimulus light rather than an opponent’s movement was used to initiate each trial.
5. Only male subjects were used.

6. The assumption was made that full extension of movement is where target contact would occur.

7. Light stimulation and motion analysis synchronization was performed manually by the researcher.

Definition of Terms

**Action Time**

Time measured from onset of movement until full extension of the elbow joint during the punch.

**Karateka**

A Karate student.

**Kumite**

Coming together of hands or sparring, meant as a match between two karateka.

**Lead Punch (Oi tsuki)**

A punch with the arm on the same side as the leg forward.

**Peak Resultant Velocity**

Highest linear instantaneous velocity measured at the wrist during the execution phase.

**Reaction Time**

Time measured from stimulus to onset of movement.
**Resultant Linear Displacement**

Resultant displacement measured from the initial starting point of a marker to its final point at extension of the wrist.

**Reverse Punch (Gyaku tsuki)**

A punch with the arm opposite the leg forward.

**Total Time**

Time measured from stimulus until full extension of the elbow joint during the punch.
CHAPTER II

REVIEW OF LITERATURE

The purpose of this study was to examine the three-dimensional components of a karate punch using both the reverse and lead technique variations. The first objective was to evaluate and compare the techniques using kinematic variables. The second objective was to provide qualitative performance cues for coaches and athletes to improve training and performance respectively. This study will help encourage biomechanical descriptions of the karate punch and will be useful for practitioners of the martial arts as well as coaches and instructors.

A description of the karate punch is provided with respect to historically accepted execution. Next, biomechanical studies and expert opinion are presented for both the reverse and lead punch. This is followed by a discussion of the relevant core concepts of speed, range of motion, coordination, and balance in relation to the punch. Methods of measurement for the punch will be discussed among the available literature in the last 50 years.

History of the Karate Punch

Beginning in 1609, the Satsuma clan of Japan samurai invaded Okinawa and the people were not permitted to possess bladed weapons on the islands. The combat art, now known as karate, was developed for self-preservation in response to the oppression
of these Japanese samurai (Haley’s Martial Arts Handbook, 2001). The different karate styles that originated on Okinawa were named after the region they came from: Shuri te, Naha te, and Tomari te. Control by the ruling samurai lasted for hundreds of years and karate was practiced in secret. Although karate’s spiritual essence and teachings are defensive, practitioners were sometimes faced with life-threatening danger and had to rely on the physical skills they had learned. Karate could be used for killing or maiming highly trained opponents and survival necessitated effective technique derived from intense training. When Okinawa was formally annexed by Japan in 1872, control was relaxed, and the need for unarmed combat declined. The emphasis shifted to self-improvement and sport applications of karate as new focus refined development. In 1936, the term karate was formally used to describe the art that had developed (Haley’s Martial Arts Handbook, 2001, p. 3).

The introduction of karate competition allowed participants to test and display hard-earned skill in a controlled and safe environment. After World War II, international tournaments for karate were just starting to be held and teachers realized that tournament recognition accomplished the goal of greater exposure for their respective styles. Tournament victories also provided status among styles that were competing for membership and superiority. Since the late 1990s, there has been a proliferation of martial arts training and competition in the USA. One-time pay-per-view events, depicting fighting between opponents, are ordered frequently by nearly one million viewers (Fox, 2013). As the popularity of these events increased so did the need for quality coaching and training methods.
Many in the United States are more familiar with boxing and may have been introduced to the jab technique. The boxing punch has been studied extensively and involves straight line and curving trajectories also found in karate (Atha, Yeadon, Sandover, & Parsons, 1985; Favre, Mass, & Aminian, 2007; Hristovski, Davids, Araújo, & Button, 2006; Walilko, Viano, & Bir, 2005; Whiting et al., 1988). Similarities exist between punching techniques among these different disciplines and the results of studies may be used to help explain that relationship. Western society would benefit from increasing the depth and availability of martial arts research.

The reverse punch is described in the literature but rarely using biomechanical methods. Corcoran and Farkas (1983), during the compilation of a martial arts history encyclopedia, stated that the reverse punch is the most widely used technique in karate. In 2008, Hofmann et al. studied the punch with respect to sport application. In observation, but without quantification, they noted that the most frequently used fist punch was also reverse punch. The reasons attributed to the selection of this technique by competitors were given as a short execution time, and simpler mechanics compared to kicking in karate. This study pointed to the prevalence of the reverse punch at competition as a reason to scientifically analyze the motion in three-dimensions.

Description of the Karate Punch

Learning Japanese karate terminology is part of the curriculum in traditional dojo. When the term tsuki is paired with a direction or description, it becomes the way to name the punch in karate. *Gyaku tsuki* can be translated to English as reverse punch and *Oi tsuki* can be translated to English as lead punch in this way. During this review
kinematic variables in the literature are discussed along with important findings and limitations. Studies focused on the kinetics of the punch motion are briefly summarized according to relevant data.

The motor pattern determines when and which segments are used during the execution of technique. The feet, legs, hips, torso, and arm each have a part to play. The punch is usually thrown with either hand from different stances at a target directly in front of the individual. This straight line is the basis of all punch motions. Nakayama (1966) stated that the performance is accomplished by allowing the elbow to brush the torso as the punch is delivered. The arm rotates inward as one extends terminating behind the target (p. 98). The energy flows from the legs through the hips and torso out the shoulder and is transmitted to the arm for striking.

**Qualitative Biomechanics**

The muscles used in punching include the biceps, triceps, deltoids, teres major, serratus anterior, latissimus dorsi, external obliques, pectoralis major, and rectus abdominis (Nakayama, 1966, p. 103). This list outlines the muscles of the upper half of the body used in delivering the punch. Referring to what Wallace and Flanagan (1999) wrote, the muscles of the lower body contribute in the earlier energy generation phase. A detailed list of each lower extremity muscle used would be exhaustive. The whole body contributes to the execution of the technique. This lower half energy is built up and transferred through the body to the striking hand.

The energy generated by the legs and transferred to the hand begins with the stance, or foot positioning, of the individual. In the coronal and sagittal planes, the feet are shoulder width apart or greater depending on length of limb of the individual. The
relative angle and weight distribution of each foot are subject to modification. The toes of the front foot are at nearly 0 degrees and the rear foot may angle outward from 20 to 45 degrees from the sagittal plane (Loczi, 1985) though this is debatable. Stull and Barnham (1988) agreed with Loczi and indicated the proper weight distribution of 60% front and 40% rear when describing the reverse punch. Other research described 70% of the weight on the front foot (Liu & Wang, 2002). However, none of the study explains why this distribution is preferred over another.

At the beginning of execution, a natural body stance is assumed where the center of gravity sits above the center of the base of support. After the onset of movement, the lower abdominal area and the hips play a great part in the movements of karate. If the power concentrated in this region is used when executing karate technique, the activation of abdominal torque allows stability of body components and compactness between the pelvis and trunk for an improvement in balance (Sforza et al., 2000). A displacement of the hips is observed during the performance of a punching technique even without an advance of the body (Sforza et al., 2000). This indicates that the torso is accomplishing a form of energy transference. Wallace and Flanagan (1999) stressed that a strong flexible trunk is essential not only for protection of internal organs and avoiding muscle strains but also for generating and transmitting high impact forces to the opponent. They determined that the obliques played an integral role in helping transmit the torque generated in the punch.

**Balance.** The concept of balance, as defined in biomechanics, investigates the location of the center of gravity in relation to the base of support. Those mechanics or body movements where the center of gravity is found to remain within the base of
support are termed balanced. Once the center of gravity strays outside the base of support, balance is reduced and mobility increases. Studies on performance optimization related to balance and center of gravity during punch technique are scarce.

