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Kinematic analysis of the gyaku-zuki (reverse punch) in zenkutsu-dachi (front stance)

Steven Ward McCann
San Jose State University

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McCann, Steven Ward, M.A.

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U·M·I
300 N. Zeeb Rd.
Ann Arbor, MI 48106

KINEMATIC ANALYSIS OF THE GYAKU-ZUKI (REVERSE PUNCH) IN ZENKUTSU-DACHI (FRONT STANCE)

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by

Steven Ward McCann

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APPROVED FOR THE DEPARTMENT OF HUMAN PERFORMANCE

Gail G. Evans

Dr. Gail Evans

Susan Wilkinson

Dr. Susan Wilkinson

Irv Ploke

Mr. Irv Ploke, M.A.

APPROVED FOR THE UNIVERSITY

M. Lou Lewandowski

ABSTRACT

KINETIC AND KINEMATIC ANALYSIS OF THE
GYAKU-ZUKI (REVERSE PUNCH) IN
ZENKUTSU-DCHI (FRONT STANCE)

by Steve McCann

The purpose of this study was to conduct a kinematic analysis of the reverse punch in a front stance as performed by five male Shotokan expert black belts. Relationships between selected kinematic variables and expert evaluators' rankings were investigated. A description of differences when punching into a target and without a target are presented.

This study revealed two discriminating kinematic variables that correlated highly to ranked scores: 1) The time for the wrist to reach maximum resultant linear as a percent of total punch time, and 2) maximum resultant hip velocity. Although the mean punch time was the same for both Condition I and Condition II, mean wrist resultant linear velocities were different. In addition, a biomechanical description of the reverse punch in a front stance is presented.

This thesis is dedicated to five important people in my life. To my wife, Andrea, who has provided me an incredible amount of support during the preparation of this study. She has acted as my proof-reader, editorial guide, and general assistant. Without her patience and help I would never have been able to complete this overwhelming project.

To the memory of my grandparents, Therl and Marguerite Johnson, who have always been inspirational role models for me in every aspect of my life. To my brother, Mike, who has encouraged me to challenge the future and fulfill my dreams, and to my mother, Marilea McCann, for her continual love and support.

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I would also like to thank Mr. Irv Ploke, whom I have been friends with for over 15 years. Mr. Ploke is the head karate instructor of my dojo. He has guided me and acted as my mentor in karate. I will always be grateful for his instruction and leadership.

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CHAPTER 1

Introduction

There is tremendous interest in the oriental martial arts around the world, which is evidenced frequently in books, films, and on television (Oyama, 1984). There are large numbers of international, national and local clubs involved in the study of the many different types of martial arts. At the present time, karate is practiced throughout the world. Competitive events, in kata as well as kumite, are held on regional, national, and international levels. The reasons behind this great popularity are many and include the benefit of improved physical fitness and the development of self-defense skills (Funakoshi, 1981). It is probable that these physical benefits have always been an integral part of karate training but it seems likely that in modern times improved physical fitness is the most common motivation behind karate training (Okazaki, 1984). Gichin Funakoshi (the founder of karate) believes that karate training provides for spiritual benefits including perfection of character, sincerity, diligence, courtesy, and self-control, in addition to fitness and self-defense (Funakoshi, 1981).

The Shotokan style was developed in Okinawa by Gichin Funakoshi and introduced to mainland Japan in 1922 (Haines, 1981). Funakoshi taught the maxim, "Karate ni sente nashi" (there is no first attack in karate). Shotokan was developed as a weaponless method of self-defense (Nagamine, 1976).

Since many course offerings of colleges and universities include classes in Asian combative arts, it is the responsibility of the physical educators to teach these activities. Many karate instructors teach techniques based on tradition, not scientific research or the results of competition. Substantiated qualitative and quantitative information would be desirable for describing the exact movement pattern of various techniques. The lack of such scientific information in this area suggests the need for research in order to better describe these movements. This study will focus on a primary skill common to the "Shotokan" style of Japanese karate, the reverse punch in front stance. The results of this study will provide a description of the gyaku-zuki (reverse punch) in zenkutsu-dachi (front stance), one of the most common techniques used in martial arts (Nakayama, 1988). Suggestions for teaching will be included based on the performance description.

Statement of the Problem

The primary purpose of this study was to conduct a kinematic analysis of the reverse punch in front stance as performed by expert Shotokan karate black belts. Specific problems were:

1. To describe the temporal relationships of the kinematic variables which contribute to a reverse punch in front stance performed by karate experts.

2. To determine the relationship between selected kinematic variables and expert evaluator's rankings of the quality of performance of a reverse punch in front stance during Condition I (no impact into target).

3. To expand upon the definitions of a reverse punch in front stance.

4. To describe and compare any difference in temporal relationships of the kinematic variables of the reverse punch in front stance when the punch terminates with impact and when impact was not part of the activity.

Delimitations

This study was delimited to:

1. The use of five right-handed Shotokan karate black belts.

2. Five male subjects with at least eight years experience.

3. Subjects who range in age from 26 to 36 years.

4. Subjects who have volunteered to participate in this study.

5. Subjects who are Shotokan karatekas only, not inclusive of other styles of karate.

6. Subjects who were all members of the same Shotokan karate school.

7. Subjects who normally wear traditional karate uniforms during practice were videotaped without wearing the karate uniform.

8. The target type for use in videotaping was the same type as subjects use during normal training.

Limitations

The results of this study were subject to the following limitations:

1. Subject's punching pattern may vary due to the effects of practice, diet, psychological, or motivational considerations.

2. The assumption that the body is a link system, with each segment considered a rigid body without deformation, and each joint considered a pinned connection with negligible friction forces acting within the joint.

Assumptions

It is assumed that at the time of the testing all subjects were in excellent physical condition. It is further assumed that each subject demonstrated a true maximum effort on all trials with a target at impact and without a target.

Definition of Terms

Displacement. The length of the straight line joining the start and the finish, with some indication of direction (Hay & Reid, 1988).

Focus. The concentration of all energy of the body for one instant on one specific target. The point at which the greatest momentum has been generated by the total body and is now expended in the most effective form of destructive force (Nistisco, 1982).

Force. A push (or pull) that alters, or tends to alter, the state of motion of a body (Hay & Reid, 1988).

Front stance. A static position in which the front knee is bent over the front foot so that the plumb line from the knee will fall just inside the ball of the foot. The back leg is fully extended straight while the subject maintains a straight back with the upper body perpendicular to the ground. The hips and shoulders are at a 45 degree angle to the direction of travel (forward). The distance between the front and back foot is approximately 32 inches. The participant maintains a width between the feet equivalent to the width of the hips with the front foot pointed slightly inward. The participant turns the back foot to the front as much as possible so that both feet point in the same direction with the body weight distributed so that the front leg supports about 60 percent and the rear leg supports about 40 percent of the total weight (Nakayama, 1989).

Karate. A form of weaponless self-defense primarily employing kicks and strikes with the feet and hands. This name was given to the Okinawan unarmed form of martial arts during the twentieth century (Reid & Croucher, 1983).

Karateka. One who studies the art of karate (Nakayama, 1989).

Kata. A pre-arranged form of demonstrating methods of attack, defense, and counter attack (Oyama, 1977).

Kime. To focus all of one's thoughts and movements into one precise point of impact (Nakayama, 1989).

Kumite. The process of sparring utilizing karate skills performed by two opponents (Oyama, 1984).

Momentum. The quantity of motion of a body that is equal to the product of the body's mass and velocity (Hay & Reid, 1988).

Reverse punch (gyaku-zuki). The intent of the reverse punch is to create the maximum amount of destructive force when an object or opponent is encountered (Nakayama, 1989). The reverse punch is delivered from a strong, stable stance. The hips rotate and are kept the same level during the rotation. The rear leg straightens and the center of gravity shifts slightly forward. The power of the hip movement is transmitted to the chest, shoulder, arm, and fist, and culminates in a strong shock into the target. The feet maintain their original position. The hips rotate counterclockwise, when viewed from above. The left arm, within a para-sagittal plane, is forcefully retracted accompanied by elbow flexion and forearm rotation to a supinated position. The right arm is thrust forward. Elbow extension directs the fist straight towards its intended target. Just prior to contact, the forearm pronates 180 degrees. At the instant of impact, all the muscles of the body are tensed so as to create a single rigid unit. Upon completion of the technique, the hips are facing forward and the arms have essentially reversed positions.

<u>Rigid body</u>. A body which is considered free of deformation (Plagenhoef, 1973).

<u>Shotokan</u>. A Japanese term meaning, literally, "the place of Shoto." Gichin Funikoshi, who introduced Shuri-te karate to Japan, used "Shoto" as a pen name, and later named his style Shotokan (Reid & Croucher, 1983).

<u>Velocity</u>. The displacement of a body divided by the time taken to undergo that displacement (Hay, 1985).

CHAPTER 2

Review of Literature

The purpose of this study was to investigate the selected kinematic variables of a karate reverse punch in a front stance. Although there is limited published research on the reverse punch this chapter will review the literature completed in other karate skills including the analysis of karate punches, karate strikes, judo throws, Taekwondo kicks, (including the physics of karate techniques, and impact characteristics while punching with three selected gloves) and characteristics relevant to the reverse punch.

Quantitative Factors in Karate Techniques

Cavanagh and Landa (1983) utilized high speed cinematography, accelerometery, and electromyography to study six experienced subjects for angular accelerations and the pre-impact movement of the trunk and striking limb during karate "chops" intended to break pine boards. The researchers estimated average forces between 2,400 and 1,200 Newtons (N) for the downward karate strike. A film speed of 200 fps was used to obtain kinematic data from which joint angles throughout the activity were measured and compared. A kinematic analysis showed a sequential pattern of action at the shoulder and elbow joints. Electromyography supported the finding of the sequential pattern action by revealing a sequential pattern of muscular action.

Hirata (1971) found the average speed of a reverse punch to be 5.3 meters per second (m/s) in unskilled subjects and the maximum speed to be 8.1 m/s for skilled subjects. Hirata estimated forces as high as 6860 N for the karate punch.

A study by Feld, McNair and Wilk (1979), using high speed cinematography at a film speed of 1,000 fps, indicated that the fist in a karate punch reaches maximum speed shortly before the arm is fully extended. The karate expert focuses the punch just inside the target, so that the fist reaches maximum speed at the point of contact resulting in a large momentum to the target. The researchers measured the range of speed for seven common karate techniques. The front forward punch was found to have a range of between 5.7 m/s and 9.8 m/s. The primary finding of the study was that the hand of a karateka was capable of delivering a force of approximately 4000 N at speeds between 10 m/s and 14 m/s.

A study conducted by Grabiner (1982) used electromyography on two subjects performing a karate reverse punch. The investigator concluded that movement speed was one of the most important factors in the martial arts. He found that greater speeds enable the karateka to have more mechanical energy available for the strike.

Vos and Binkhorst (1966) concluded that producing high velocities in the striking limb was extremely important in impact situations. They measured the linear velocities of five subjects performing a downward karate strike using photographs calibrated with strobe lights. They measured velocities between 12.5 m/s and 14.2 m/s for three advanced karate students and 10.8 m/s to 11.1 m/s for two control subjects.

Hwang (1989) performed a biomechanical analysis of three highly skilled Taekwondo players performing the front kick used in Taekwondo when kicking without a target compared to kicking with a target. It was concluded that there was a different velocity pattern between kicking with a target and without a target. The absolute speed of the kicking foot at the target was 11.0 m/s, and it was 9 m/s in kicking without a target. The tendency for decreasing the speed of the kicking foot at the target area was due to the decreasing of the horizontal component of the velocity.

Smith (1985) studied five low skilled (white belt), five intermediate skilled (green belt), and five highly skilled (black belt) subjects who were randomly selected to punch a heavy bag with a reverse punch. He concluded that highly skilled karatekas were able to generate more momentum with their punches than intermediate or low skilled subjects with no differences in fist velocities. The investigator's contention was that highly skilled karatekas could better coordinate body mass into the punch and supported the concept known in karate as focus as well as the force summation principle. This study confirmed the findings of previous studies completed by Smith (1977) and Hirata (1971).

Nakayama (1966) compared the reverse punch to the lunge punch from cinematographic analysis of three advanced karatekas. He found average forces to be from 1,666 N to 6,860 N, respectively. This force is considerable and could cause injury to another human. He discovered terminal speeds of 5.16 m/s, peak speeds of 7.1 m/s, and average speeds of 5.06 m/s in the straight punch. He concluded that the advanced karatekas were able to develop greater speeds in the striking limb than the three beginning level karatekas. He also found that maximum speed was achieved between 70% and 80% of the total elapsed movement time.

Walker (1975) concluded (with a single experienced subject) that the fist reached maximum speed at 75% of the arm's full extension during a punch. He also found a maximum velocity of 7 m/s in the karate reverse punch with an estimated force of 4,900 N. Blum (1977) estimated the maximum speed of a reverse punch is between 7 m/s and 14 m/s depending on the skill of the subject. He also stated the initial kinetic energy available between 171 and 687 Joules.

Van Gheluwe and Van Schandeviji (1983) studied five karate experts to measure trunk rotation during the execution of the reverse punch. The researchers used pipe cleaners attached to five points on the spinal column as reference points to the spine. They filmed a single subject performing a reverse punch with a 16 mm camera set at 200 fps. They found both translational and rotational motion in the spinal column. They compared it "to the movement of a long curtain set in motion by someone pulling at the lowest end of it in order to get the top of the curtain sliding over the rails in the desired direction" (p. 881). The authors concluded that the hips moved first, creating torsion on the spinal column, followed by movement of the shoulders. The study showed that the spinal column does not move like a "solid block" during the performance of the reverse punch.

Qualitative Descriptions of Reverse Punch in Front Stance

Nakayama (1989) described many characteristics of effective karate techniques from a scientific basis in

Dynamic Karate. He stated that the front stance is a strong stance to the front and especially effective when power must be directed forward. The destructive force of karate is generated by turning the body, especially the hips, while withdrawing the opposite hand. Nakayama (1989) stated that an effective punch cannot be delivered with arm and shoulder strength alone:

> Power generated by rotating the hips is conveyed to the spine, then to the muscles of the chest and shoulders, and finally to the arm and fist, resulting in a powerful technique. The speed of the punch gains additional acceleration if the fist is driven forward with the intention of straightening the elbow. If these points are followed, the fist should strike the target with maximum power (p. 58).

He further stated that the reverse punch begins with rotation of the hips. The power of hip movement is transmitted to the chest, shoulder, arm, and fist, and culminates in a strong shock on the target. He stated that to prevent any loss of power, make sure the result of the impact is supported in reverse order by the fist, arm, shoulder, chest, and hips. The upper body and arm muscles must be tensed at the moment of impact in order to increase power transmitted into the target. All muscles necessary for the reverse punch must work together and contract powerfully at the moment of impact.

The Textbook of Modern Karate, Okazaki (1984), examined the physics and physiological factors associated with karate. He stated that karate power is the result of the momentum generated by body muscles acting in the correct sequence and the tensing of these components at the instant of impact. This confirms Nakayama's (1989) description of proper technique. He discusses the principles of force in karate as varying in impact according to five factors:

1. Magnitude: the magnitude of force depends on the size of the muscle and number of muscle fibers firing.

2. Direction: the direction of force should be at a right angle to the intended target.

3. Speed: the greater the speed, the greater the force. If either the mass of an object or its velocity is increased, momentum will also increase. The greater the momentum, the greater the force into the target.

