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The back thrust kick is a karate technique used primarily in a defensive setting. This research described the kinematic variables involved in the skilled execution of the kick. Variables examined included movement sequencing, angular position of the trunk, thigh and leg, angular velocity of the thigh and leg, linear velocity at the ankle and duration of the kick.

High speed cinematography was used to film seven subjects as they performed three trials of the back thrust kick. Subjects were highly skilled black belts, four males and three females. Digitizing and computer analysis were done to obtain the variables needed for quantitative analysis. Visual analysis of the film and of graphs showing the quantitative data were used for the qualitative analysis. The two sample t-test and non-parametric Mann-Whitney analyses were used to compare the influence of gender upon the kinematic variables.
Data did not support the hypotheses of significant differences occurring as a function of gender among the variables analyzed. All subjects performed the kick in a similar fashion with males exhibiting minor variations in form during the extension phase of the kick.

The major educational implication derived from this research is the necessity to adapt instructional techniques and methods for populations which may vary by gender, height, weight and segment lengths.
A KINEMATIC ANALYSIS OF THE
KARATE BACK THRUST KICK

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A KINEMATIC ANALYSIS OF THE KARATE BACK THRUST KICK

CHAPTER I

INTRODUCTION

Martial artists are constantly searching for ways to increase the efficiency and speed of their movements, as well as to increase the force generated. Efficient execution of physical skills such as the judo breakfall and karate punch depend upon proper utilization of mechanical laws. In the case of the judo breakfall, the martial artist utilizes a slapping action to take advantage of the action/reaction principle. The slapping of the mat activates an equal and opposite reaction and tends to cancel out some of the downward momentum of the falling body. The karate punch tries to reduce the impact area of the fist to two knuckles. Reducing the surface impact area increases the pressure transferred to the target, thereby increasing the effect of the strike. It is important for both martial arts students and instructors to understand how these mechanical laws actually affect the technical execution of each movement series.

Today, karate is benefiting from improved understanding of the applications of physical and mechanical laws to specific techniques. For example, Blum (1977), using a mathematical model, identified the
optimal impact time during execution of a punch. This information
can help karate instructors train students to achieve maximal effects
from their techniques. Nistico (1982) studied differences in the
execution of both impact and non-impact punches. He concluded that
performance of the punch was condition specific, and the movement
sequence and path of motion were different between the impact and
non-impact conditions. Each of the body parts moved a greater
distance toward the target during the second half of the movement for
the impact punch. This information has implications for the type of
training conditions used by an instructor to achieve the desired
outcome. For example, an instructor training a full-contact kick boxer
would want to design workouts with a high percentage of impact
techniques, thus reflecting the impact nature of the sport. Self defense
instruction would also benefit from the development of training drills
which incorporate punching bags, target pads and other impact surfaces
designed to simulate a more realistic impact setting.

In analyzing the front snap kick, Shaw and Bos (1982) discovered
that five of the eight subjects tested exhibited knee hyperextension
which exceeded fifteen degrees. They suggested the need for further
research to determine possible effects resulting from this
hyperextension. Gray (1979) also analyzed kicking techniques in the martial arts. He reported terminal velocities ranging from 32 to 61.3 ft/sec. It was determined that the force from these kicks could produce severe chest injury if the kicks were executed at full force. Data such as this can be used to impress upon martial arts students the serious nature of their art. The front snap kick used under both impact and non-impact conditions was also analyzed by Hwang (1987). The conclusions from this study also indicated differences between impact kicks and non-impact kicks. These included differences in the velocity patterns and in the sequential involvement of the muscles used in the two kicks. Instructors are using the results of studies such as these to improve the karateka's training methods and performance style while also minimizing the likelihood of injury.

To increase the efficiency of learning and performing martial arts techniques it is necessary to teach not only the techniques themselves but also to teach the kinematic principles that facilitate efficient and fluid movement. The recent development of several products specifically designed to measure the martial artists' reaction times and force at impact reflect the practitioner's desire to implement the results of recent research studies. Also, several texts are now available that examine the application of mechanical laws and efficient movement
(ie. Karate: Basic Concepts and Skills, What the Masters Know and A Guide To Freestyle Sparring). Karate Kinematics and Dynamics, authored by Ingber, also contains specific drills designed to teach individual kinematic principles as they apply to the martial arts. Snyder's (1981) seven principles for Maximum Effective Kicking Force (M.E.K.F.) are a part of this desire to teach principles of movement along with technique. She includes among these principles preparation of the kicking leg, hip rotation/projection, complimentary arm/shoulder movements, support leg flexibility/stability, extension/retraction of the kicking leg, line of force/attack and weight distribution. She states that the student who understands the application of these principles to kicking techniques will be able to achieve M.E.K.F.