Loczi (1985) touched on weight distribution in his analysis of lead punch, mentioning the controversy surrounding the appropriate amount of weight for each foot. Many martial artists and authors disagree on the percentages of weight distribution between the legs. Drawing support from Nakayama’s study, Loczi (1985) used 60% lead foot and 40% rear foot in his research design. Actual results show that the weight distribution on average among the subjects was 53.8% and 46.2%, for lead and rear foot, which appears closer to evenly distributed. Curiously, Stull and Barnham (1988) also describe 60% (lead foot) and 40% (rear foot) distribution while describing the performance of the reverse punch by karateka. Additionally, Liu and Wang’s (2002) study specifically altered the weight distribution between feet in order to evaluate its effect on performance. Loczi failed to find significant differences in execution times between different weight distributions while Liu and Wang were able to show decreased action time when lower extremities generated the energy for the punch. The appropriateness of modifying the weight distribution as it relates to punch execution is disputed (Beasley, 2003; Nakayama, 1966). Still the results suggest that stance analysis can be applied to movements where hand speed is a key factor.

In Italy, Cesari and Bertucco (2008) coupled punch efficacy and body stability. Expression of efficacy required development of upper limb velocity and force combined with dynamic control of body stability during the punching motion. The study focused on how two techniques differ in terms of performance while observing center of
pressure movement on a Kistler force platform. Additionally, upper limb velocity and impulse applied at impact was calculated. Experts were able to produce higher speeds of 7 m/s to 9 m/s, a greater displacement of the target, and greater impulse during the punch. Larger linear punching impulses could be more effective in throwing an opponent off balance and should be evaluated further (Gulledge & Dapena, 2007). Results were explained as the ability to control movement by limiting the backward center of pressure displacement after target contact and indicated the experts had more control capability during the punch. Future investigations on displacement of the center of gravity as it moves through three dimensional space will be an effort to shed light on movement patterns that accomplish greater fist velocities.

Coordination. The positioning and motion of the body is not enough to describe the punching movement. The proper coordination of each body segment must also be accomplished. Relaxation of the body is crucial in executing the punch and any muscle groups that are tensed at the wrong time will hamper the speed and smoothness of the technique (Nakayama, 1966). In 2002, Costelloe et al. reported that “qualitative analysis of the EMG data revealed simultaneous activity of both the agonist and antagonist muscles at the start of the punch movement among experts” (p. 5). The karateka group and an untrained control group provided EMG punch data measured at the biceps and triceps in an attempt to evaluate coordination. The study concluded that greater punch velocities found in the expert group suggested coordinated muscular activity that may increase muscle tone, combined with training response. Coordination of different muscle groups within each body segment is useful but focusing on the coordination between segments may help improve teaching cues more readily.
The sequence and way in which actions of the body segments are timed is known as another method to determine coordination. What appears to be broken and jerky movement while performing is considered uncoordinated. Most movements fall on a continuum between simultaneous and sequential coordination depending on the objectives of that movement. Coordination has been alternatively referred to as segmental interaction and can be the number of segments involved or the nature of that involvement. High-speed movements by skilled performers usually rely on sequential coordination as in most throwing or striking motions seen in baseball, golf, and hockey (Hudson, 1995).

The kinetic linking theory has been used to explain throwing or whip like motions in other sports and could be a useful framework for the coordination of punching motion (Wallace & Flanagan, 1999). Specifically the karate punch may follow the kinetic link principle, a sequential pattern, that was touched on by VencesBrito et al. (2011) and Yoshihuku et al. (1987). Findings from Cavanagh and Landa (1976) show a sequential pattern of motion specifically in the shoulder and elbow joints during the punch. This was supported by EMG data that revealed sequential firing during muscle action. Wallace and Flanagan (1999) mentioned the kinetic link system as applied to the straight punch motion as involving ankle flexion, knee and hip extension, trunk rotation, and arm extension.

The kinetic link principle describes proximal-to-distal coordination and relies on the fact that proximal body segments, like the trunk or pelvis, have more mass and tend to have a greater moment of inertia. During movement, larger muscles that are connected to those segments attempt to achieve maximum angular velocity. Next, these
large muscles contract increasing the angular velocity of distal segments and then relax thereby transferring this velocity to the next distal segment by conservation of angular momentum. Loczi (1985) indicated that body parts measured did not reach their respective peak velocities simultaneously for the lead punch technique. Also, the more advanced participants reached peak velocity at each body segment in a shorter time range, leading us to believe that sequential coordination among segments exists along with effective transference of peak velocities. VencesBrito et al. (2011) confirmed these results with Portuguese karate experts who were observed as having significant differences in movement time. Peak angular speed of the forearm rotation was reached after the peak in the upper arm and much closer to contact. These results support the proximal-to-distal characteristics of punch techniques. Expanding the knowledge base for coordinated movement should be part of any research concerning the whole body.

The karate punch focused on the middle chest is often the first technique learned and is an example of a ballistic action. A specific motor program and neuromuscular coordination pattern related to the task is used to accomplish the punch motion. The short duration of the punching movement limits the amount of visual or proprioceptive correction that can be applied by the puncher (VencesBrito et al., 2011). The interaction between body segments may be difficult to adjust but the use of more or less segments involved in motion can be qualitatively observed and adjusted.

Coordination can be used to make biomechanical systems easier to describe. Yoshihuku et al. (1987) said that in tsuki motion it is necessary to accelerate the arm, by rapid movement of the shoulder, to a high velocity for maximum energy. Focusing on horizontal velocity, they surmised that the upper arm accepts a large force from the
shoulder joint and the angle between the trunk segment and transverse plane was not changing significantly. As the trunk rotates about the longitudinal axis, its angular velocity in the sagittal plane also had small values. The authors decided that those values were small enough to treat the arm as a pure linear velocity heading toward the intended target. This theory could be an important step for reliability of the comparison among techniques. In three-dimensional space, it may be more apparent whether this is an accurate or useful indication of velocity.

**Range of Motion.** The distance a body or segment travels over a specified interval of time is what biomechanists are looking for when the range of motion concept is used. This concept is tied tightly to speed of motion for the purposes of the study. As the distance over which force can be applied increases so does the velocity. Adjusting the amount of motion can be one of the easiest changes for performers to accomplish.

Effective karate punch techniques are difficult to perform and require the use of the entire body to apply the technique over a very short time period. The *Gyaku* is executed in sparring stance and the attacking force is transferred by rotating the trunk and extending the arm. The *Oi* is executed with the lead hand as the entire body moves forward (Chiu & Shiang, 1999). Shoulder and hip displacements need to be measured and compared among the variations. The measurements can possibly point out deficiencies or areas of concrete improvement for performance enhancement. It could be as simple as advising the need to rotate the torso more based on an observation of prior performance.

Gulledge and Dapena (2007) supposed that the power or lead punch, while having a smaller range of motion than the reverse punch, should have a slower velocity. This is due to the shorter time and distance over which to develop this velocity. Values of
4 m/s for the lead punch versus 6.4 m/s for the reverse punch were reported. Shahbazi, Sheikh, and Amini (2005) wanted to quantify the speed difference between throwing the reverse punch from the waist and midway along the hip using both classical and modified technique. Even though speed was the variable of interest, this study manipulated the range of motion available to the technique in order to determine its effect. Results indicated that changing the position of the starting hand did not significantly increase punch velocity. These two studies show the disparity between conclusions reached and further analysis is needed. Perhaps three-dimensional data will help determine the range of motion that results in increase velocity and improved performance.

Quantitative Biomechanics

Reaction and Movement Time. Speed measures are useful in description once the technique has been selected and begun. Reaction and movement time become critically important to success when considering the dynamic aspect of tournaments and unpredictability of opponent’s motion. Chiu and Shiang (2000) measured reaction time from the stimulus light to the foot leaving the force plate for both punches. Based on mean values a faster reaction time was observed for the reverse variation versus the lead but could be due to technique preference or chance, as it did not reach significance.

Favre et al. (2007) advocated that researchers should consider using visual stimulus of an adversary to create better conditions for studying reaction time. This is supported by earlier work of Mori, Ohtani and Imanaka (2002) in determining response times for video and dot stimulus while working with karateka. Video choice reaction time was more than twice as slow as any other condition, at 552ms, though the reaction time was faster for karateka over novices. The advantage was attributed to superior
anticipation of the attacking position, or trained response. All reaction times indicate that decisions were made before the offensive actions were completed in the video stimuli.