4. Range of motion: force is directly proportional to distance of the fist from the target. One way to increase force is to increase the distance the punch travels.

5. Stability: a good stable stance and body posture is necessary for the effective application of force.

All of these factors must work together to maximize force.

Okazaki (1984) described focus (kime) "as the process of combining all components of a karate technique" (p. 104). Only at the instant of focusing can momentum and effect be maximized. A reverse punch is a complex movement and requires the integration of five factors: (a) distance of the fist from the target; (b) proper technique; (c) muscle contraction; (d) speed of movement; and (e) proper timing. The act of pulling back one hand while the other is pushing forward is emphasized by Reid and Croucher (1983) as "adding enormously to the power of the out-going punch. It is almost as if the energy of pulling back flows across the back, which is held upright, and down the attacking arm" (p. 168). They stated that greater force is given by rotating the punching hand 180 degrees just before the punch makes contact. The punch is delivered with a screwing motion, which greatly accelerates the impact force of the fist and deepens the penetration of the blow. In a correct strike with the fist, the first two knuckles should contact the opponent. The knuckles and the wrist must be kept directly in line in order to prevent the wrist from bending or buckling on impact. Nagamine (1976) explains that the wrist must be kept straight; "It is an extension of the right angle formed between the top and front of the fist" (p. 69).

The karate reverse punch has limited follow through and terminates just centimeters beyond the target. The focus point is just inside the target area. Blum (1977) described "focus" as the ability to combine great speeds (by relaxing the muscles involved in the movement just prior to impact) and highly effective mass upon impact (contracting the muscles at impact thereby locking the striking limb to the body at the last possible instant). After impact, the karateka is taught to rapidly return the striking limb for defensive purposes or for another strike. The karate punch is designed to damage tissue and bone, not to push the opponent back such as in boxing (Walker, 1975). The objective is to impart great force to a small area.

<u>Biomechanical Analysis of Other Sport Skills</u>

Other studies of biomechanical analysis research have used a similar protocol in the number of subjects, filming techniques, digitizing, and reporting of the kinematic results. Takei (1989) filmed 40 elite male gymnasts with a 16 mm camera at a rate of 101 fps to compare the kinematic results to the score of each trial given by gymnastic judges. Fifty frames of each trial were digitized. Takei found a significant correlation for only two of many selected kinematic variables and the expert judge's scores.

A kinematic analysis of top American female 100-meter hurdlers (Rash, Garrett, & Voisin, 1990) filmed 6 subjects at 100 fps with a 16 mm camera. The cameras were positioned to film the sagittal view. Digitizing resulted in velocity and displacement data for analysis.

A kinematic study of judo throws selected five highly-skilled adult male judo athletes (Harter & Bates, 1989). A super 8 mm camera with a 7.5 to 65 mm zoom lens placed perpendicular to the sagittal plane of motion was used to film selected trials. Trials were filmed at 150/frames per second to identify any kinetic and/or temporal patterns that were present during selected judo throws.

Stroking characteristics for the front crawl (Chatard, Collomp, Maglischo, & Maglisch, 1990) were investigated by filming nine male competitive freestyle swimmers. A video camera operating at 30 fps was fixed at 9 meters and perpendicular to the direction of swimming at approximately 20 cm underwater. A yardstick was used as a reference for distance measurement and was placed on the bottom of the pool.

Movement Principles

Kreighbaum and Barthels (1981) discussed the principle of "open kinetic chain" activities where the distal segment is free at the end of the chain. When the objective is to develop maximum linear velocity at impact to a target in a specific direction, the largest and most forceful segments precede the weaker more distal segments in order to transfer maximum angular momentum. An example of the open kinetic chain is a karate kick in which the shoulders move, then the hips, and finally the kicking foot. The foot is the last link of the chain. This illustrates the "open kinetic chain." While throwing a light object, for example, the distal segment lags behind and the object is "pulled" along behind by the more proximal segments. This is the "push/pull continuum." Pushing is used to apply forces behind an object, where the mass and/or size of the object is greater. The pull pattern, according to Kreighbaum and Barthels, conforms most to the "kinetic link principle."

Summary

There appears to be a consensus in regard to the description and important factors of an effective reverse punch in front stance. Quantitative research in this area, however, is extremely limited in terms of scope as well as in numbers of studies completed. Videography appears to be a viable approach to investigating the selected aspects of a karate reverse punch.

CHAPTER 3

Methodology

Subjects

The subjects in this study were five males ranging in age from 26 to 36 years. The subjects were all Shotokan karate black belts. All subjects have at least ten years of karate experience and have achieved the rank of second degree black belt or higher. All subjects actively train in karate and teach karate. Age, height, weight, and years of experience were recorded for each subject. All subjects were volunteers and signed human subject release forms (Appendix A).

Pilot Study

A preliminary study was conducted with one subject who was not in the actual study. The preliminary study was performed to determine the best camera-to-subject distance, lighting requirements, and the best method of identifying joint parameters for digitizing.

Cinematography

Each karateka was videotaped performing one trial of a reverse punch in front stance under two different conditions. Condition I required the performer to complete a reverse punch without a target and Condition II required the performer to complete a reverse punch with impact into a target. The trials by each subject were digitized from videotape for computer analysis of kinematic variables. One Panasonic AG450 Super VHS video camera and one Panasonic D5000 video camera were used in videotaping. A calibration frame was videotaped and digitized for 3D analysis in order to determine real distance from image size.

Cinematographical Data Collection

Kinematic data were collected with the Peak Performance Technologies 3D Motion Measurement System. Two phase locked video cameras (one Panasonic AG450 VHS and one Panasonic D5000) were used to tape the reverse punch in a front stance. The cameras were placed at oblique angles relative to the object space (the area in which the subject is restricted to perform the punch). In addition, the cameras were positioned at 90 degrees to one another. The distance from the target was approximately 6.95 meters from the middle of the object space and approximately 1.14 meters from the floor (Appendix B). The cameras were synchronized at a picture rate of sixty fields per second.

A calibration frame was assembled and videotaped to establish actual dimensions from the videotape dimensions.

Sixteen non-linear control points defined specific points and distances on the X, Y, and Z axes. The calibration frame was videotaped for 2 minutes before the subjects were videotaped. Once the calibration frame was videotaped it was removed from the object space. The position of each calibration frame post was marked with a piece of masking tape on the floor to aid in the proper placement of the subject for videotaping. Videotaping was performed at De Anza College in the main gymnasium, where the subjects normally train.

The reference points marked with adhesive tape and felt pen were: (a) top middle finger knuckle (proximal phalanx); (b) styliod process of radius and ulna; (c) olecranon processes of the elbow; (d) acromion processes of the shoulders; (e) iliac crests of the hips; (f) lateral and medial epicondyles of the knee; (g) malleolus of the ankle; (h) calcaneus of the heel; (i) the phalanges of the foot; and (j) the right ear. These points were marked for both left and right sides in order to obtain 3-dimensional data (Appendix C).

Data Reduction

The punch parameters analyzed were:

1. Linear displacements of wrist, shoulder and hips.
2. Linear velocities of the wrist, shoulder, and hip.

3. Linear accelerations of wrist.

4. Angular displacements of the elbow and hip.

5. Total time of punch.

6. Temporal punching patterns.

All kinematic data were analyzed using the wrist, elbow, shoulder, hip, and knee parameters.

Protocol

All videotaping was completed in one day at De Anza College's main gymnasium. Subjects were instructed to perform each trial at maximum effort. Each subject was videotaped performing one trial under each condition (Condition I was a punch with no impact into a target, Condition II was a punch with impact into a target). A "Perma-Bilt" kicking shield target, the same type used during normal practice, was used during videotaping. All subjects wore shorts, but did not wear shoes or shirts. The subjects were videotaped performing on a wooden floor, the same floor used during normal practice. The trial for each condition, per subject, was digitized. Subjects were given as much time as needed to warm-up prior to the videotaping of any trial.

Judges Scoring Procedures

For purposes of this study it was necessary to determine the level of performance for each subject's trial during Condition I. To achieve this purpose, a total of five (one trial for each of the five subjects) videotaped trials were viewed at a normal speed and were judged and scored by a panel of three Shotokan karate expert evaluators.

The scoring sheet was designed by the investigator, based on a modification of a 10 point scoring system used for scoring karate kata (Appendix D). Internal validity of the scoring sheet was determined by a panel of three karate experts. The experts were asked to assess the scoring sheet for ease of use and understandability. The experts were in agreement that the finalized scoring sheet would provide a instrument to judge and score the performance of a reverse punch in a front stance as demonstrated by karate experts. The evaluators were trained to use the scoring sheet prior to their judgement evaluation of the subjects. Training consisted of practicing with the score sheet on a videotaped performance which was not selected for analysis.

To alleviate evaluator bias based on ordering, each trial was presented for evaluation in a random sequence. The videotaped trials were viewed and scored numerically by the three evaluators. The trials were ranked in order from best to worst. Intrajudge reliability was measured by having each judge score the trials again, but in a different order and with several days between each viewing. The second viewing and judging of the performances by each evaluator resulted in the same ranking of scores as did the first viewing and judging. The first viewing scores were used for analysis in this study.

Analysis of Data

In order to determine common or differing patterns of motion among the trials, graphs and tables of the following data with respect to time were examined: (a) linear displacement, velocity, and acceleration for the wrist, shoulder, and hips; (b) linear accelerations for the wrist; and (c) angular velocity of the elbow and hips.

The Funakoshi Karate Association rules for tournament scoring were used as a guideline for a skillful karate technique performance. Accordingly, a skillful karate performance must include a strong stance, correct form, proper timing with good focus, swiftness, and power of movement. In order to investigate the relationships between the variables for which data were quantified, Spearman rank difference correlations (Safrit, 1990) were calculated between the ranking of scores and the following variables: (a) total time for punch; (b) percent of punch time for the wrist to reach maximum velocity; (c) maximum linear wrist displacement; (d) maximum resultant linear velocity of the, wrist, shoulder, and hip; and (e) maximum resultant linear acceleration of the wrist.

In order to develop a more thorough understanding of the mechanics of the reverse punch in front stance a qualitative analysis was performed. A biomechanical description of the reverse punch in front stance was based on the kinematic data obtained from the videotape.

CHAPTER 4

Results of the Investigation

The results of the study are presented in this chapter under seven major headings; (1) pilot study; (2) subjects; (3) results of judges' ranking; (4) results of correlations to kinematic variables; (5) temporal relationships of the kinematic variables in a reverse punch: Condition I; (6) temporal relationships of kinematic variables in a reverse punch: Condition II, and; (7) qualitative analysis.

Pilot Study

The results of the pilot study indicated that the set-up of subject videotaping was adequate to allow for proper computer digitizing and the production of kinematic information. In addition, the study indicated that the 3-dimensional peak performance system was functioning properly.

Subjects

Five male Shotokan karate experts volunteered to participate as subjects in the investigation. All subjects were members of the Pacific Coast Karate-do Association and hold the rank of second degree black belt or higher. All subjects were considered experts with at least ten years of karate training. Age, height, weight, and years of experience are given in Table 1 for all subjects.

Results of Judges' Rankings

Each subject's performance of the reverse punch for Condition I was observed. The three evaluators used the scoring sheet and criteria for evaluation (Appendix D) to score each subject's trial. The actual scores and the rankings of scores for each evaluator are contained in Table 2. There was disagreement among evaluators' rankings for each subject's score. Spearman rank difference correlation coefficients calculated between the rankings of performances by evaluator 2 showed no correlation with the rankings of evaluator 1 or evaluator 3, therefore, the scores and rankings of evaluator 2 were not included in this study. The Spearman rank difference correlation coefficient calculated for the ranking of performances by evaluator 1 and evaluator 3 was 0.78. This suggested a strong correlation between evaluators 1 and 3. There was further consideration to determine the best choice of rankings to be used in correlating rankings to kinematic variables since the actual rankings of evaluators 1 and 3 differed. The numeric scores of evaluator 1 and evaluator 3 were combined and the combined scores were ranked. The Spearman rank difference correlation coefficient was

Table 1

Subjects' Data

Subject	Weight (N)	Height (m)	Age (yrs)	Yr Training
A	733.9	1.73	35	20
B	725.0	1.75	32	12
C	704.6	1.75	31	11
D	777.6	1.85	32	12
E	867.0	1.88	32	10
Mean	761.3	1.79	32.4	13

Table 2

Judges' Evaluations of Reverse Punch

for Condition I (no target)

	Score of Each Evaluator				
Subject	1	2	3	Total	Rank
A	16	19	18	53	4
B	17	17	21	55	3
C	17	17	22	56	2
D	24	14	21	59	1
E	15	18	17	50	5

calculated to be 0.98 between the ranking of combined scores and the ranking of scores by evaluator 1. The Spearman rank difference correlation coefficient was calculated to be 0.82 between the rankings of the combined scores and the ranking of scores by evaluator 3. Evaluator 1's rankings demonstrated the strongest correlation to the combined scores. The ranking of evaluator 1's scores were selected as the rankings to be used in calculating rank difference correlations to kinematic variables.

The selection of evaluator 1 and the exclusion of evaluator 2 in this study is similar to the process actually used during a karate competition. There are typically five judges who score the performance of a karate contestant during a competition. In the application of scoring and ranking the performance of a karate contestant, the highest and lowest scores of all the judges' scores are not included, and only the three judges' scores in the middle range are used for total ranking of scores.

A rank of 1 was assigned to the highest score and a rank of 5 was assigned as the lowest score. The highest score is associated with the best performance. Interpretations of correlations were based on Safrit (1990).

Results of Correlations to Kinematic Variables

The correlation between total punch time and rank was calculated to be 0.23, suggesting that there is no relationship between time for the punch of a given subject and the ranking of scores. The Spearman rank correlation coefficient for percent of total punch time for the wrist to reach maximum resultant linear velocity was -0.83. There was a strong tendency for the rank of scores to increase as the percent of time for the wrist to reach maximum resultant linear velocity decreased. A Spearman rank difference correlation coefficient of 0.38 was calculated for maximum linear wrist displacement and the ranking of scores. There was a slight tendency for the rank of scores to approach 1 as maximum linear wrist displacement of a given subject increased. A correlation of -0.33 was calculated between maximum resultant linear wrist velocity and the rank of scores. There was a slight tendency for the rank of scores to increase as maximum resultant linear wrist velocity of a given subject decreased. The correlation between maximum resultant linear shoulder velocity and the rank of scores was calculated to be 0.03. This suggests that there was no relationship between the rank of scores and the maximum resultant linear shoulder velocity. A correlation of -0.83 was calculated between maximum resultant linear hip velocity and the rank of scores. There is a strong tendency for the rank of scores to increase as maximum resultant linear hip velocity of a given subject decreased. The Spearman rank difference correlation coefficient calculated between maximum resultant linear wrist acceleration and the rank of scores was 0.48. This suggests that there was a moderate tendency for the rank of scores to approach 1 as maximum resultant linear acceleration of the wrist increased.

In summary, this study showed that only two of the selected kinematic variables demonstrated a high negative correlation with judges rankings. As the rank of scores increased, there was a strong tendency for the percent of time for the wrist to reach maximum resultant linear wrist velocity to decrease. As the rank of scores increased, there was a strong tendency for the maximum resultant hip velocity to decrease.