Vieten, Scholz, Kilani, and Kohloeffel (2007) were able to find significant differences in the reaction time of national team members versus other groups ($p < .05$). In a study of attention in athletes of high and low experience while engaged in open skill sports, Fontani Lodi, Felici, Migliorini, and Corradeschi (2006) identified karate as a sport requiring high reactivity. Varying types of attention tests were performed on all subjects and karateka of high experience reacted faster than those of low experience in simple reaction time, but no significant differences were found among all tests or groups.

For predicting performance, it appears anticipation and reaction time alone may be insufficient and will need to be coupled with defensive strategies regarding distance to opponent and technique selection (Mori et al., 2002). The study of reaction time by expert participants among different techniques and between studies is needed. Furthermore, the punch movement can be divided into different phases according to time elapsed and this have been utilized successfully for clarifying movement. Favre et al. (2007) evaluated four parameters including reaction and touch time, timing and coordination in a study of rated boxing competitors. Future studies may reliably choose between visual or audio stimuli when looking at punching technique, as no significant differences were found between reaction or touch times measured for either signal. The fastest reaction times and touch times were not recorded for the highest rated performer and an absence of significant difference among timings and coordination between skill levels for the boxers may indicate rating complexities or at worse invalid design and measurement.
In 1985, Loczi completed his study in order to better scientifically describe the lead punch thrown by experts. The purpose of the study was to find new information which could be used to develop teaching cues to help others improve. The study hypothesized that the lead punch execution time would be faster with a 0 degree rear foot angle from the sagittal plane similar to how track and field athletes push off the ground. Four subjects using different rear leg configurations were videotaped in order to calculate velocity at the fist, body, and ankle. Findings revealed there were no significant differences in execution times among the different rear foot angles.

Furthermore, Chiu and Shiang (2000) proposed different stance configurations coupled with stationary and moving punch variations. They reported that no detectable difference in attacking speed existed between reverse and lead punches but that the standing lead punch required the shortest total time to execute. Wang and Liu’s (2002) results directly contradict that when they reviewed lead and reverse punches in subsequent studies. Although the findings indicated that reverse punch had shorter attack time between stances for 24 male and female elite karate competitors, the results were not statistically significant.

Later, Liu and Wang (2002) introduced weight distribution conditions among the variations that may convolute the comparison of findings for temporal variables. Once results from their studies were run through a two-way analysis of variance the only important factor related to attack time was that of stance, and not technique selection. Differences in technique selection should be examined if the effect of weight distribution on attack time was deemed negligible.
In Chiu and Shiang’s (2000) study, they also used a different approach to evaluating karate punching technique that looked at reaction time, attacking speed, and punch force; while Hofmann et al. (2008) focused on total time and fist velocities in order to optimize punch execution. Before the 1998 Bangkok Asian Games, with the help of 12 subjects from the National Karate Team in Taiwan, Chiu and Shiang (2000) used a free motion design that allowed subjects to strike the suspended target as velocity and time phases were calculated. They concluded that the rear foot pushing off was more important for attack speed in the lead punch over the reverse punch, which seem to contradict Loczi’s (1985) previous findings and reveal the need for further analysis on the lead punch. Implications of this finding may still lead to the promotion of the lead punch technique in the competitive arena. However, results could be affected by small sample size and individual preferences for weight distribution and additional data should be collected from a larger sample size. Additionally, Favre and colleagues (2007) in Switzerland have evaluated the boxer’s jab in search of ideal execution; however, it has still yet to be determined.

**Punching Velocity.** Speed of motion and the ways of capturing it may be the most critical concept for punching motion. The rate of change of an object in motion describes this concept. That object can be hand or wrist, or the body as a whole unit, in the case of attacking speed. Hand velocity, movement time, muscular contraction speeds are just a few examples of measureable types of speeds. It can be measured at its peak, directly and instantaneously or derived from time and distance and reported as a mean speed. The speed of a punch can be manipulated by muscle forces, or mechanics of execution.
In the available literature punching motions measured at the fist result in average velocities dispersed around 6 m/s compared to peak velocities of approximately 8 m/s (Hofmann et al., 2008; Chiu & Shiang, 2000). These values were consistent with findings by Nakayama (1966), Yoshihuku et al. (1987), Whiting et al. (1988), and Cesari and Bertucco (2008). Looking at research completed by Shahbazi et al. in 2005, a range of 10.2 m/s to 16.2 m/s for average linear velocities of trained female subjects departs from the literature. This high linear speed data in relation to other studies could be one limitation of the two-dimensional method. In addition, the study concluded that the classical technique performance resulted in greater linear speeds. Peak linear velocities in studies of karate are seldom reported above 8 m/s. On the other hand, Yoshihuku et al. (1987) showed significant difference of punching velocity between trained experts and untrained novices ($p < 0.01$). However, a small number of subjects were tested and results indicated velocity in the 7 m/s range. A larger group of subjects may enable a closer approximation of peak velocities and may yield valuable comparisons with previous research.

The priority for punch speed exists when there is a rigid time constraint and the performance goal is to produce a quick response. In light contact sparring or kumite the goal is to score points to selected target areas on an opponent. To be effective one must maximize the speed of response since the goal is to score a point by touching the opponent in the valid area (Shahbazi et al., 2005). In order to achieve maximum speed the opposite arm becomes critical in the application of a punch. The faster the opposite arm is retracted, the more speed and power is translated into the punch (Nakayama, 1966, p. 100). While Neto, Silva, Marzullo, Bolander, and Bir (2012) found no significant
differences in punching accuracy, they found the hand speed was greater when strikes were performed with the dominant hand and moving towards the target \((p < .001)\). When stepping forward was not part of the performance, there were no significant hand speed differences between dominant and non-dominant hands. The difference in hand speed dominance was only significant for strikes performed while stepping towards the target. On average, dominant hand strikes were 11% faster and when moving, 18% faster.

**Other Variables.** Others have realized other factors beyond hand speed may play equally important parts. Neto et al. (2012) looked at peak impact force on a pressure sensor, instantaneous hand speed before impact, effective mass, and accuracy of hand strikes. They concluded that differences in effective mass, and not the hand speed, was responsible for what was observed during stationary striking. This finding is interesting because mass is not as viable or sensitive to manipulation as hand speed. Support for this finding is presented by Vieten et al. (2007) in a Tae Kwon Do kicking reaction time study. They concluded that during an attack is advisable to move as little mass as possible to accelerate those segments involved in the movement as quickly as possible.

The kinetic forces of the punch are also available (Walker, 1975). Karate strikes were used to break wood and concrete bricks. The peak punching force exerted by the reverse punch reached 1446N almost double that of the power punch at 790N in Gulledge and Dapena’s (2007) study. One conclusion they reached was that force values reported are valid for comparisons within each study but should not be compared across studies due to variation in types and thickness of padding, targets, or sensitivity of measuring devices. Individual measurements of values beyond force are often relative and are not always representative of the greater population.
Methodological Issues

The free motion target design was repeated and the results confirmed successfully by Neto et al. (2012) who were studying the effects of hand dominance and multiple stance conditions on martial arts striking. The authors observed straight-line trajectory of the punch from overhead footage and were able to reliably quantify hand speed laterally. Results were consistent with findings by Sforza et al. (2000) as well. Relevant to the discussion, Gulledge and Dapena (2007) suggested that in similar literature it is sometimes unclear if the subjects threw punches at the air or towards a target and suggested that the patterns of motion could be different. Comparison between air and target conditions for one type of punch may be another interesting avenue of research. Favre et al. (2007) recommended future punch studies consider using visual stimulus of an adversary for creating more competition specific conditions. Alternatively a fixed target consisting of a striking board was used for participants performing multiple punches without complications (VencesBrito et al., 2011).

Unlike previous examples, expert subjects performed unmodified techniques as kinematic comparisons were carried out by Gulledge and Dapena (2007). With the help of Kistler force plates, investigators compared the reverse punch from karate to a three-inch power punch. Measured horizontal ground reaction force produced by the feet was used to calculate the body’s center of mass impulse and video capture of upper body markers was used for peak fist velocities. The reverse punch produced greater average horizontal velocities than the power punch for whole body center of mass, and the fist. Perhaps introducing the classical karate technique lead punch, modeled after the power punch, to this method of study would yield the same results.
What is known is that reverse punch has been used and studied more than the lead punch. More is known about average and peak velocities of punching motions in boxing than martial arts. Knowing more about the important kinematic similarities and differences between these techniques would help illuminate critical features of the lead punch and punching in general.

Core Concepts of Biomechanics

Core concepts of biomechanical analysis have been successfully introduced for analysis of human movement by Hudson (1995). It can be beneficial to think of the concepts as radio buttons that can be dialed or adjusted to affect human performance. This can be especially helpful for educators and coaches as they guide training and performance. These concepts can be applied to complex human movement in an attempt to describe or learn from it. A review is provided for the concepts speed of motion, range of motion, coordination, and balance. They were felt to be the most useful factors in the literature on punching but should not be treated as all inclusive.
CHAPTER III

METHODOLOGY

The main purpose of this study was to compare kinematic variables in the reverse and lead punching techniques. Specifically, the peak resultant velocity and linear displacement were obtained and compared between the two techniques. Time spent in each phase of movement and total execution times were measured for each punch. In addition, the associations between the peak velocity at fist and other kinematic variables were examined. Finally, both techniques were compared and discussed qualitatively.

Subject Recruitment

Fourteen male subjects from the northern California area volunteered to participate in this study. They were between the ages of 10 and 50 with no outstanding injuries. All subjects were actively training at least 4 hours per week in Okinawan karate and held at least a Shodan, or first degree blackbelt, rank. Each subject verified receiving prior training in both reverse and lead punching technique. Each subject gave informed consent approved by the California State University Chico Human Subjects in Research Committee (see Appendix A). Subjects were asked to wear shorts and a tight fitting shirt appropriate for athletic movement.
Data Collection Procedure

Testing was completed in the month of November in 2012 and conducted in the Maglishco Biomechanics Laboratory at CSU, Chico. Data collection was performed individually for each subject and took one hour to complete. After all the demographical data were recorded (e.g., age, height, weight, years of experience, and preference of technique), the procedure for testing was discussed and preparation for testing began. The performance of all trials was not considered fatiguing for all trained subjects. Order of performance for the techniques was not a factor in results.

After reading and signing the consent form each subject completed five minutes of full-body stretching and upper body warm-up exercises. Next, each subject was fitted with 29 reflective markers covering the whole body (Helen Hayes Model, Appendix B). A cap was used to affix markers to the head, and subjects performed barefoot mimicking competition. Next, the subject was instructed to start from the ready position with the proper foot placement. Subjects were instructed to perform a reverse punch as they recognized the stimulus light. Data capture began as the stimulus light was lit. The primary researcher reviewed the live capture looking for any obvious or technical error. If errors were found the subject was asked to repeat the trial. Successful trials were saved according to subject and trial number. A rest period of ten seconds occurred between trials until five successful trials were gathered. Subjects were next asked to start from the ready position with the proper foot placement for lead punch. Subjects were asked to perform a lead punch as they recognized the stimulus light. The procedure for punch capture is repeated for five successful trials of lead punch. After all trials were collected five minutes of stretching was required as a cool down. The investigators
repeated this procedure for each subject. Three total trials had to be repeated for corrupted capture.

Filming Protocol

A six-camera infrared system from the Motion Analysis Corporation was used in conjunction with Cortex v3.1 software to track markers in three-dimensional space. Cameras capturing movement at 120 frames per second allowed for motion analysis. An L-frame reference marker was used prior to collecting data in order to calibrate the system and capture volume. Subsequently a calibration wand was walked over the entire volume to ensure tracking by all cameras. Any reflective areas a part of the surrounding room or floor were masked by the system to prevent interference.

Reflective markers, of 1mm diameter, were placed according to the Helen Hayes markerset model. This model consists of 29 marker locations and is included in Appendix B. Reflective joint markers were attached to the skin, cap, shirt, and shorts at the predetermined locations.

The stimulus for punching was created using a push button activated light bulb in full view of the subject (Figure 2). The activation of the light was hidden from the subjects to prevent early cues.

Digitizing

Data was processed and digitized using the Cortex Motion Analysis system. Five trials gathered from reverse and lead punch variations were used for each of the subjects. All trials were processed with the marker template based on each subject’s initial standing pose, creating the motion model. The primary investigator reviewed all
Figure 2. Camera setup showing capture volume and subject marker set.

trials for gaps in the data or where markers obscure each other in motion and corrected using Cortex post processing tools. Data was smoothed using the Butterworth filter set at 12hz cutoff frequency.

Data Analysis

Table 1 defines variables calculated for use in this study.

Table 1

*Summary of Calculated Variables*

<table>
<thead>
<tr>
<th>Variable</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Experience</td>
<td>Years of training in Okinawan Karate (4 years minimum to attain blackbelt)</td>
</tr>
<tr>
<td>Temporal Variables</td>
<td>Time phases during punch extension Reaction Time, Action Time, Total Time</td>
</tr>
<tr>
<td>Peak Resultant Velocity</td>
<td>Peak instantaneous velocity at each marker during punch extension</td>
</tr>
<tr>
<td>Linear Displacement</td>
<td>Resultant displacement measured at each marker from initial starting point to final point at extension of wrist</td>
</tr>
</tbody>
</table>
Statistical Analysis

Descriptive statistics of means and standard deviations for each variable were calculated. Paired $t$ test for paired samples were used for determining the significance of variable difference scores. To control for type I errors, Holm’s correction formula was used to calculate new adjusted critical $p$ values (Knudson, 2009). Zero order correlations were performed on peak resultant velocity at the wrist with respect to age, experience, temporal variables, marker peak resultant velocities, and linear displacements at each selected marker. Significance level set at 0.05. All statistics were calculated using Microsoft Excel.
CHAPTER IV

RESULTS AND DISCUSSION

Results

The purpose of this study was to compare the reverse and lead variations of punching techniques. The main goal was to examine the kinematic variables related to the results of movement between two techniques. This chapter is organized into two major sections, Results and Discussion. In the Results section, the findings of this current study is presented in the following order: subject characteristics, statistical comparisons (t test and correlations), and inter-joint coordination. In the Discussion section, the significant findings are interpreted quantitatively and qualitatively regarding these two punching techniques.

Subject Characteristics

Fourteen male subjects successfully completed the testing procedure. All subjects were drawn from the northern California area and were actively training karateka of black belt rank. All subjects were trained in Okinawan karate and had knowledge of both punching techniques for at least four years. Subject characteristics are presented as mean values with standard deviations in Table 2. The age range and experience for the participants are depicted in Figure 3.
Table 2

*Summary of Subject Characteristics*

<table>
<thead>
<tr>
<th>n = 14</th>
<th>Age (yr)</th>
<th>Height (cm)</th>
<th>Mass (kg)</th>
<th>Experience (yr)</th>
<th>Preference</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean ± SD</td>
<td>25.5 ± 14.4</td>
<td>177.1 ± 9.1</td>
<td>70.4 ± 24.4</td>
<td>10.6 ± 7.3</td>
<td>R 71% - L 29%</td>
</tr>
</tbody>
</table>

Note. R – reverse punch, L – lead punch

Figure 3. Age and experience for each participant.