Temporal Relationships of the Kinematic Variables in a Reverse Punch: Condition I

Temporal relationships were investigated with regard to percentage of time for the hip, shoulder, and wrist of the punching arm to reach maximum resultant velocity in relation to the total time of the punch. The percentages were calculated and appear in Table 3. The mean percentage

Table 3

Percentage of Total Punching Time for the Hip, Shoulder, and Wrist to Reach Maximum Resultant Linear Velocities During Condition I (no target)

Subject	Hip	Shoulder	Wrist	Total
A	0.07 a	0.112	0.192	0.245
	28% b	45%	78%	
B	0.07	0.14	0.178	0.250
	28%	56%	71%	
C	0.057	0.10	0.17	0.240
	23%	39%	70%	
D	0.05	0.14	0.15	0.267
	18%	52%	54%	
E	0.15	0.19	0.24	0.333
	44%	56%	73%	
Mean	0.05	0.134	0.18	0.267
	28%	50%	69%	

a - Denotes times in seconds.

b - Denotes a percentage of total punch time.

of total time for the hip to reach maximum resultant linear velocity was 28%, maximum resultant linear shoulder velocity was reached at 50% of total punch time and the wrist reached maximum resultant linear velocity at 69% of the total punch time. Total mean punching movement time was 0.267 seconds.

Kinematics of punch: Condition I. Kinematic measures of displacements, velocities, and accelerations were compared with respect to their temporal and sequential patterns for each subject during Condition I (punching without a target).

Horizontal displacements of the wrist varied from 0.870 m to 1.240 m with a mean of 1.120 m. Horizontal displacements of the hip ranged from 0.150 m to 0.173 m, with a mean of 0.162 m. The horizontal displacements of the shoulder ranged from 0.347 m to 0.454 m with a mean of 0.400 m (Table 4). The greatest horizontal displacement of the wrist, hip and shoulder was for subject D. Subject D also achieved the highest total score and was ranked as number 1. Subject A demonstrated the lowest wrist and shoulder displacements, 0.87 m and 0.34 m, respectively. Subjects E and B recorded the lowest hip displacements of 0.16 m.

The resultant linear velocities of the hip, shoulder, and wrist appear in Figures 1 through 5 for subjects A

Table 4

Horizontal Displacements of the Hip, Shoulder and Wrist

Subject	Hip (m)	Shoulder (m)	Wrist(m)
A	0.20	0.34	0.87
B	0.16	0.45	1.00
C	0.15	0.36	1.07
D	0.17	0.45	1.24
E	0.16	0.42	1.17
Mean	0.16	0.40	1.12
Range	0.02	0.11	0.27

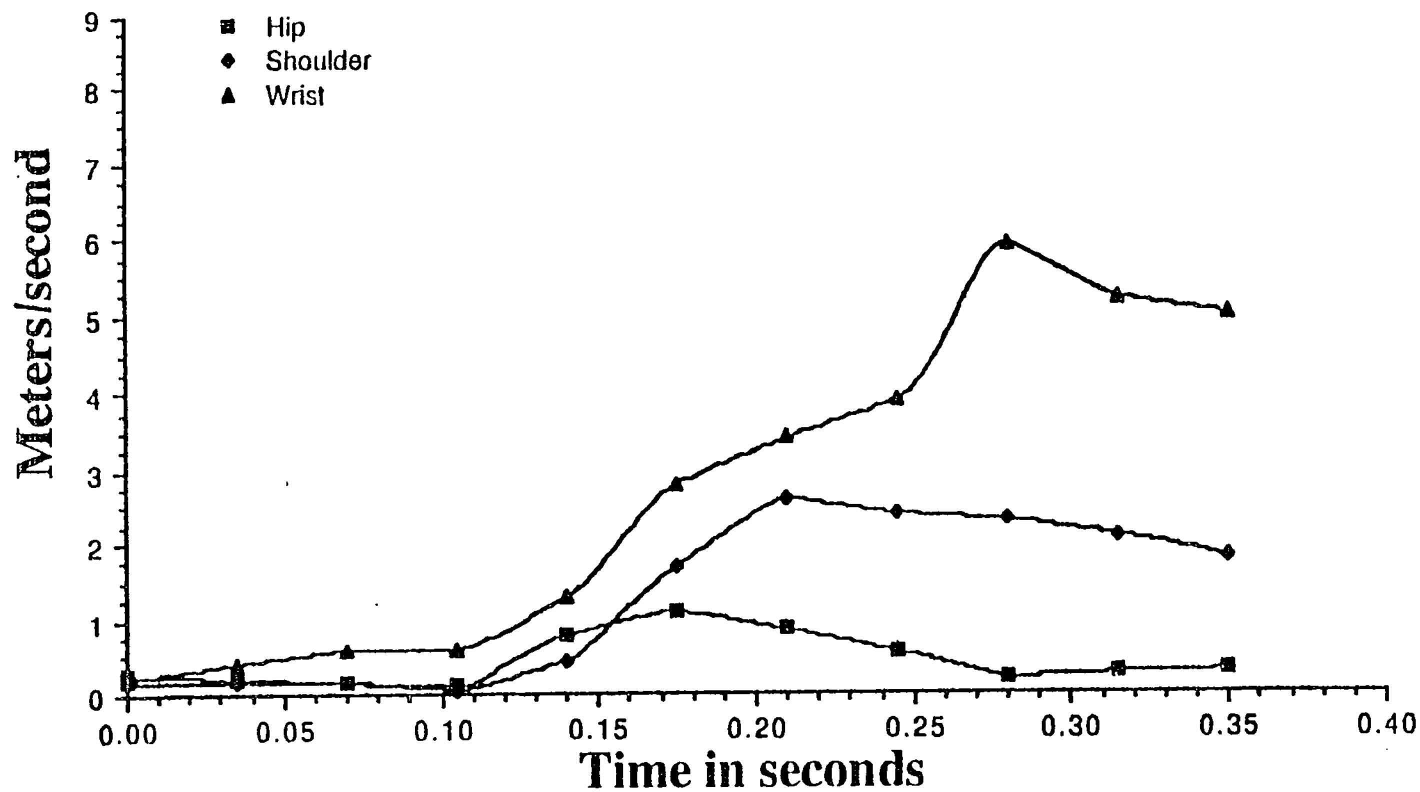


Figure 1. Resultant linear velocities of the punching wrist, shoulder, and hip during Condition I for Subject A.

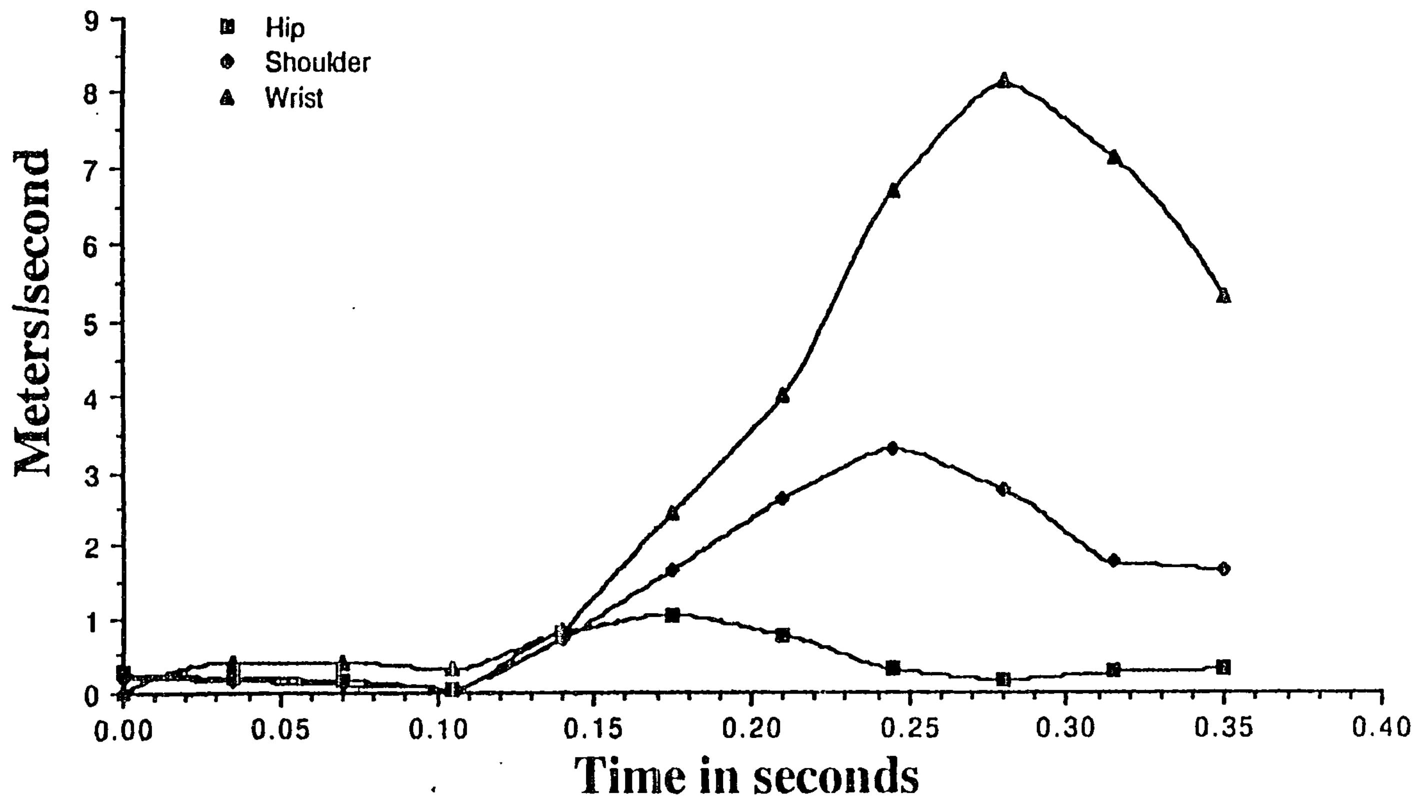


Figure 2. Resultant linear velocities of the punching wrist, shoulder, and hip during Condition I for Subject B.

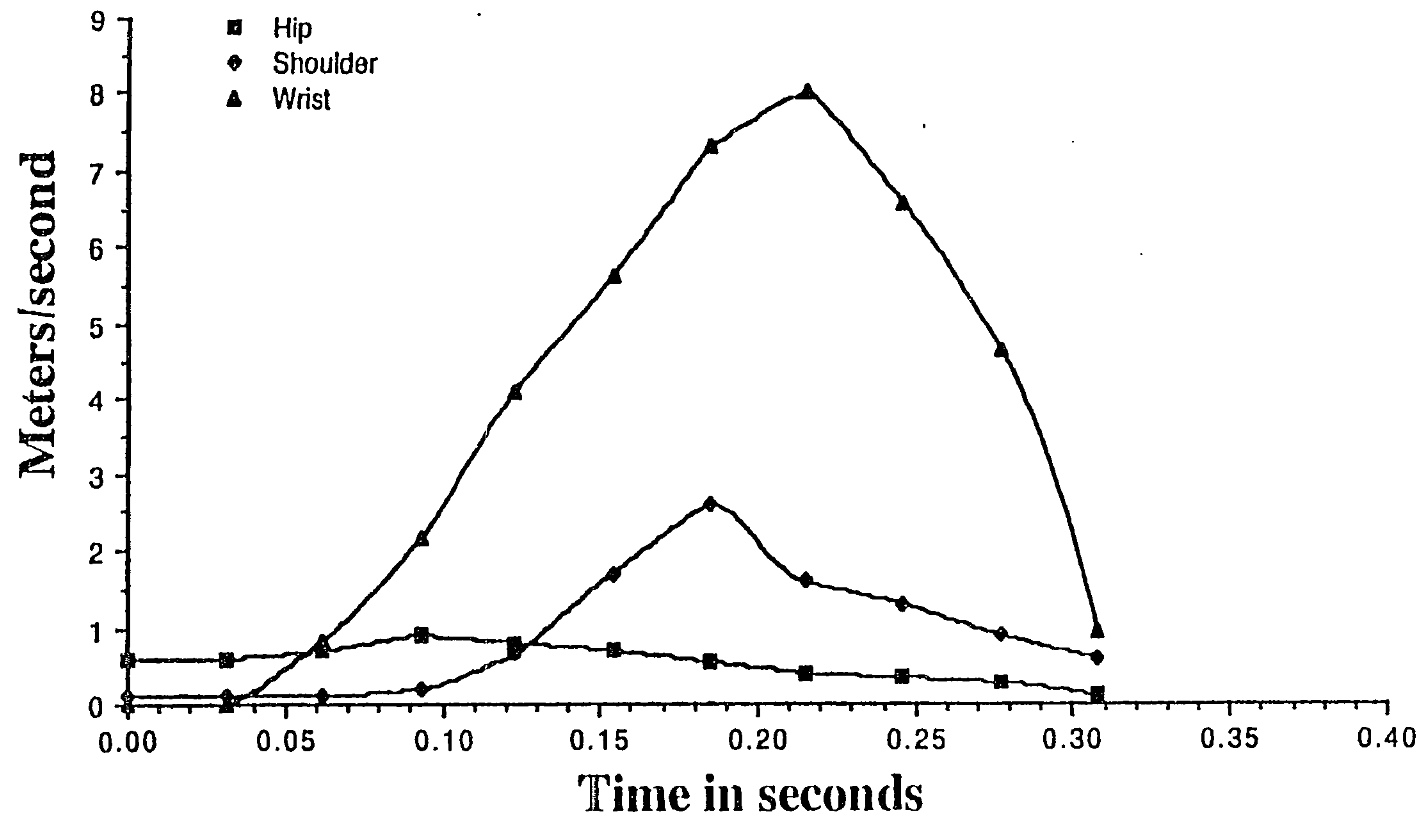


Figure 3. Resultant linear velocities of the punching wrist, shoulder, and hip during Condition I for Subject C.