Statistical Comparisons Between Techniques (Paired t test)

In this section, the kinematic variables were compared between the two punching techniques. The findings are presented in the following sections: temporal variables, linear peak resultant velocities, and linear displacement.
Temporal Variables

The punch movement time can be separated into reaction and action phases. The reaction phase was defined from the onset of stimulus light to the beginning of movement. The action phase was the duration from the beginning of movement to the end of punching performance identified as full extension of the elbow joint. Finally, the total movement times (reaction and action) between techniques were compared. Table 3 shows mean values and standard deviations for all the temporal variables among the entire group between techniques. The shortest time from among all trials for all subjects is also reported.

Table 3
Temporal Variables for the Reverse and Lead Punch

<table>
<thead>
<tr>
<th>Techniques</th>
<th>Reverse (mean ± SD)</th>
<th>Lead (mean ± SD)</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reaction Time</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>mean ±SD</td>
<td>194 ± 31.3 ms</td>
<td>204 ± 46.2 ms</td>
<td>0.08</td>
</tr>
<tr>
<td>quickest trial</td>
<td>67 ms</td>
<td>83 ms</td>
<td></td>
</tr>
<tr>
<td>Action Time</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>mean ±SD</td>
<td>213 ± 51.6 ms</td>
<td>169 ± 31.1 ms</td>
<td>&lt;0.01</td>
</tr>
<tr>
<td>quickest trial</td>
<td>125 ms</td>
<td>100 ms</td>
<td></td>
</tr>
<tr>
<td>Total Time</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>mean ±SD</td>
<td>406 ± 7.2 ms</td>
<td>373 ± 6.3 ms</td>
<td>0.06</td>
</tr>
<tr>
<td>quickest trial</td>
<td>250 ms</td>
<td>208 ms</td>
<td></td>
</tr>
</tbody>
</table>

Note. Statistical significance $p < 0.05$ ($\alpha = .05$).

Reaction Time

There was no significant difference of reaction time between the two techniques ($p = .08$). On average, the reaction times for reverse and lead punch are 194 ±
31.3 milliseconds and 204 ± 46.2 ms milliseconds, respectively. Additionally, there is a reaction time difference between the techniques on the quickest trials.

**Action Time**

The action time of the lead punch was significantly shorter than reverse \((p < .01)\). The mean action times for reverse and lead punch were 213 milliseconds and 169 milliseconds, respectively. Two subjects performing reverse punch had the same quickest movement time.

**Total Time**

There was no significant difference in total movement time \((p = .06)\). The average total movement time for reverse punch was 406 milliseconds. The lead punch had a total average movement time of 373 milliseconds.

**Peak Resultant Velocity**

The peak resultant velocities for the markers on the upper extremity are compared and presented in this section. The markers from the punching side were the wrist, elbow, shoulder, and hip. Hand speed was operationalized by examining the peak resultant velocity (PRV) at the wrist during the extension of the punch. Mean values and standard deviations for peak resultant velocities are given in Table 4. All the resultant peak velocities at each marker were significantly faster in reverse punch than lead punch \((p < .01)\).

In addition, peak resultant velocity curves at the wrist for each technique are shown in Figure 4. The blue curve represents reverse punch while the red for lead punch. During the discussion, the curves will be examined in more detail.
### Table 4

**Peak Resultant Velocities (PRV)**

<table>
<thead>
<tr>
<th>Markers</th>
<th>Reverse (mean ± SD)</th>
<th>Lead (mean ± SD)</th>
<th>$P$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wrist</td>
<td>5.63 ±0.87 m/s</td>
<td>4.84 ±0.84 m/s</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>Elbow</td>
<td>5.81 ±1.02 m/s</td>
<td>4.49 ±0.65 m/s</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>Shoulder</td>
<td>1.79 ±0.74 m/s</td>
<td>1.09 ±0.38 m/s</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Hip</td>
<td>1.04 ±0.45 m/s</td>
<td>0.79 ±0.36 m/s</td>
<td>&lt;0.01</td>
</tr>
</tbody>
</table>

*Note. Statistical significance $p < 0.05$ ($\alpha = .05$).*

### Linear Displacement

The linear displacements for reverse punch at each marker were significantly greater than lead punch ($p < .05$). Table 5 summarizes the means and standard deviations of the linear displacements at the wrist, elbow, shoulder, and hip on the punching side of body for both techniques.

### Statistical Correlation Between Variables

In this section, the association between the peak resultant velocity at wrist and several selected kinematic variables were examined in both techniques. The variables selected are: 1) age and experience; 2) times for reaction, action, and total movement times; 3) linear resultant velocity at other markers; and 4) range of motion of each marker.

#### Age and Experience

For reverse punch, the Zero-order correlation showed no significant association ($r = .02; p = .68$) between resultant peak velocity at wrist and age.
Additionally, there is also no significant relationship between peak punching velocity and experience ($r = .02; p = .67$).

For lead punch, the same was true. No significant association was found for either age or experience with respect to resultant peak velocity ($r = .2, p = .67; r = -.07, p = .8$).

**Time for Reaction, Action, and Total Movement**

For reverse punch, the association between linear peak velocity and reaction time was found insignificant ($r = .16; p = .21$). Additionally, no significance was found
Table 5

*Linear Displacements*

<table>
<thead>
<tr>
<th>Markers</th>
<th>Reverse (mean ± SD)</th>
<th>Lead (mean ± SD)</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wrist</td>
<td>255.4 ±80 mm</td>
<td>174.9 ±56.9 mm</td>
<td>&lt;0.00001</td>
</tr>
<tr>
<td>Elbow</td>
<td>365.9 ±122.4 mm</td>
<td>140.5 ±105.4 mm</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>Shoulder</td>
<td>121 ±51.8 mm</td>
<td>16.6 ±19.2 mm</td>
<td>&lt;0.00001</td>
</tr>
<tr>
<td>Hip</td>
<td>56.4 ±30.3 mm</td>
<td>19.9 ±22.8 mm</td>
<td>&lt;0.001</td>
</tr>
</tbody>
</table>

*Note.* Statistical significance $p < 0.05$ ($\alpha = .05$).

between linear peak velocity at the wrist and action time, ($r = .22; p = .09$), nor with total movement time ($r = .23; p = .07$). Figure 5 graphically represents the associations between peak punching velocity and reaction, action, and total movement times, respectively.

For lead punch, no significant association was found between linear peak velocity and reaction time ($r = .21; p = .09$). An association was found between linear peak velocity at the wrist and action time ($r = .55; p < .05$). A correlation was found between linear peak velocity and total time ($r = .4; p < .05$). Figure 6 shows the described correlations.

**Linear Resultant Velocities**

For reverse punch, zero order correlation was performed for the peak resultant velocity at the wrist versus the peak resultant velocity at the other upper extremity markers, hip, shoulder, and elbow. These correlations reveal significant associations between linear peak resultant velocity at the wrist and PRV at the hip, shoulder, and elbow ($r = .74; p < .05$; $r = .68, p < .05$; $r = .64, p < .05$).
Figure 5. Time phase correlations for PRV in reverse punch.
Figure 6. Time phase correlations for PRV in lead punch.
For lead punch, there were significant associations between linear resultant velocity at wrist and PRV at the hip, shoulder, and elbow \((r = .62, p < .05; r = .78, p < .05; r = .81, p < .05)\). The largest correlation for lead punch at the wrist was the PRV at the elbow.

Range of Motions

For reverse punch, there are statistically significant associations between linear peak resultant velocity and range of motion at the shoulder \((r = .7; p < .05)\). There is also an association between linear peak resultant velocity and range of motion at the hip \((r = .54, p < .05; \text{Figure 7})\).

![Figure 7](image.png)

*Figure 7. Correlation between PRV at the wrist and displacement at the hip in reverse punch.*

For lead punch, there was an association between linear peak resultant velocity and range of motion at the shoulder and elbow \((r = .47, p < .05; r = .33, \text{Figure 7})\).*
There was no association found between linear peak resultant velocity and range of motion at the hip or wrist ($r = .23, p = .08; r = .08, p = .56$).

**Inter Joint Coordination**

By examining the timing of markers’ movement, both punching techniques from all subjects showed a sequential segmental PRV timing from proximal to distal end. Puncing performance was consistent, the sequence was hip, shoulder, elbow, and finally wrist.

The timings for each body segment in the lead punch coordination are shown in Figure 8. The subjects’ trials were chosen to represent sequential performance in both techniques.

**Discussion**

The aim of this study was to compare the difference between two karate punching techniques, reverse and lead punch. This section is organized to discuss the findings in the following subsections:

- Meaning of data
- Implications
- Research design

**Meaning of Data**

Temporal Variables. Speed of motion takes multiple forms in the competitive setting. How fast the body is moving, how long it takes the technique to reach the scoring target, and the time to recognize opportunity to score are all measures of this core
Figure 8. Coordination pattern for reverse and lead punches respectively.

concept. Time phases for the punch will be discussed followed by resultant velocities at selected markers.

Simple reaction time, where the response is pre-selected and the motion used is practiced, fit nicely with the chosen research design. The response to the stimulus light is pre-selected per trial requirement and the motions had been practiced extensively by all subjects over the course of training.
Values of 194 ± 31.3 ms for reverse and 204 ± 46.2 ms for lead punch are within normal ranges of simple reaction times. The average simple reaction time in humans for visual stimulus is generally estimated at 200 ms (Brebner & Welford, 1980). Measured reaction times that are faster than this average could stem from a training response learned from repeated punching.

In most trials, the lateral right knee marker was the first to signal movement and has important ramifications from a defensive standpoint. Occasionally, subjects instead showed hip displacement first indicating a different coordination pattern. When the alternate coordination pattern was observed, the PRV was reduced and warrants further study. Hip and shoulder were also early indicators of reaction in a tae kwon do kicking study (Vieten et al., 2007) so it was thought that punching may be similar. Since reaction times were consistent against differences in technique, locating the body segment that visually moves first during punch execution may be more important to coaches and performers.

No significant differences were detected between means for reaction time or total time between the variations. Expectedly the reaction times are close as both are punch movement patterns and the stimulus is unchanging. Surprisingly close values for elapsed time were found, 406 ms for reverse and 373 ms for lead punch. With both punches arriving at the potential target in near the same time and without significant differences in reaction time between the two techniques, movement time and distancing becomes more critical and possibly predictive of successful performance.

The lead punch had a shorter movement time on average ($p < .05$) with mean times of 169 ms compared to 213 ms for the reverse. This quicker time can have both
advantages and disadvantages. The faster time to contact could preclude defense but the
time to develop force and increase velocity at the wrist is more limited, similar findings
were found by Gulledge and Dapena (2007). These findings do not entirely negate the
relative advantage of the lead punch getting to the target first and remain important to the
practitioner.

Additionally, the fastest recorded lead punch trial was very close to the
average reaction time among the group, 208ms and 204ms. This essentially means that
the lead technique would be landing just as the opponent attempts to react to the stimulus
of the approaching attack. This finding, while noteworthy, must be treated with caution
because reaction times when initiating and responding to attack may not be similar.
Often, a counter attack is the necessary defense and would be sensitive to the data. In this
study, the time to return to guard position from each technique was not measured but
would be critical in a competitive setting as one would recover from each technique and
factor in defensive positioning.

Individually, seven of the subjects demonstrated a time phase pattern that was
the same: shorter mean times for reaction and movement phases in the lead punch
variation. This may relate to the distance of full extension between both starting
positions. All subjects had the punching hand retracted farther in the starting position of
reverse compared to lead punch. In reverse punch, the speed that the hand is traveling
may not make up for the time it takes to get there. The competitor may still have an
opportunity to score with a slower hand speed but shorter movement time. Remember in
a competition setting the opponent would have a chance to react and respond to each
technique as it is thrown. Defensive reaction times should be looked at to determine the
optimum trade off and subsequent interactions with elapsed time. Only Subject 11, who also had the greatest overall mean peak resultant velocity performing the reverse punch, showed faster mean times in all categories for the reverse punch. Four other subjects only had faster mean movement times for the lead variation. For these subjects even though the movement time was slower for reverse they made up that time with faster reaction times for those trials.

When investigating the quickest trial the outliers were revealed. Subject 7 had average reaction times of 137 ms and 128 ms which seem consistent with the literature regarding simple reaction time. Single trial reaction times of below 100 ms were recorded for this subject. For a quick comparison, male Olympic level track and field athletes and officials regard anything faster than 100 ms time off the block as a fault (International Association of Athletics Federations, 2013). The runner is considered to have reacted prior to the gun going off. The quickest reaction time in the study was measured for the same subject on both variations at well below this value, 67 ms and 83 ms. This result is attributed to the subject anticipating the stimulus light and beginning the punch motion early in an attempt to influence their scores.

Interestingly, total time elapsed for performing both variations had small standard deviations across all subjects and all trials. This could indicate that technique selection may not be as responsive to time as desired. Further research into repeatability for either punch over many trials could illuminate any critical factors that may be obscured.

**Linear Resultant Velocity.** Reverse punch had a significantly greater PRV than lead punch measured at the elbow and wrist ($p < .0001$). At the shoulder, reverse
punch again had a significantly greater PRV \((p < .001)\). A smaller significant difference was found in PRV at the hip for the reverse punch \((p < .01)\). In the current study, the wrist values are resultant and are consistent with measurements in Neto et al. (2012), Nakayama (1966), Yoshihuku et al. (1987), and Whiting et al. (1988) who reported wrist PRV ranging from 4-8 m/s for both techniques. In most of the reviewed studies, peak speed measures were identified as linear horizontal velocity in two dimensions. Using those measures Gulledge and Dapena (2007) found significantly higher contact velocities in the reverse over the lead punch.

The relatively higher mean values for PRV at the elbow can be explained through research design. Because resultant velocity was used, the elbow marker was changing faster in space due to the internal rotation of the punching arm. This was most evident in the reverse punch trials. Other segments had more linear motion and less rotation. Again, these observations are important for the individual but for poor for comparing between subjects or studies. Peak velocities were occasionally greater during the retraction of the punch, though this would have little bearing on time to score during the execution of technique in a tournament setting. Yet it still may be worth investigating further when defensive considerations are introduced. Strategy for competitors would be affected if differences can be found for time to retract to guard among the punches.

After the stimulus light, lead and reverse punch reached its maximum velocity at the wrist within approximately 300 ms and 460 ms, respectively. Figure 8 shows the peak resultant velocity timing occurrence of selected body segments joints for purposes of contrast between variations. In the selected trial, a proximal-to-distal coordination among body segments is represented. The same coordination pattern was similarly
observed in all reverse trials. The fastest reverse punch reached its maximum hip velocity at 392 ms, maximum shoulder velocity at 425 ms, maximum elbow velocity at 467 ms and maximum wrist velocity at 483 ms. The peaks for each segment are clustered and spread out by approximately 20 ms in this trial. In the fastest lead punch PRV occurred for the hip at 242 ms, the shoulder at 275 ms, the elbow at 308 ms, and the wrist at 317 ms. The observable difference being that lead punch body segments reach their peaks sooner and more tightly than reverse punch. This reduces the time available to impart velocity to each segment.

When comparing the velocity curves there is a double peak in the reverse variation that is markedly different than lead (Figure 4). Traditional hip motion for the reverse punch could explain what is indicated by that feature measured at the wrist. The retracting arm provides a counter hip movement present in the reverse punch which may help explain the greater peak velocity measured at the wrist. The retraction provides a greater range of motion of the hip thereby increasing time to develop velocity. Variability of energy transference may exist between segments as a consequence of dissimilar movement patterns among the techniques. The lead punch displays a single peak curve and resulted in a lower PRV.

**Linear Displacement.** In Table 4, the linear displacement means for reverse punch are more than double that of lead punch at each marker. The elbow, shoulder, and hip were particularly sensitive with less variation at the wrist between techniques. In practical terms as a defender, one would be able to see the movement of reverse punch more readily since each body segment is moving over more distance.
The relatively large standard deviation at the hip can be explained by physical size differences among subjects and can be addressed in future studies by keeping adults and juniors separate. Understanding current research design it would appear that the elbow is internally rotating more in the reverse punch variation, with an average linear displacement of 365.9 mm compared to 140.5 mm.