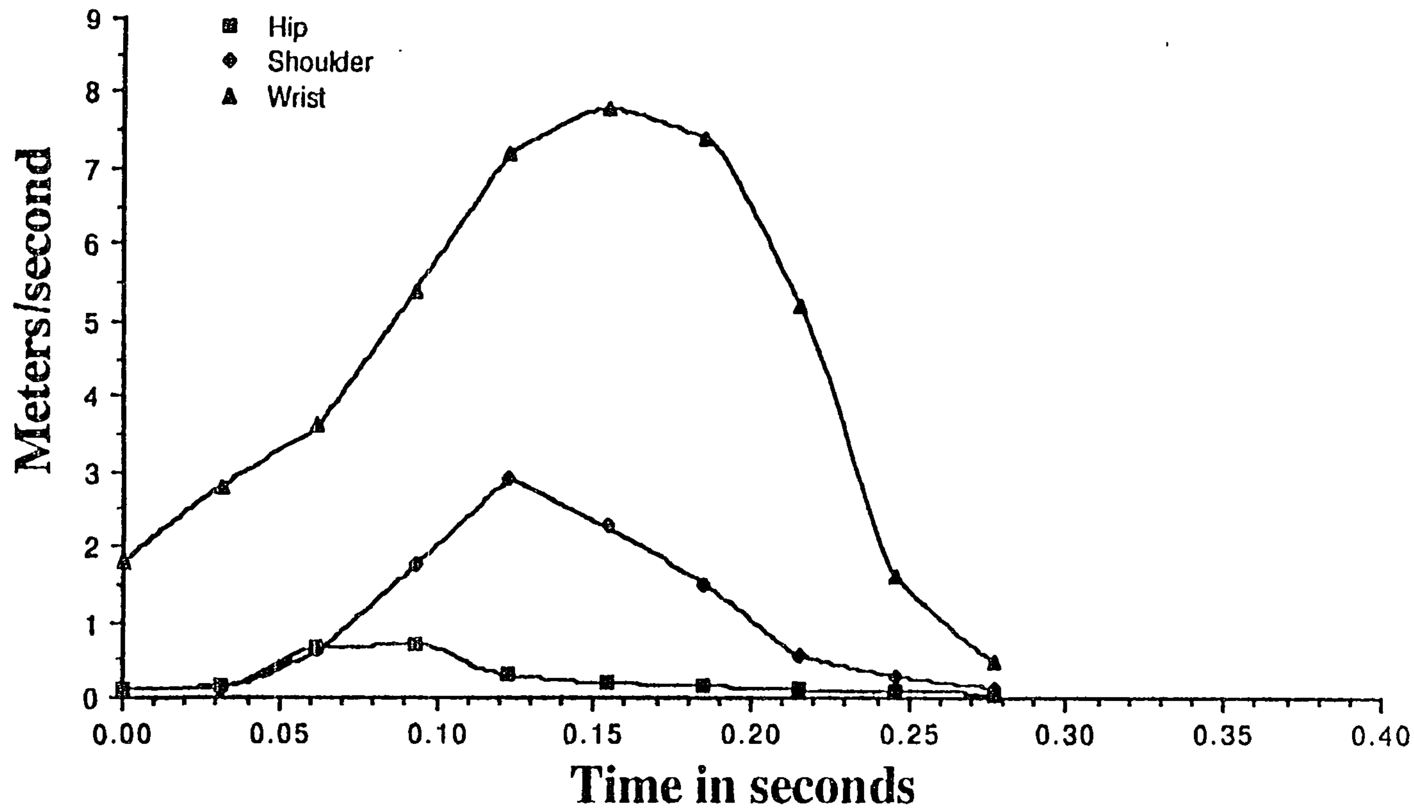


Figure 4. Resultant linear velocities of the punching wrist, shoulder, and hip during Condition I for Subject D.

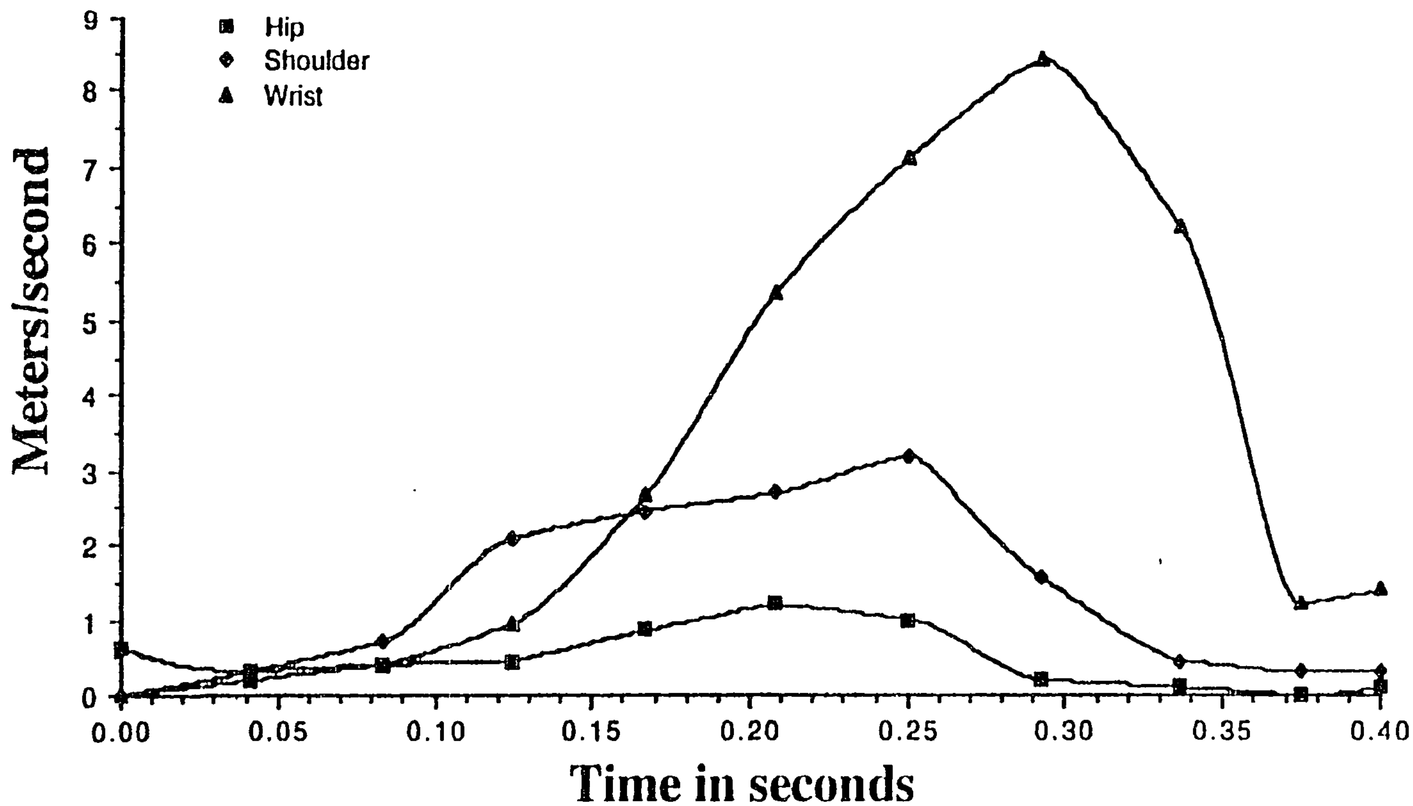


Figure 5. Resultant linear velocities of the punching wrist, shoulder, and hip during Condition I for Subject E.

through E, respectively. The punching pattern was similar for all five subjects. The right hip reached maximum velocity prior to the right shoulder; the right shoulder reached maximum velocity prior to the right (punching) wrist. The wrist was selected as the best point to measure punch velocity because it is the most distal joint of the punching arm. The knuckle was not chosen due to digitizing errors and the deformity of the fist during the punch. The resultant linear wrist velocities for all subjects appear in Figure 6. The maximum resultant linear velocities for the hip, shoulder, and wrist of the punching arm for all subjects is recorded in Table 5. The greatest resultant linear velocity of the wrist was 8.4 m/s, demonstrated by subject E.

Linear accelerations of the punching wrist and hip were measured and are recorded for all subjects in Table 6. The mean maximum resultant linear wrist acceleration was 100.3 meters per second per second (m/s/s) and the mean resultant linear hip acceleration was 21.37 m/s/s. Resultant linear wrist accelerations ranged between 45.34 and 139.53 m/s/s and the resultant linear hip accelerations were between 15.4 and 28.4 m/s/s. Subject C demonstrated the greatest resultant wrist acceleration of 139.5 m/s/s (Figure 7). The acceleration patterns were similar for all

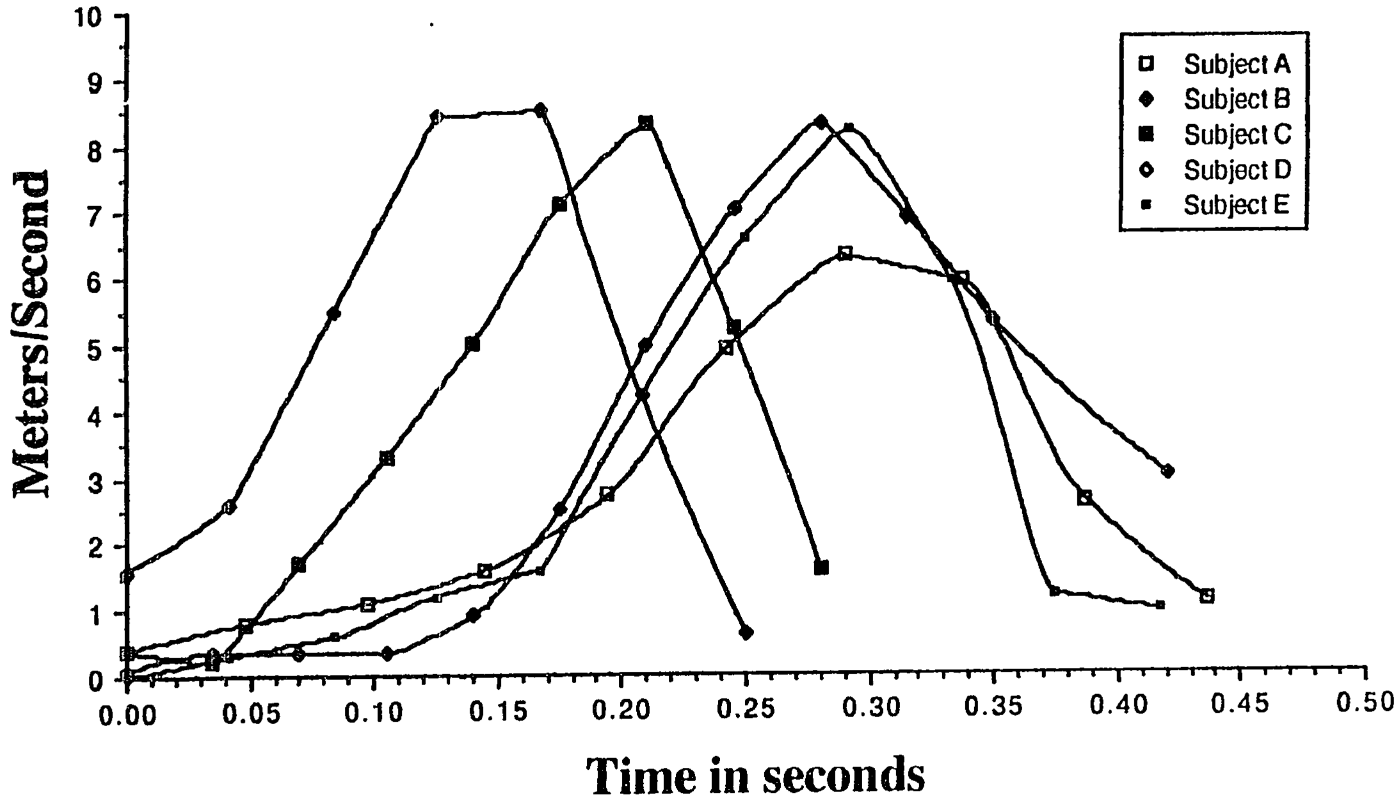


Figure 6. Resultant linear velocities of the punching wrist during Condition I for all subjects.

Table 5

Maximum Resultant Linear Velocities of the Hip, Shoulder, and Wrist During Condition I

Subject	Hip (m/s)	Shoulder (m/s)	Wrist(m/s)
A	1.1	2.6	5.9
B	1.1	3.3	8.1
C	0.9	2.6	8.0
D	0.7	2.9	7.8
E	1.2	3.2	8.4
Mean	1.0	2.9	7.6
Range	0.4	0.7	2.5

Table 6

Maximum Resultant Linear Accelerations of the Wrist and Hip During Condition I

Subject	Wrist (m/s/s)	Hip (m/s/s)
A	45.3	21.6
B	81.2	28.4
C	139.5	20.9
D	124.5	15.4
E	111.3	20.6
Mean	100.3	21.57
Range	94.1	13.0

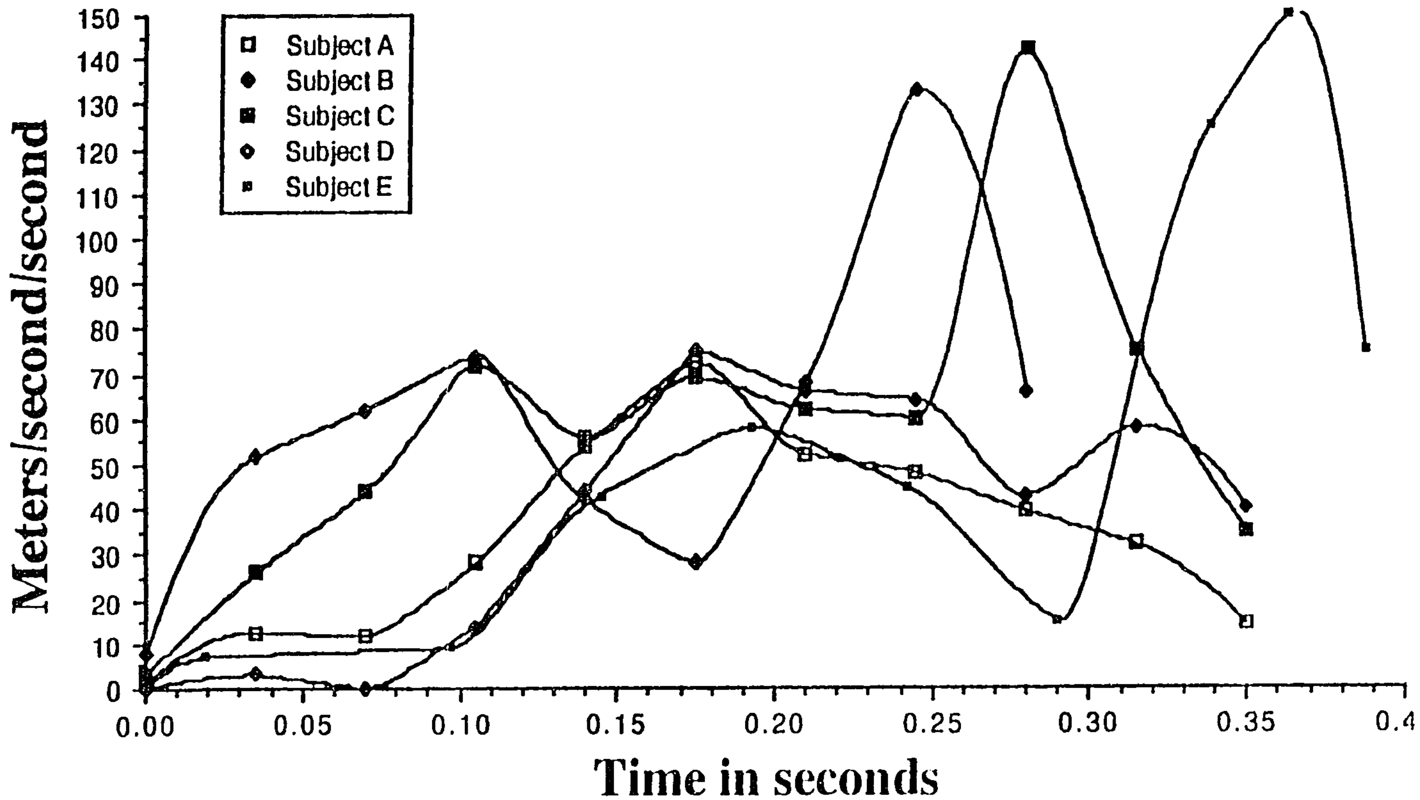


Figure 7. Resultant linear accelerations of the punching wrist during Condition I for all subjects.

subjects. The mean maximum acceleration of the wrist was attained at 74% of the total punch time. The maximum resultant linear hip acceleration for all subjects was attained prior to the maximum resultant linear wrist acceleration. The mean maximum resultant linear acceleration of the hip was attained at 35% of the total punch time. The acceleration phase of the wrist indicated two positive acceleration phases followed by two negative acceleration phases. The first positive acceleration phase of the wrist occurred at the beginning of the punching movement and the second positive acceleration phase of the wrist occurred at a point approximately 65% of the total punching movement time. The first acceleration phase of the wrist was on average 70% as great in magnitude as the second acceleration phase. The second acceleration phase of the wrist was maximal for all subjects except for subject B. Subject B reached a maximum wrist velocity at 62% of the total punch time followed by another acceleration phase which reached 88% of the magnitude of the first curve. Subject B also had the greatest hip acceleration of 28.4 m/s/s.