Orientation of the subject and hand positioning between techniques and trials need to be controlled in the future as this can affect linear displacement measurements in three-dimensional space and distance to target becomes critical in the competitive setting.

The biomechanical concept, range of motion, was also used for looking at the center of mass of the body. Center of mass was given by the Cortex system as calculated from subject characteristics and marker capture. The researcher observed that in all trials for all subjects the center of mass stayed within the base of support defined as the area beneath the torso and pelvis and between the feet. As observed qualitatively reverse and lead punch may be treated as balanced motions.

**Correlation: Age and Experience.** Relatively new or young participants and older lifetime karateka make up a majority of those training in martial arts. Longevity in training occurs after the initial drive to start a new activity wanes; as in physical fitness most drop out of the program before realizing its true benefits.

Age and experience were not found to be predictive of PRV for either variation. As reported the correlation \( r \) values were all below .2 and for reverse below .02. This important finding reveals that being older and training for many years may not translate to a greater peak velocity at the wrist during the punch. This lends hope to coaches and younger athletes as accumulated time in training is not the sole way to
improve. It may be more important to adjust biomechanical variables to achieve peak performance.

As a result of training each subject would naturally develop a preference between techniques. In Table 1, the preference of technique among subjects is listed as a percentage of responses for reverse and lead punch. When preference of technique was compared against performance the subjects that chose lead punch (29%) were unsuccessful in producing greater peak resultant velocities at the wrist with lead punch. In the cases where subjects preferred reverse punch (71%) they produced either greater peak velocities or negligible differences between reverse and lead when performing the reverse punch. The frequency in which reverse punch is practiced in training and used in competition may explain why performance overrode preference in the data.

**Correlation: Reaction, Action, and Total Time.** The only correlation of importance with respect to the time phases is action time in the lead punch variation ($r = .55, p < .05$). Longer action times were correlated with faster PRV at the wrist. This opens up modification of technique in order to increase or decrease PRV. If the attack from lead punch is consistently landing too late or traveling too slowly then increasing the time over which the punch is traveling may help. Consequently, using reverse punch to increase the action time phase thereby allowing a greater PRV at the wrist is also plausible. Coaches could instruct the athlete to use the reverse punch technique, but from a closer range to make up for the distance to target changes.

**Correlation: Linear Peak Velocities.** All peak resultant velocities from other markers were correlated with the wrist to some extent with $r$ values greater than .6. The strongest correlation for reverse punch peak resultant velocity at the wrist was with the
hip and elbow for the lead punch. It is important to note that the hip is more responsive in the reverse variation. Findings are consistent with kinetic linking theory and make logical sense that as each segment travels faster each subsequent segment also travels faster.

**Correlations: Range of Motion.** Range of motion at the shoulder and hip were the most representative for reverse punch. Karate punching technique is taught to start from the hips and transferred to the arm in order to use the whole body. The nature of this technique makes its segment range greater and resulted in greater peak resultant velocities as found in the data. Manipulations of the range of those segments would be the best place to start.

In lead punch variation, the emphasis was placed on the shoulder’s range of motion which had a moderate correlation with peak resultant velocity at the wrist. A coach or athlete trying to improve lead punch velocity should look to the shoulder and ensure that the range is sufficient.

**Inter-segmental Coordination.** Human movements can be judged on a coordination continuum between simultaneous and sequential and high-speed motions tend to have more sequential muscle and joint actions (Hudson, 1995). Figure 8 helps to illustrate the coordination and provide the construct with which to discuss differences among technique. The figure represents peak resultant velocity over time for two subjects performing the lead punch variation. Subject 11 has a sequential movement pattern as the hip first reaches peak velocity followed by the shoulder, elbow, and wrist. Subject 1 recorded the slowest peak resultant velocity, 3.14m/s for the lead punch and findings may explain why. The coordination is out of order and does not follow patterns identified previously. The hip reaches peak first followed by the elbow and then shoulder and wrist
peaks are nearly on top of each other. This is not a proximal to distal relationship and may be the cause of the slower speed. Sequential interaction among segments must be dissected in greater detail in future studies to determine if timing can be altered for improving performance.

For lead punch, although the coordination is similar the time between peaks is tighter near the distal segments. Remember that Subject 5 produced the fastest overall PRV of all punches. In reverse punch, the punching hand had minimal velocity as it was finishing the retraction prior to execution while at the same time the hip was reaching its peak resultant velocity. This was followed by the shoulder and elbow reaching their peaks and transmitting this stored energy in the hip through the kinetic chain down to the wrist. The wrist was not retracting as far in the lead variation and the related range of motion in the hip and length of time to impart velocity must be smaller. Since the movement time for the reverse punch was longer it allowed peak velocities to spread out. Those subjects with a greater relative mean PRV at the hip did not always equate to the fastest PRV at the wrist between subjects. Undetermined factors are affecting the data as a simple hand off of peak velocity from segment to segment does not fully explain what was observed.

Implications

Qualitative analysis helped bridge quantitative analysis and real world performance. Additionally qualitative analysis facilitates the application of quantitative analysis. Equipping coaches with descriptions of biomechanical data for speed, motion, coordination, and balance can benefit the performer and help develop teaching cues.
This current study shows that coordinated movement patterns are much more indicative of peak velocities than merely accumulated experience. Expert karateka performing punches can reach ceiling values for hand speed and is not dependent on their age and experience. Having a close number of years of experience in karate, Subjects 5 and 1 were particularly representative of the range of PRV at the wrist and are taken as examples of good and bad technique execution for discussion purposes. While registering the single highest PRV of 7.1 m/s for reverse punch, Subject 5 was also the only subject to achieve a mean PRV greater than 6 m/s in both punch variations. Subject 1 failed to reach 4.5 m/s for either variation.

Both subjects had very different coordination patterns. As described previously the pattern itself should be sequential. Subject 1 failed in many cases to reproduce that coordination. From trial data, it appears that Subject 1 also minimized overall contribution of body segments resulting in little to no range of motion at significant markers, such as the shoulder and elbow. Lack of coordination coupled with poor transference of energy among segments led to smaller PRV at the wrist. Temporal variables for this subject were also affected, as shorter movement times and less range of motion prevented the hand from accelerating for long enough.

Alternatively, Subject 5, 11, 6, and 3 had good results for both techniques in PRV at the wrist. The movements of these subjects appeared relaxed and coordination patterns of PRV at markers were close in sequence. This seeming natural, though practiced, ability to engage the proper muscle group at the right time. Distinctively range of motion at the hip clearly contributed to the additional PRV measured at the wrist in the mentioned subjects. In order to bring the power of the whole body into play, the subject
reacted to the stimulus quicker extending the range of motion of the punch to include all body segments. The movement time of the punch now lasted longer allowing the PRV at the wrist more time over which to increase. This combined with the retraction of the hip as the punch was reaching extension describe the results presented. In order to improve the performance of Subject 1, a special focus should be on the hip. This is where a concrete change can be made for the better.

By increasing the range of motion at the hip athletes can immediately increase the time over which to reach peak velocity at the wrist. Out of the competitive context, this can be practiced and honed so that temporal times can be reduced. This would help negate the penalty for increasing movement times needed for greater PRV. Back inside competition strategy must be weighed so that appropriate importance is given to both fast enough and just enough to score. Increased PRV may not be beneficial when sacrificing the ability to change directions quickly as movement times are longer necessitated by the higher PRV. Once movement pattern has been initiated, it becomes impossible to change in the middle of the technique. The current technique must be abandoned or completed and then change can be made.

Research Design

The present study was a quasi-experimental design comparing paired sample groups amongst themselves on two different technique variations. Start position of the hands and orientation of the feet was not controlled for and could have affected movement times. It was incorrectly assumed that subjects trained in one martial art would have minimal differences in those two aspects and without explicit instructions minimal variation did occur.
Several observations were made for the interaction among variables. Because stronger or larger subjects’ muscular development and activation time was not known or restricted, they may have had the ability to generate more powerful acting forces on the muscles resulting in relative speed increases. Larger muscle groups would be able to produce more force and could be translated into a faster punch. The demographics of martial artists taken for sampling would suggest that breaking the groups into adult and juniors may reveal information that is obscured when averaging them together. Future studies could also study these groups independently to determine differences.

Limb length among subjects was not considered but could directly affect movement times and range of motion, including the distance to target and the actual danger of counter attack in competition. Subsequent research design may develop a method to correct this and attempt to even the playing field for more indicative results.

The current study helped to provide evidence that kinematic and kinetic descriptions of the punch movement are valuable but must be deciphered from amongst all the contributing factors of performance.
Coaches and athletes are always looking at ways to get quicker and faster. When punches are being performed, the coach may tell the athlete to snap his punches or retract the hand faster. This is a good example of manipulating biomechanical parameters in order to affect athletic performance. Once technique is fine-tuned in practice, it needs to be tested in the competitive setting in order to get feedback for adjustments.

Often western studies in the field of biomechanics, and specifically on punching, have centered on the sport of boxing and performance enhancement by strength training. There is a need for the biomechanical analysis of martial arts and its techniques as these arts become a more prevalent part of our culture. Currently many experts continue to disagree as to which techniques should be trained and how they should be executed. This study was designed to help scientifically describe the punching techniques of karate and help shed light on the debate.

The purpose of this study was to compare the reverse and lead variations of punching technique. The first goal was to examine if the reverse punch variation had a significantly greater peak resultant velocity measured at the wrist. The second goal was to determine the association between kinematic variables and the peak resultant velocity
measured at the wrist. The last goal was to provide the qualitative analysis information to improve the training and practice on both punching techniques.

Fourteen expert karateka trained in Okinawan karate completed the testing procedure. The subjects performed five trials of reverse and lead punch motion. All trials were captured in three-dimensions by the Cortex motion analysis system.

Peak resultant velocity was measured at the wrist between the techniques. Temporal variables like simple reaction time were measured during each defined phase of punch extension. Mean values were calculated for all subjects among all trials of a variation. For reverse punch and lead punch, the average peak resultant velocity among all subjects was 5.63 m/s and 4.84 m/s, respectively. The paired $t$ test was applied to examine the difference between techniques among the subjects. Statistical significance was found for peak resultant velocity of reverse punch over lead punch ($p < .01$) measured at the wrist. Additionally, lead punch mean movement times were also significantly shorter than reverse punch times ($p < .01$). All other time phase differences were important categorically but failed to reach significance at an alpha level of .05.

Range of motion was of specific interest between the two variations and it was demonstrated that an optimum range may exist such that greater velocities are probable. The reverse punch was particularly sensitive to this range, depicted by the correlation, $r = 0.64$ ($p = .02$). This technique provided greater velocities than the lead variation and is thought to be a result of the body’s ability to accelerate segments over this greater range. Sequential coordination was demonstrated and is consistent with many high speed motions like pitching and hitting which are well known for the using the entire body for energy generation.
Qualitative information derived from quantitative data can be useful for many coaches and athletes. A surprising takeaway from the study revolves around the minimal influence that accumulated experience had on the results for peak resultant velocity. Manipulation of biomechanical characteristics has a place in traditional martial arts technique execution and training. Both techniques are sensitive to changes in range of motion at the hip and peak velocities at all markers are related to peak velocity at the wrist.

The ability to engage the proper muscle group at the right time is crucial for achieving sequential coordination and greater peak velocity. Range of motion at the hip also clearly contributed to the additional PRV measured at the wrist and is needed in order to bring the power of the whole body into play. This combined with hip retraction as the punch was reaching extension describe the results presented previously. By increasing range of motion at the hip, athletes can immediately increase the time over which to reach peak velocity at the wrist. Increased PRV may not be beneficial when sacrificing the ability to change directions quickly as movement times are longer. The more restricted hip movement of the lead punch versus the whipping motion found in reverse may have contributed to the slower peak velocities that have been observed and discussed previously. Future studies could control hip movement through research design and help determine this.

Furthermore, an interesting observation of center of mass displacement in a three dimensions revealed a corkscrew path as the center of mass drops during the execution of the punch. Karate teachers have described the cyclone motion of the center of mass of the body anecdotally. It was demonstrated by the subjects and may be similar
to the counter movement found in athletic movements allowing the body to press against the floor like a spring to produce explosive movement. For more in depth information about center of mass movement, the force plates may be helpful to conduct a center of pressure study on either variation.

Tournament strategy needs to be studied in order to find out if expert karateka keep more of the body still, as observed qualitatively during execution of lead punch, to deceive opponents and reduce effective defense. Defensive movements should be studied from a competitive context so that the variables of reaction time and movement time might give greater insight into the opponent’s ability to react to the different techniques. Anticipatory studies by Mori et al. (2002) determined that karateka had a better ability than untrained subjects to anticipate attacks in the vertical visual field but did not compare that anticipation with action.

Through a better understanding of both karate punches, one can form the biomechanical picture of martial arts punch performance. Further studies need to be done to assess defensive capabilities enabling more comparisons to be made on competitive dynamics and research brought into context. A spectacular marker suit to measure full body motion at specific joint centers should be designed and implemented. They could be used to assist data collection as any segment that is not accounted for any frame can hinder center of mass calculations.

Suggestions for Future Research

1. Investigate coordination, range of motion, and center of mass in more detail to understand optimum values if such exist.
2. Break the subjects into two groups, adults and juniors, in order to detect any developmental differences that may be obscured in this design.

3. Study defensive movements from a competitive context in order to find correlations and greater significance of the current findings.

4. Increase number of trials per subject to decrease signal to noise ratio.

5. Open the study to other martial arts styles and western boxing for comparison and commonalities.

REFERENCES


Purpose of the Study

The purpose of the study is to conduct a kinematic infrared analysis of gyaku-tsuki and oi-tsuki as performed by skilled karate-ka in order to investigate the relationships between stimulus reaction time, movement time, and fist velocities.

Explanation of Procedures

The data collection will be performed in the Biomechanics laboratory at Chico State University for a single one hour session. Prior to testing you will be required to sign a consent form and perform a five minute warm-up of the upper body extremities. During the session you will be asked to perform ten variations of each of the techniques, gyaku and oi, while being filmed. Each trial should be performed at maximal effort with the speed of technique being of primary concern. Each trial will begin upon detection of the stimulus light. After the data collection, you will be required to execute cool-down exercise such as stretch all the major muscle groups.

Potential Risks and Benefits

Potential risk of injury such as muscle soreness may occur due to the quick extension of the arm. In order to minimize this risk the use of warm up and cool down session will be employed. The potential benefits of this study include an analysis of punching technique selection, and reaction and movement times will be provided for each individual to improve their performance at competition.

Confidentiality

Information gathered from you during this study will be kept and treated confidentiality. Your name will not be used in publishing the results of this study. Only group data, age, and gender information will be disclosed. The data are kept in a locked cabinet in my office on campus. Only myself as the principal investigator and my research advisor will have access to the cabinet where they will be stored in.

Voluntary Participation and Withdrawal

We appreciate your interest in being a subject in this study. Understand that your participation is entirely voluntary and that you may withdraw at any point during the course of the study. In case of any questions, you may contact the investigator (Doug Gallaher, 530-693-1629).

__________________________________    ____________________
SIGNATURE OF PARTICIPANT     DATE
APPENDIX B
Helen Hayes Marker Set Placement

Note: This marker set is used in the Helen Hayes Marker Set samples found in \Cortex\Samples\KinTools RT Examples\Helen Hayes Marker Set and in the Helen Hayes Marker Set sample data found in \Cortex\Samples\Helen Hayes Marker Set.

Source: Figure developed using Cortex Motion Analysis Software (on site at CSU, Chico).