Angular displacement of the (right) punching arm and front (left) knee were investigated and are recorded in Table 7. All subjects demonstrated a similar pattern of the elbow with slight flexion at the beginning of the

Table 7

Angular Displacement of Elbow

and Knee During Condition I

Subject	Elbow (degrees)	Knee (degrees)
A	95	5.7
B	112	24.0
C	112	17.9
D	110	11.0
E	120	12.0
Mean	110	14.1
Range	25	18.3

movement followed by a rapid extension of the elbow as the punch was delivered forward (Figure 8). The angular displacement (extension) of the elbow was extremely similar for all subjects. The angular displacement ranged from 95 degrees to 120 degrees. The mean angular displacement of the front knee was 14.1 degrees and ranged from 5.7 to 14.1 degrees. The mean angular displacement of the punching elbow was 110 degrees and ranged from 95 to 120 degrees. Subject A demonstrated a different pattern for angular displacement of the elbow. Subject A demonstrated extension followed by flexion, then a final extension of the elbow. In viewing the videotape more closely, one sees that subject A lowered his fist from his hip prior to punching straight forward, thus explaining the different pattern of angular displacement of the elbow.

Temporal Relationships of the Kinematic Variables in a Reverse Punch: Condition II

Temporal relationships were investigated with regard to percentage of time for the hip, shoulder, and wrist of the punching arm to reach maximum resultant velocity in relation to the total time of the punch. The punching pattern was similar for all subjects, except subject A. The resultant linear velocities of the hip, shoulder, and wrist for subjects A through E appear in Figures 9 through

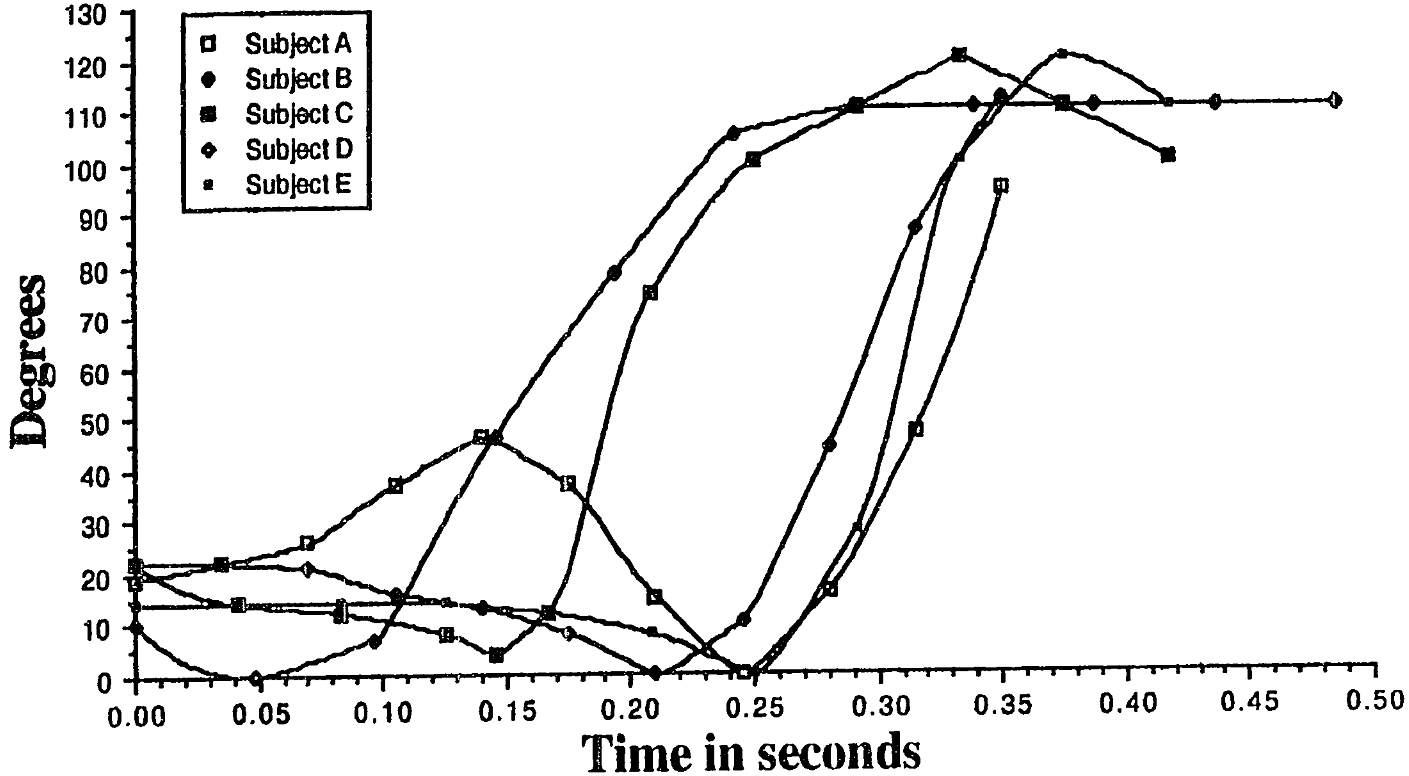
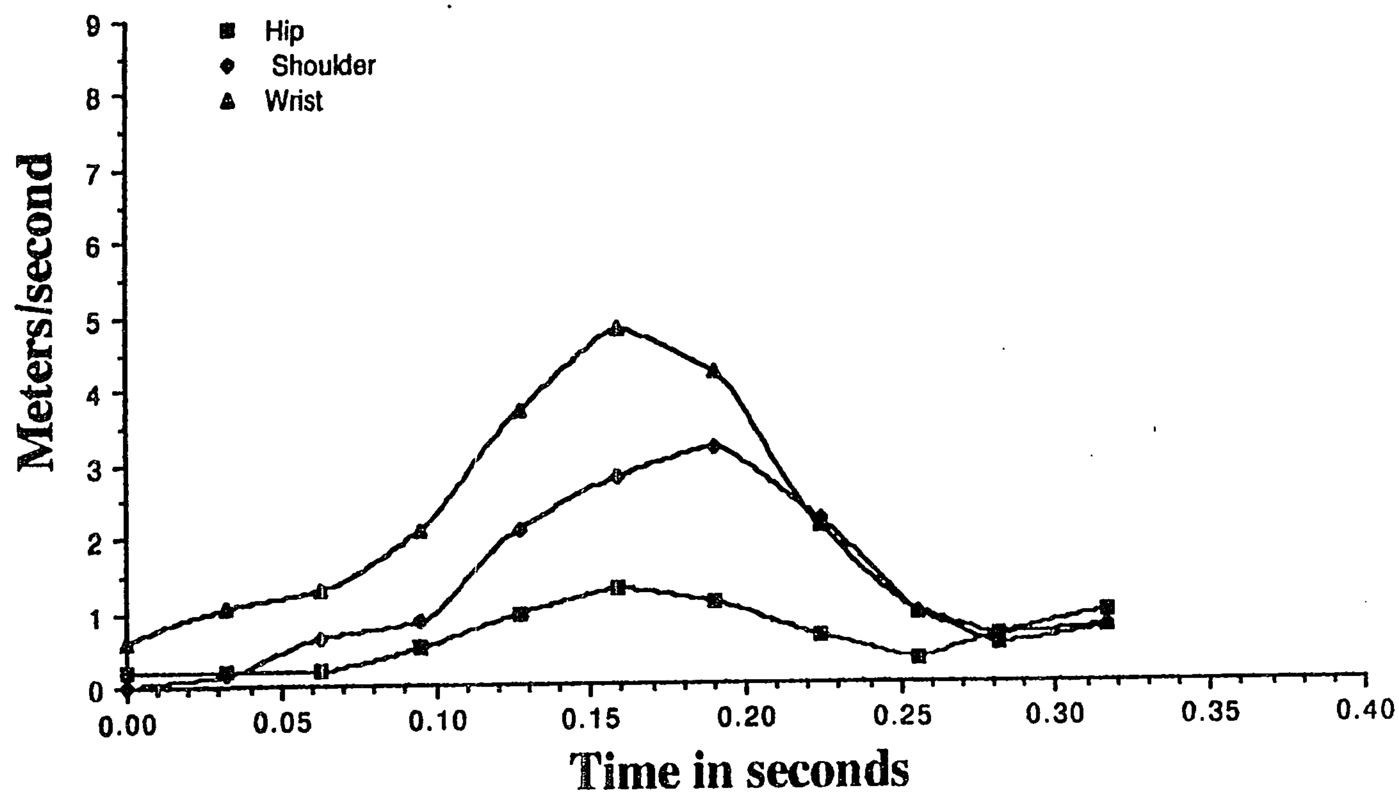


Figure 8. Angular displacements of the punching elbow during Condition I for all subjects.

13, respectively. Hip, shoulder, and wrist velocities reached maximum value in respective order. This would indicate hip rotation first, followed by shoulder rotation, and finally the arm movement in a punch pattern. Subject A reached maximum hip velocity first followed by maximum wrist velocity, and maximum shoulder velocity lastly. The percentages of total time for the hip, shoulder, and wrist to reach maximum resultant velocities and the total time of the punch were calculated and appear in Table 8.

The mean percentages of total time for hip, shoulder, and wrist to reach maximum resultant velocity as a percent of total time of the punch were 42%, 56%, 61%, respectively. The mean total punch time was 0.267 seconds. This temporal pattern is different for a reverse punch without a target. In comparison, the (punching arm) hip and shoulder reached maximum velocity considerably earlier in the total movement time of the punch for a reverse punch without a target. However, the maximum wrist velocity was reached earlier in the total movement time for the punch into the target (Table 9). Subject B , however, was almost identical for both punching conditions.

<u>Kinematics of punch: Condition II.</u> Resultant linear velocities of the hip, wrist, and shoulder for all subjects are recorded in Table 10 for comparative analysis to velocities obtained for reverse punch with no target. The



<u>Figure 9</u>. Resultant linear velocities of the punching wrist, shoulder, and hip during Condition II for Subject A.

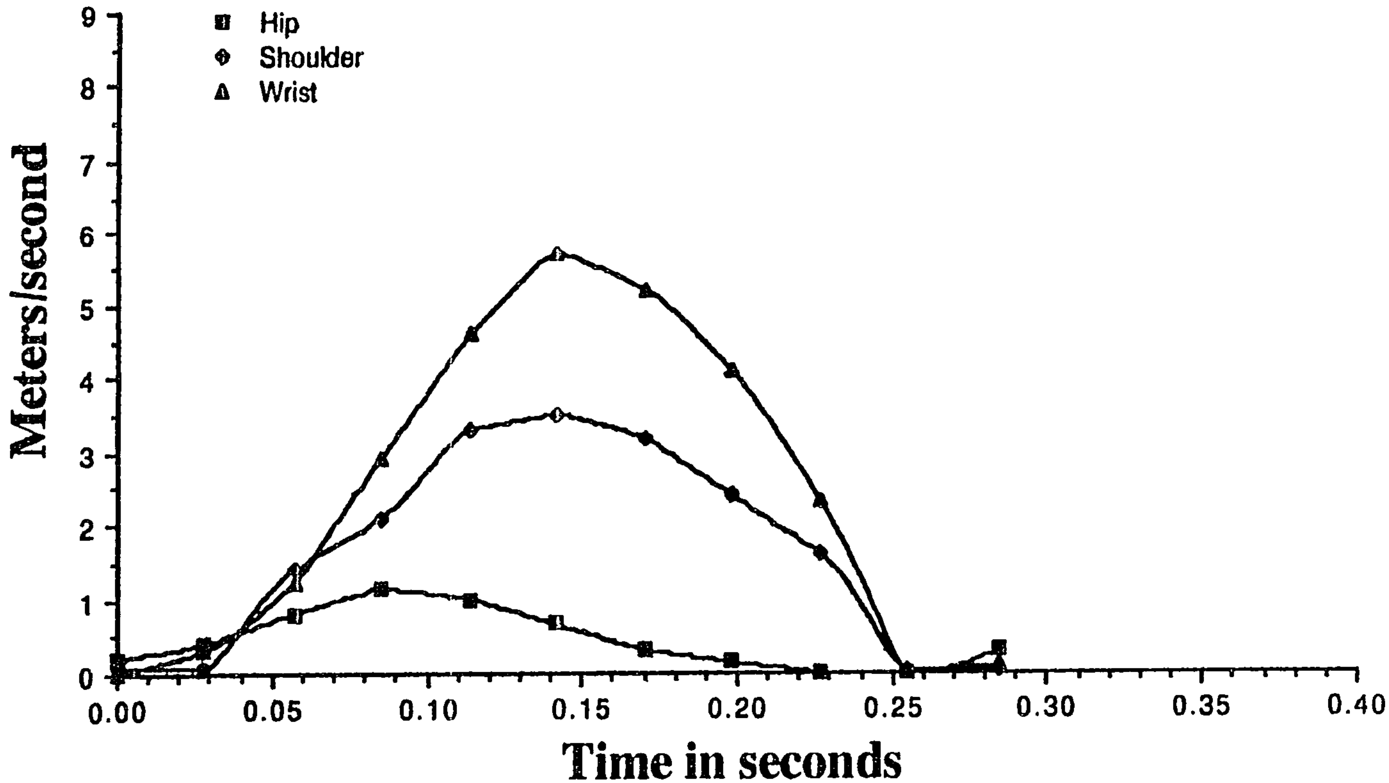


Figure 10. Resultant linear velocities of the punching wrist, shoulder, and hip during Condition II for Subject B.

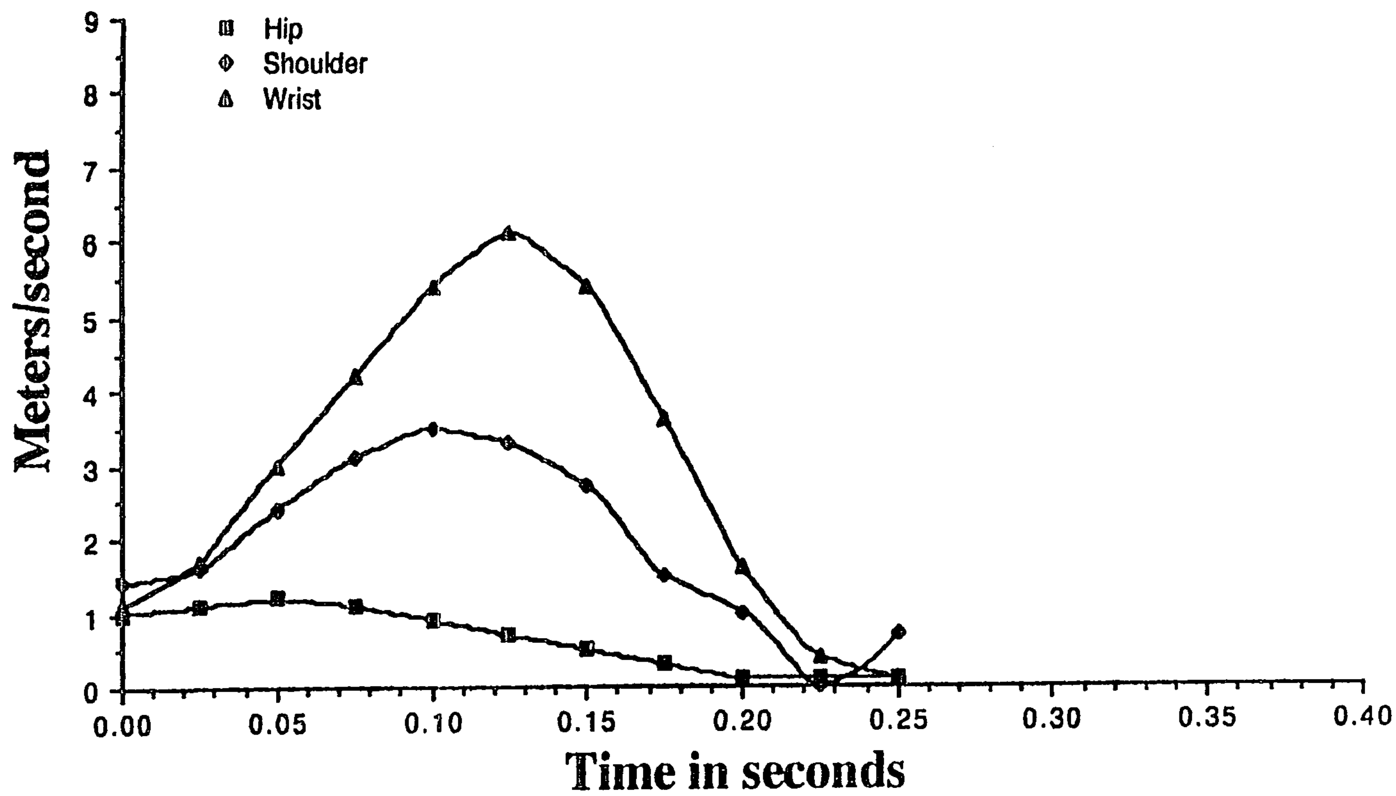


Figure 11. Resultant linear velocities of the punching wrist, shoulder, and hip during Condition II for Subject C.

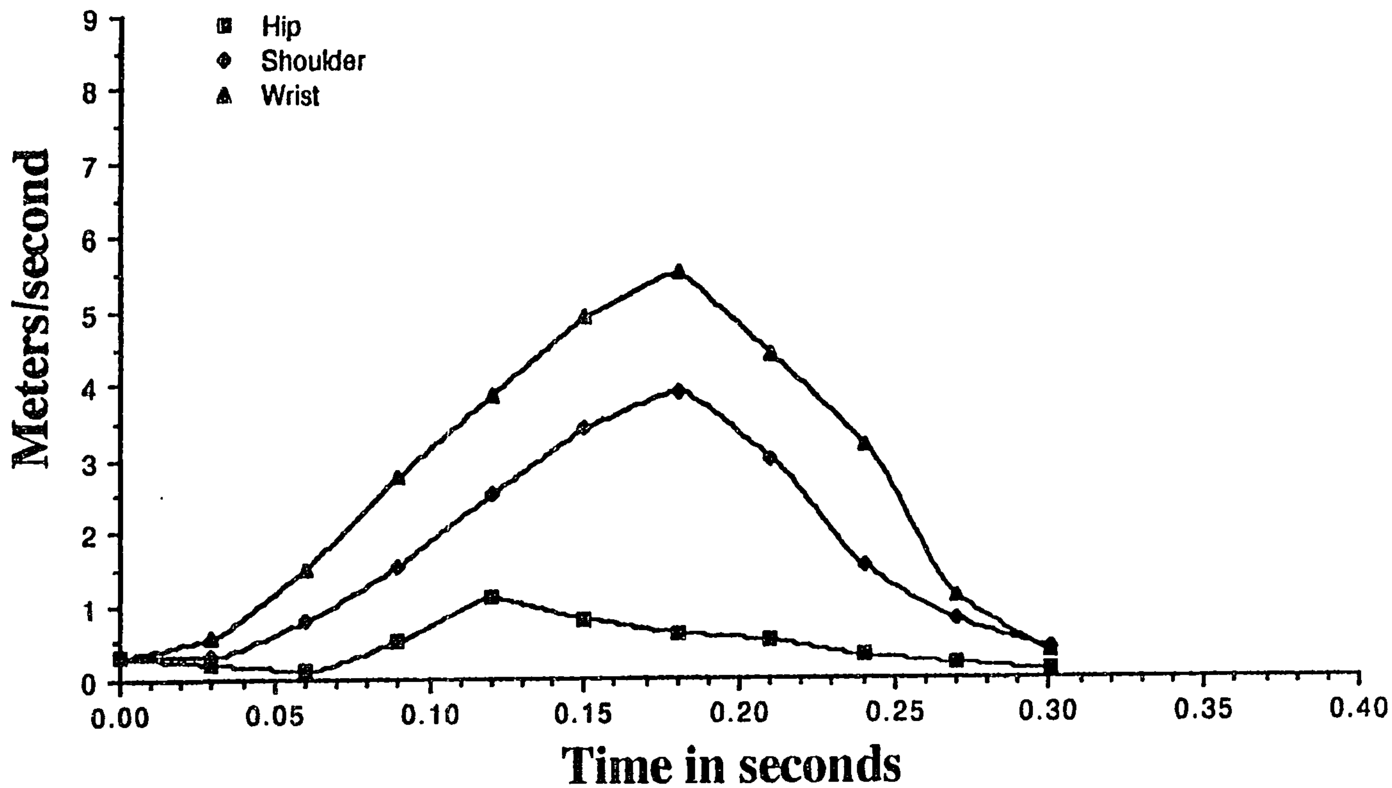


Figure 12. Resultant linear velocities of the punching wrist, shoulder, and hip during Condition II for Subject D.

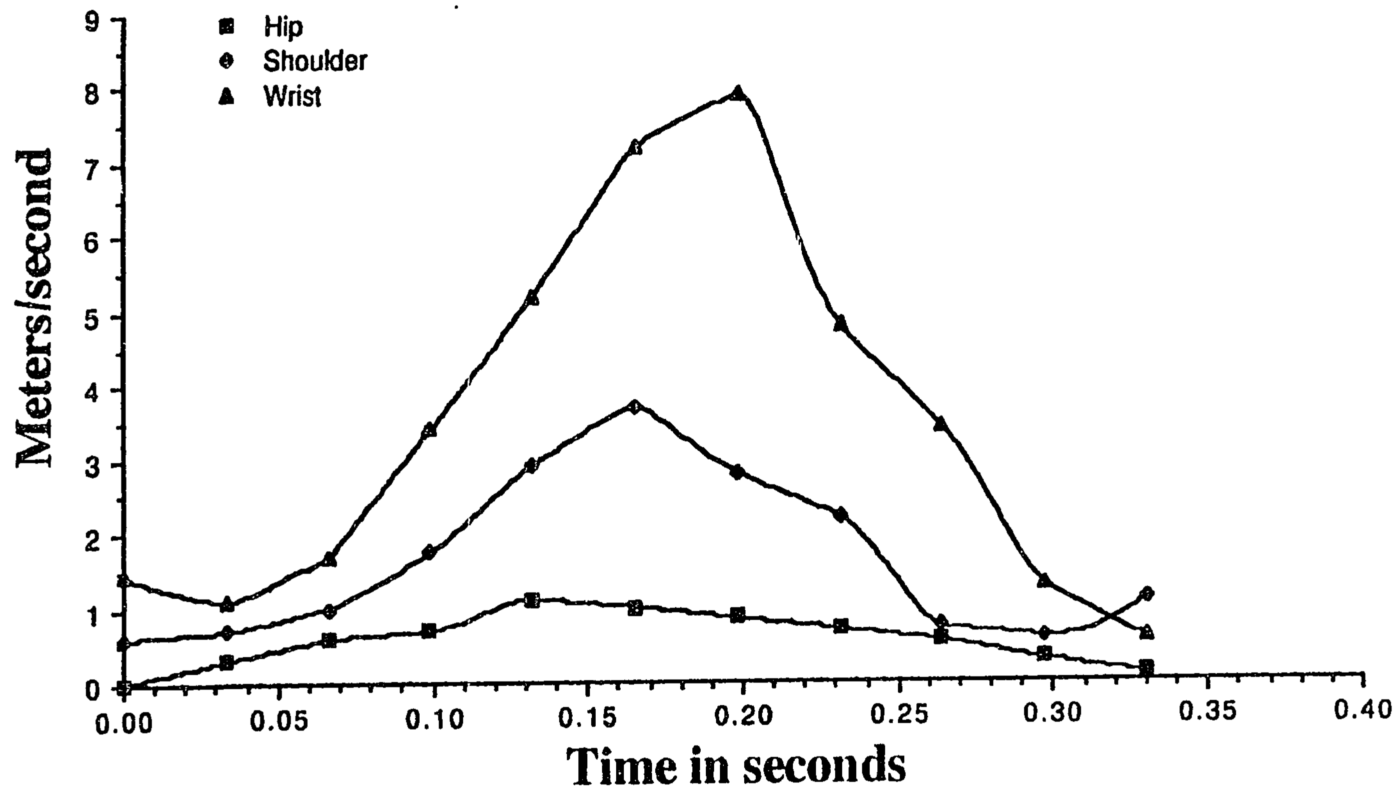


Figure 13. Resultant linear velocities of the punching wrist, shoulder, and hip during Condition II for Subject E.

Table 8

Percentage of Total Punching Time for the Hip, Shoulder, and Wrist to Reach Maximum Resultant Linear Velocities During Condition II

Subject	Hip	Shoulder	Wrist	Total Time
A	.15 a	.18	.17	.26
	60% b	69%	65%	
B	.08	.14	.15	.25
	32%	56%	60%	
C	.05	.10	.13	.21
	26%	47%	59%	
D	.15	.18	.18	.30
	50%	60%	60%	
E	.14	.16	.20	.32
	45%	50%	63%	
Mean	.12	.15	.17	.27
	42%	56%	61%	
Range	.07	.08	.08	.11

a - Denotes times in seconds.

b - Denotes as a percentage of total punch time.

Table 9

Temporal Comparisions of the Hip, Shoulder, and Wrist Velocities During Condition I and Condition II

Subject	Hip (sec)	Shoulder (sec)	Wrist (sec)	Total Time
A - Con. I	0.07	0.12	0.19	0.25
A - Con. II	0.15	0.18	0.17	0.25
Difference	0.08-	0.06-	0.02+	0.00
B - Con. I	0.07	0.14	0.18	0.25
B - Con. II	0.08	0.14	0.15	0.25
Difference	0.01-	0.00	0.03+	0.00
C - Con. I	0.06	0.10	0.17	0.24
C - Con. II	0.05	0.10	0.13	0.21
Difference	0.01+	0.00	0.04+	0.03
D - Con. I	0.05	0.14	0.15	0.27
D - Con. II	0.15	0.18	0.18	0.30
Difference	0.10-	0.04-	0.03-	0.03-
E - Con. I	0.15	0.19	0.24	0.33
E - Con. II	0.14	0.16	0.20	0.32
Difference	0.01+	0.03+	0.04+	0.01+

Table 10

Maximum Resultant Linear Velocities of the Hip, Shoulder, and Wrist During Condition II

Subject	Hip (m/s)	Shoulder (m/s)	Wrist (m/s)
A	1.30	3.2	4.8
B	1.14	3.5	5.7
C	1.21	3.5	6.1
D	1.11	3.9	5.5
E	1.6	3.7	7.9
Mean	1.27	3.56	6.00
Range	.049	.71	12.70

mean value for hip velocity was 1.27 m/s, the mean shoulder velocity was 3.56 m/s, and the mean wrist velocity was 6.0 m/s. The mean punching time was the same as Condition I, 0.267 seconds. Wrist velocities ranged from 1.11 m/s to 1.60 m/s. The range of hip velocities was 3.5 m/s to 3.86 m/s and wrist velocities ranged from 4.8 m/s to 7.9 m/s. Subject E achieved the greatest wrist velocity of 7.9 m/s, which is consistent with the results of the investigated reverse punch with no target indicating that subject E also achieved the greatest wrist velocity.

The maximum hip and shoulder velocities were greater for all subjects except subject B (hip, shoulder, and wrist velocities were less with a punch into a target compared to a punch without a target) when compared to a punch with no target. However, maximum wrist velocities for all subjects were less in the same comparison (Table 11). The punching patterns were demonstrated to differ with respect to the temporal relationship and amount of maximum velocities of the hip, shoulder, and wrist. The total amount of punch time is not considerably different for either punching condition.

Qualitative Analysis

In the front stance, all of the subjects' (right) rear leg was extended straight back with flexion on average of

Table 11

Comparision of Maximum Resultant Linear Velocities of the Hip, Shoulder,and Wrist During Condition I and Condition II

Subject	Hip (m/s)	Shoulder (m/s)	Wrist (m/s)
A - Con. I	1.10	2.60	5.90
A - Con. II	1.30	3.20	4.90
Difference	-0.20	-0.60	+1.10
B - Con. I	1.15	3.31	8.10
B - Con. II	1.14	3.15	5.70
Difference	+0.01	+0.16	+2.40
C - Con. I	0.92	2.57	8.00
C - Con. II	1.21	3.48	6.06
Difference	-0.29	-0.91	1.94
D - Con. I	0.71	2.90	7.8
D - Con. II	1.11	3.86	5.54
Difference	-0.40	-0.96	+2.26
E - Con. I	1.20	3.18	8.40
E - Con. II	1.60	3.78	7.90
Difference	-0.40	-0.60	+0.50

12 degrees at the knee (Figure 14). The front foot turned out on average 30 degrees to the right from the forward facing position. The (left) front foot faced approximately 20 degrees from the forward facing position the same direction as the rear foot. The feet were placed approximately 1 m apart in length and approximately 0.4 m apart in width. The upper body was held straight and perpendicular to the ground. The hips were rotated back to approximately 75 degrees from the forward facing position and the shoulders were rotated back approximately 85 degrees in the same direction. The punching hand was to the side of the body with the fist in a supinated position between the hip and the ribs in a ready position. The elbow at the beginning of the punch was flexed at approximately 70 degrees (Figure 15).

In all subjects the punch was initiated with the rotation of the hips, followed by rotation of the shoulders, and lastly the fist moves forward. The average punch time was calculated to be 0.267 seconds. The fist traveled forward and had both a positive horizontal as well as a vertical component. As the punch traveled toward its intended target, the fist pronated just prior to impact. At the conclusion of the punch, the punching arm was almost fully extended with slight flexion. The hips and shoulders had fully extended. The feet remained in

Figure 14. Side view of all subjects at the start of the punch during condition I.

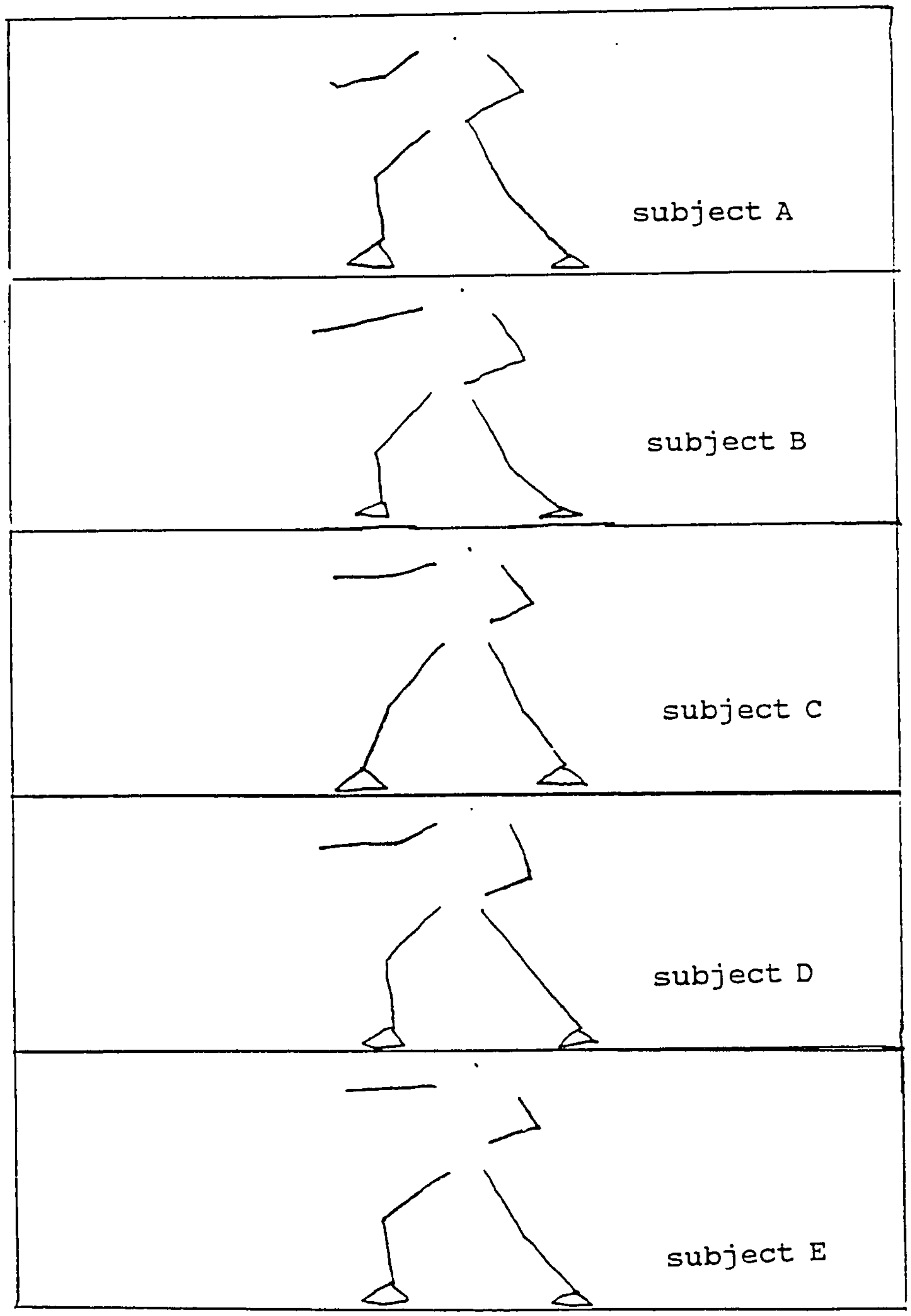
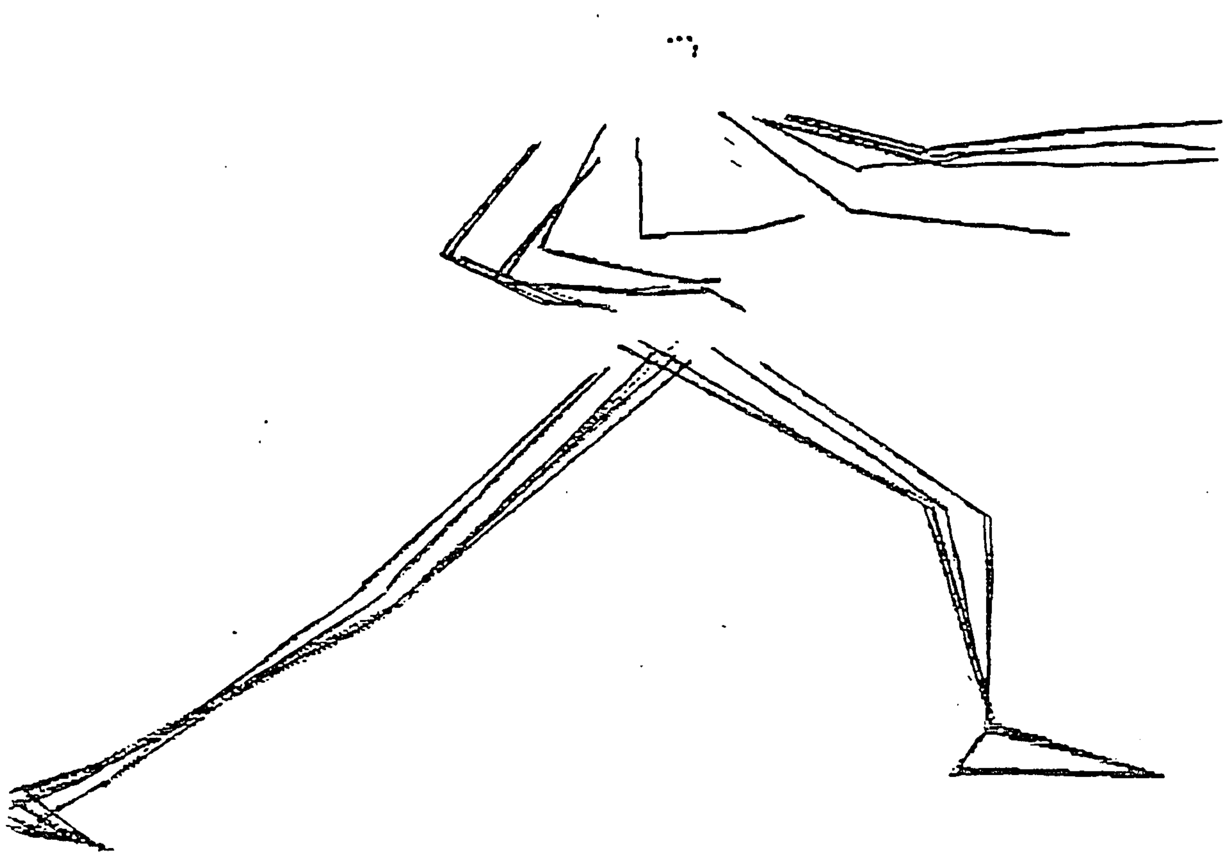


Figure 15. Representative illustration of the reverse punch in front stance through entire range of motion.



their original position. The front knee extended and tended to move back in a straight path to compensate for the rotation of the hips. The rear leg extended slightly as the punch was delivered to compensate for the rotation of the hips. The non-punching hand withdrew to a position between the hip and ribs on the opposite side of the upper body as the punch was delivered. The hips remained the same distance from the ground throughout the entire punch as did all of the subjects' right ear. The right ear moved slightly forward, only in the horizontal direction for all subjects.

CHAPTER 5

Discussion, Summary of Findings, Conclusions

Kinematics of Condition I (No Target)

The temporal patterns for all subjects were similar and consistent with Kreighbaum and Barthels (1981) discussion of the "open kinetic chain" theory. The objective of the reverse punch is to develop as much destructive force as possible upon impact into a target. One method of achieving this goal is for the karateka to develop maximum linear velocity of the fist toward the intended target, as discussed by Vos and Binkhorst (1966). The "kinetic link system" was demonstrated in the execution of the reverse punch in a front stance. The largest and most forceful body segments precede the weaker and more distal body segments in movement in order to transfer angular momentum.

All subjects demonstrated maximum hip velocity followed by maximum shoulder velocity and then maximum wrist velocity. This concept relates to the research of Van Ghelewe and Van Schandeviji (1983) which reported rotation of the spinal column during a reverse punch. Hip rotation was followed by shoulder rotation as a means of generating a greater wrist velocity during the reverse punch by all subjects.

Kreighbaum and Barthels (1981) also described the "pull pattern". The reverse punch conforms to this pattern whereby the fist lags behind the hip and shoulder movement. The fist is pulled along by the more proximal segments. This transfer of angular momentum generated by the hips and shoulders confirms Nakayama's (1989) findings. Nakayama stated that hip and shoulder rotation are essential to the proper execution of the reverse punch delivered in a front stance. This study indicated that on average the subjects displaced the hips forward 14% of the distance the wrist traveled during the entire punch. The shoulders were displaced a distance of 36% of the distance the wrist traveled during the punch. This would suggest that increased horizontal wrist velocity is achieved by rotating the hips and shoulders during the execution of the punch when compared to no rotation during a punch.

Quantitative Analysis. Wrist velocity is considered a key kinematic measure of the effectiveness of a punch. Velocity is a component of momentum. "Momentum is the quantity of motion of a body and is equal to the product of the body's mass and velocity" (Hay & Reid, 1988, p.145). Momentum is of major importance in impact situations such as a punch into a target. The result of the impact depends to a great degree on the momentum possessed by each of the bodies involved in the impact (Hay & Reid, 1988). The amount of momentum generated by the punching hand is a measure of the effectiveness of the punch. The goal of an effective punch is to deliver as much destructive force on impact as possible. The expert karateka is able to project more body mass into a target than the mass of the fist alone. However, the karateka cannot appreciably change the mass of the fist. To increase momentum of the punch at impact, the karateka must strive for increased linear velocity of the punching fist.

Walker (1975) reported that a karate expert was able to project more of the body's mass into the target during a punch than an unskilled puncher. Greater mass at impact results in greater force at impact. Punching in a straight line preceded by hip and shoulder rotation transfers the momentum of the hip and shoulder to the target through the punching arm and fist.

In this study the velocity of the wrist was found by dividing the wrist displacement by the time taken for the wrist to undergo that displacement. Increasing the displacement of the wrist and decreasing the punching time are two methods of increasing the wrist velocity and momentum into the target, thereby resulting in a more effective punch. Instantaneous wrist velocity must be taken into consideration when determining the maximum wrist velocity over a specific period of time. Subject E was able to achieve the greatest wrist velocity for a specific period of time, even though subject E recorded the greatest total movement time of all subjects.

Horizontal displacement may not be important in achieving a high score and rank as demonstrated by the low correlation of .38 between the rank of scores of evaluator 1 and maximum resultant linear wrist displacement. However, evaluator 1's score of performance of subject D was ranked as number 1. Subject D also had the greatest horizontal displacement for the hip, shoulder and wrist. Subject D was the second tallest subject in the study and it would be assumed that he would have comparatively high displacement values due to the length of his extremities. Subject D developed a maximum wrist velocity of 7.8 m/s, higher than the mean of 7.6 m/s. Since subject D had the greatest wrist displacement his fist traveled the furthest distance during the punch, resulting in greater velocity and momentum into the intended target.

It should be emphasized to the karateka that the fist must be placed between the hip and ribs for the fist to maximize the distance traveled during the punch. The karateka should also be instructed to initiate the punch with the hips and shoulders rotated back. The hips should begin to rotate first, followed by hip rotation and then finally the fist begins to move forward toward the intended target.

The values for wrist (punch) velocities appear to be consistent with previous studies. Hirata (1971) investigated skilled and unskilled karate subjects performing a reverse punch. The maximum value for wrist velocity in this study was 8.4 m/s and compares closely to 8.1 m/s of the expert subject in Hirata's study. Feld, McNair, and Wilk (1979) reported the reverse punch to have a range of 5.7 m/s to 9.8 m/s. The mean value for punch velocity in this study was 7.6 m/s. The mean value for this study is approximately in the middle of the range reported in the 1979 Feld, et al. study. Nakayama reported maximum punch velocity of 7.1 m/s for the three karate experts investigated in his 1966 investigation. Walker (1975) analyzed a single experienced subject and found a maximum velocity of 7 m/s in the karate reverse punch. Based on a comparison of previous studies, it is concluded that this study confirms that the approximate average value for maximum punch velocity developed by karate experts is 7 m/s.

The mean percentage of time for the wrist (punch) to reach maximum velocity compared to the total punch time was 69%. The punch in this study reached maximum velocity at 69% of the total punch time. Nakayama (1966) reported that the maximum velocity of the fist was achieved at 70% of the total elapsed movement time. Feld, et al. (1979) reported that the fist reached maximum speed at a point just inside of the intended target. As a result, the punch imparts a large momentum to the target. Grabiner (1982) stated that movement speed was one of the most important factors in the martial arts. He found that greater punching speed enables the karateka to have more mechanical energy available for the strike. This study confirms the findings of these previous studies that the punch reaches maximum velocity just prior to the elbow (punch) becoming fully extended.

Smith (1985) reported that highly skilled karatekas could better coordinate body mass into the punch and supported the concept of "focus" as well as the force summation principle. The expert subjects in this study used hip and shoulder rotation as a method to transfer angular momentum and body mass into the intended target. Transferring more mass into the punch will generate more momentum and destructive force to the intended target of the punch.

Subject C demonstrated the greatest wrist acceleration of 139.5 m/s/s and had the least amount of total movement time. Grabiner (1982) stated that punch time was essential for an effective punch. Subject C was able to punch the same relative distance in a shorter period of time resulting in a greater acceleration of the punch. Maximum linear acceleration was similar for all subjects and was attained at a mean value of 74% of the total punch time. This supports previous studies' findings of the punch reaching maximum speed at approximately 70% of the total punch time. Maximum hip acceleration was reached at 35% of total punch time confirming the idea of hip and shoulder rotation prior to the punch extending. The acceleration pattern was interesting due to the two positive and two negative acceleration phases. The first acceleration phase reached only an average of 70% of the magnitude of the second acceleration phase. It would appear that at the initiation of movement the punch begins to accelerate until the hip and shoulders stop rotating. A second acceleration phase then begins until the punch reaches its maximum value at approximately 65% of the total punch time.

Angular displacements of the punching elbow would indicate that as the punch begins to extend forward the angular displacement will increase until the punch is fully extended. This pattern was demonstrated by all subjects except subject A. Subject A appeared to drop the punching fist down slightly prior to extending the punch forward, then lifting it back up to the starting position while extending the punch. Subject A demonstrated a punching pattern that resulted in extension of the elbow followed by flexion (as he lifted his fist back up to the starting position) and then by extension until the punch was complete. This is not considered desirable and may contribute to slowing the punch.

Kinematics of Condition II (Punch Into Target)

The punching pattern was similar for all subjects, except subject A. Total punch time on average was the same for both conditions. Hip, shoulder, and wrist velocities reached maximum values for all subjects, except subject A, in respective order. Subject A reached maximum hip velocity, followed by maximum wrist velocity, and lastly maximum shoulder velocity was achieved. It would appear that this different pattern was due to improper punching technique. However, this temporal pattern was different for a reverse punch without a target. The most significant difference was that maximum wrist velocity was reached earlier in the total movement time for the punch into a target and that all subjects recorded a lesser maximum wrist velocity when punching into a target.

Quantitative Analysis. The maximum hip and shoulder velocities were greater for all subjects, except subject B, when punching into a target compared to punching with no target. The average wrist velocity with no target was 7.6 m/s and for impact into a target the maximum wrist velocity was 6.0 m/s. This difference may be due to the karateka knowing that there will be resistance to terminate the punch when striking a target (punching bag). When striking without a target the karateka must terminate the punch without resistance or a horizontal braking force. It appears the karateka is trying to put more mass at impact into the target by rotating the hips and shoulder more when the punch terminates into a punching bag, resulting in greater hip and shoulder velocity. The wrist velocity was less for the punch in the target due to the karateka attempting to push body mass through the target instead of slowing the punch abruptly when there was no impact into a target. Therefore, this study showed that there was a considerable difference in the temporal punching patterns and absolute values obtained when punching with no target and punching with impact into a target.

Biomechanical Analysis of Reverse Punch in Front Stance

The following is a biomechanical description of the reverse punch in front stance as evaluated by analysis of five karate experts. One of the specific problems in the study was to expand on the description of the reverse punch currently found in the literature (Nakayama, 1989; Okazaki, 1984 & Nagamine, 1976).

The front foot in the front stance was flat on the ground and turned out at 20 degrees from the forward facing position to the side of the punch. The plumb line of the knee was directly over the foot. The rear leg extended to the rear with 20 degrees of knee flexion. The foot was flat on the ground. The rear leg was turned out at 30 degrees from the forward facing position to the side of the punch. The feet were approximately 1 meter apart in length and 0.4 meters apart in width. The upper body was held perpendicular to the ground. The head remained completely still during the execution of the punch. The hips were rotated back to 75 degrees from the forward facing position and the shoulders were rotated back approximately 85 degrees in the same direction. The punching fist resided at the side between the hip and ribs. At the initiation of the punch, the hips began to rotate, followed by shoulder rotation. The fist started in a supinated position. The punch traveled forward and pronated just prior to the end of the punch. The other hand was held straight out and was simultaneously withdrawn to a position between the hip and ribs on the other side of the body while the punch was delivered. The wrist was held flat and straight and the elbow followed the same straight path as the fist. At the conclusion of the punch, the punching arm was fully extended with slight flexion. The hips and shoulders were rotated forward. The feet remained in their original position.

Summary of Findings

The following summarizes the findings for the statistical analysis, the temporal analysis, and the kinematic analysis of this study.

Statistical Analysis. The following findings were based upon the Spearman rank difference correlation coefficient calculation as described by Safrit (1990). There were negative correlations between the rank of scores of the reverse punch in front stance and the following variables:

1. Percentage of time for maximum wrist velocity.
2. Maximum resultant hip velocity.

This study demonstrated no relationship between the rank of scores for the reverse punch in front stance and the following variables:

1. Total punch time.
2. Maximum resultant shoulder velocity.

This study found that there were moderate relationships between the rank of scores for the reverse punch in front stance and the following variables:

1. Linear wrist displacement.
2. Maximum resultant wrist velocity.

3. Maximum wrist acceleration.

Temporal Analysis.

The following are temporal patterns determined from the study:

1. Temporal punching patterns were the same for all subjects with hip, shoulder, and wrist reaching maximum velocity in respective order.

2. Maximum wrist velocity was at 70% of total punch time.

3. A difference in temporal punching patterns existed between punching into a target and punching with no target.

4. Temporal punching patterns were similar among all subjects for each condition.

5. Total punch time was the same for both punching conditions.

Kinematic Analysis. The following are kinematic data calculated from the study:

1. The mean wrist velocity for Condition I (no target) was 7.6 m/s.

2. The mean wrist velocity for Condition II (punch into target) was 6.0 m/s .

2. Maximum wrist velocity was greater when punching without a target when compared to punching with a target.

3. Maximum hip and shoulder velocity was greater when

punching into a target when compared to punching without a target.

Conclusions

Based on the data generated in this study it can be concluded that:

1. The magnitudes of the punch velocities demonstrated agreement with the existing literature.

2. The temporal analysis of the reverse punch demonstrated agreement with the existing literature.

3. The punch was performed according to the principles of the "kinetic link system."

4. Time for wrist to reach maximum resultant velocity as a percent of total punch time and maximum resultant hip velocity were correlated with the rank of scores of the reverse punch in front stance and were therefore the most discriminating variables in terms of a ranking performance of a reverse punch in front stance.

5. The kinematic information obtained in this study provided for a complete biomechanical description of a reverse punch in front stance.

Recommendations

This study only considered kinematic data. The information contained in this study describes the movement and pattern involved in performing a reverse punch in front stance. A kinetic analysis of the reverse punch in front stance may provide further insight into explaining the movements and patterns of the punch. Studies in the future should include an analysis of the force of the punch at impact. Analysis of torque, moments of inertia and momentum will provide a better understanding of the reverse punch.

This study was limited to the constraints of the Peak Performance system. The videotaping was at 60 frames per second for digitizing on the Peak Performance system. An increased taping speed would have enhanced the study. Access to specific kinematic data was limited to the output restriction of the Peak Performance system and resulted in difficulty in obtaining and, therefore, reporting kinematic information.

The criteria used to evaluate a quality performance of the reverse punch may be difficult to develop given the nature and purpose of karate. Current evaluation procedures, based on criteria currently being used is subjective. The performance of karate techniques have not yet come to be evaluated solely on physical merits. In addition, promotion to the rank of black belt is subject to other traditional criteria such as personality, attitude, humbleness and contribution. It is the investigator's belief that further standardization may not be warranted given the nature and purpose of karate. It is recommended, however, that if it were to be decided that more objective criteria be used in evaluation of karate performances that criteria be developed based on input from several karate experts. In addition, it would be expected that the evaluation criteria developed be subject to the same rigors and standards that other observation/evaluation instruments are subjected to.

If specificity of training is to be adhered to in karate training, the techniques practiced must be specific to the desired outcome. This study demonstrated that there were differences in kinematic variables when punching without a target and punching into a target. Karateka punching without a target often have the goal of improving technique and maintaining the more subjective "art form." Karateka punching into a target often have the goal of developing a more powerful punch with the aim to win a tournament match. The karateka who desires to win a karate tournament should practice techniques (such as punching a bag) that are specific to the competition. An individual karate expert's belief system towards karate should govern the type of activities they practice and teach.

The results of this study are in agreement with previous studies. However, the investigator recommended that this study be replicated to determine the extent to which the present studies are generalizable.

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Appendix A

Sample Subject Consent Form

Agreement to Participate in Research
Responsible Investigator: Steven W. McCann
Title of Protocol: Analysis of Gayaku-zuki in Zenkutsu-dachi.

1. I have been asked to participate in a research study investigating the kinematic characteristics of a reverse punch in front stance performed in karate.

2. I will be asked to perform a reverse punch while being filmed with a video camera. Points on my body will be marked with white tape for identification on film. The study will occur at San Jose State's biomechanics laboratory. I will need to perform only one day for approximately 30 minutes.

3. I will be taped performing a reverse punch at a target pad as well as performing the movement with no impact into a target.

4. I expect to receive no discernible benefit for participating in the study.

5. I have been informed that the results of this study may be published, but no information that could identify me as a subject will be included.

6. I understand that there will be no compensation of any kind to me for participating in this study.

7. I have been informed that any questions I have about the research my be addressed to the principal investigator, Steve McCann, at (408) 377-7587. Complaints about the research may be presented to the Human Performance Department Chair, Dr. James Bryant, at (408) 924-3010. Questions or complaints about research, subject's rights, or research-related injuries may be presented to Serena Stanford, Ph.D., Associate Vice President of Graduate Studies and Research, at (408) 924-2480.

8. No service of any kind to which I am otherwise entitled, will be lost or jeopardized if I choose to "not participate" in the study.

9. I understand that consent in the study is given voluntarily. I may refuse to participate in the study or in any part of the study. If I decide to participate in the study, I am free to

withdraw at any time without prejudice to my relations with San Jose State University or any other participating institutions.

10. I have received a signed and dated copy of this consent form.

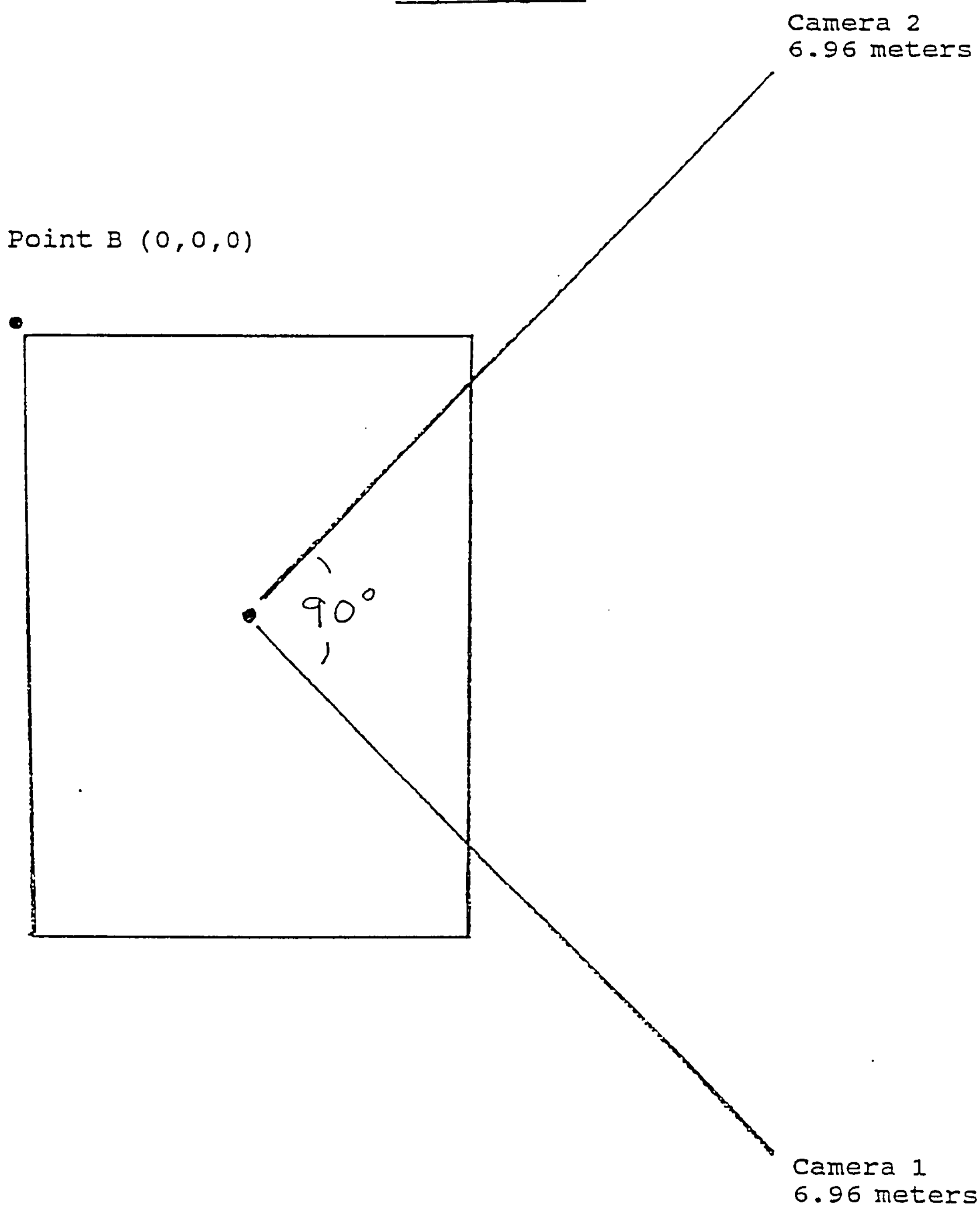
- The signature of a subject on this document indicates agreement to participate in the study.

- The signature of the researcher on this document indicates agreement to include the above named subject in the research and attestation that the subject has been fully informed of his or her rights.

Subject's Signature	**Date**
Investigator's Signature	**Date**

Appendix B

Object Space



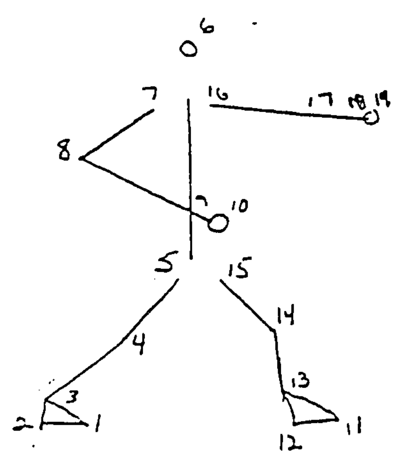
Camera Height = 1.14 meters

Appendix C

Spatial Model Set-up

Name:	PUNCH	Label	Connection			
# of Points:	19					
1	rt toe		_	_	_	_
2	rt heel		1	_	_	_
3	rt ankle		2	1	_	_
4	rt knee		3	_	_	_
5	rt hip		4	_	_	_
6	rt ear		_	_	_	_
7	rt shoulder		_	_	_	_
8	rt elbow		7	_	_	_
9	rt wrist		8	_	_	_
10	rt knuckle		9	_	_	_
11	lt toe		_	_	_	_
12	lt heel		11	_	_	_
13	lt ankle		12	11	_	_
14	lt knee		13	_	_	_
15	lt hip		14	_	_	_
16	lt shoulder		_	_	_	_
17	lt elbow		16	_	_	_
18	lt wrist		17	_	_	_

Use cursor keys to amend, ■ to file, ■ to set up Center of Mass.
There are 1 more points. Press ■ to view them.



Appendix D

Sample Evaluator Form

Evaluator: ____

Subject: ____________________ Date: _________________

Scoring grade scale: 5 = Excellent, 4 = above average, 3 = average, 2 = below average, and 1 = poor

1. SPEED - The punch should be delivered quickly and achieve maximum speed just prior to impact in order to effectively penetrate the intended target with force.
2. TIMING - The punch should be properly timed so that the hips, shoulder and wrist turn in respective sequence. The wrist should twist just prior to contact with intended target.
3. POWER - Power is evident by the ability of the performer to deliver body mass into the intended target. The punch should be executed with power sufficient to cause injury to an opponent.
4. BREATHING - The punch should be delivered as an explosive movement. The performer should exhale and tense body muscles while executing the punch.
5. CORRECTNESS OF TECHNIQUE - The punch should be performed in proper sequence with hip rotation, followed by shoulder rotation. The fist will be projected forward in a straight path directly targeted to the midsection of the performer. The wrist should be kept flat with rotation just prior to contact. The front two knuckles of the fist should make contact with the intended target.
6. FOCUS (KIME) The punch should be delivered with concentration, correct technique, and power. In addition, the performer should remain relaxed during the first part of the punch and tense most major body muscles just prior to contact to the intended target.

SCORE:

1. SPEED	1	2	3	4	5
2. TIMING	1	2	3	4	5
3. POWER	1	2	3	4	5
4. BREATHING	1	2	3	4	5
5. CORRECTNESS OF TECHNIQUE	1	2	3	4	5
6. KIME	1	2	3	4	5

TOTAL SCORE: _______________