The current requirement for foam safety gear for the hands and feet of the martial artist also demonstrates the recognition by the sport's governing bodies of the potential for injury. Revisions of the sanctioned tournament rules also reflect this concern for safety. Many striking techniques that were permissible ten years ago are now prohibited, such as elbow and knee strikes.
PURPOSE OF THE STUDY

The majority of the research literature related to the martial arts is associated with punching techniques and the resulting impacts. There are very few references, however, to kicking techniques. The primary purpose of the present study was to describe the back thrust kick in terms of parameters such as duration, angular velocity of the thigh and leg, linear velocity at the ankle, angular position of the trunk and the movement sequence involved in executing the kick. A secondary purpose was to determine whether any differences in performance were evident as a function of gender. Instructors may be able to utilize this information for the purpose of both designing specific training activities and developing methods of teaching the specific kinematic principles associated with kicking techniques.

RESEARCH AND STATISTICAL HYPOTHESES

It was hypothesized that:

1. The male martial artist will perform the back thrust kick with higher linear velocity at the ankle when compared to the female martial artist.
2. The male martial artist will generate higher linear velocity at the ankle over a shorter duration of time when compared to the female martial artist.

3. Male karatekas will demonstrate significantly greater angular positioning of the trunk at the termination of the extension phase of the kick when compared to the female karateka.

Statistical Hypotheses:

1. MLVA > FLVA

2. MKD < FKD

3. Terminal MAPT > Terminal FAPT

M = male    F = female
LVA = linear velocity at the ankle
KD = kick duration
APT = angular position of the trunk
STATEMENT OF THE PROBLEM

The research problem to be studied was two-fold in nature:

1. to describe the kinematic variables involved in a skilled performance of the karate back thrust kick. The variables of interest were movement sequencing, angular position of the trunk, angular position and angular velocity of the thigh and leg, linear velocity of the ankle, and duration of the kick.

2. to determine the influence of gender on the kinematic variables of angular position of the trunk, linear velocity of the ankle and duration of the kick.

LIMITATIONS OF THE STUDY

The karate practitioners who volunteered as subjects were all highly skilled performers with a minimum of nine years of training. This factor, however, limited the application of results to other skill or experience levels.

The study was limited to non-impact kicks only. Due to the specificity of performance factors for impact and non-impact techniques
(Nistico, 1982 and Hwang, 1987) future application of the results of this research is limited to comparison with other non-impact kicks.

DEFINITION OF TERMS

**Back thrust kick:** a kick executed from a front stance with the kicking leg traveling behind the performer. Hands remain in the guard position and the head turns toward the kicking side to make eye contact with the target. Weight is shifted to the support leg and the kicking leg is flexed at the ankle, knee and hip. Kicking thigh is drawn forward and up toward the chest. The trunk curves as a lens focusing into the target, with a slight lean forward. The sole of the kicking foot points toward the target. Hip and knee extend, thrusting the foot toward the target. The striking area for this kick is the heel, with the ankle flexed, toes pulled toward the shin and foot pointed down toward the ground. Maximum power for this kick requires the kicking foot be as vertical as possible. During the kick the supporting knee and ankle are flexed slightly (Ingber, 1981).

**Chambered position:** the portion of a striking technique during which the striking limb is retracted before being extended toward the intended target. For this technique the kicking thigh is drawn forward and up toward the chest. The sole of the kicking foot points toward
the target.

**Critical distance:** the distance at which a fighter may first make contact with a striking technique. The fighter with the longest legs assumes a fighting stance and extends the rear leg toward the opponent. When the fighter is able to just touch the opponent, the critical distance is established.

**Duration:** the time from first movement of the foot to completion of the extension phase of the kick.

**Extension phase:** referring to that part of the kick during which the foot is traveling toward the target and the leg is being extended at the hip and at the knee.

**Front Stance:** a stance that provides strong front to rear stability. Feet are hip width apart and facing in a forward direction with a between foot distance of 28" to 32" from front to rear foot. Shoulders and hips are turned to the front. Weight is distributed with 60% on the lead foot and 40% on the rear foot (Snyder, 1981).

**Karate:** a type of martial art or empty handed combat; the term itself means open or empty hand.

**Karateka:** a practitioner or student of karate; also a generic term referring to a student of the martial arts.
Supporting leg: the leg supporting the body weight while a kick is being performed.

Terminal velocity: the magnitude of instantaneous velocity of the foot just prior to completion of the extension phase of the kick as calculated from film coordinates.
CHAPTER II

REVIEW OF LITERATURE

The majority of research literature related to the martial arts is associated with punching techniques and the resulting impacts. There are very few references, however, to kicking techniques. The primary purpose of the present study, therefore, was to describe the back thrust kick in terms of parameters such as angular velocity of the thigh and leg, linear velocity at the ankle, angular position of the trunk and the movement sequence involved in executing the kick. A secondary purpose was to determine whether any differences in performance were evident as a function of gender. Instructors may be able to utilize this information for the purpose of both designing specific training activities and developing methods of teaching the specific kinematic principles associated with kicking techniques.

This chapter will begin with a description of the back thrust kick and principles relevant to its effective performance. A discussion of pertinent research related to the karate kick will be followed by discussion of research on hand techniques. A summary of the research will conclude the chapter.

The back thrust kick is primarily considered a defensive technique,
one that has to be used quickly in response to an attacker’s forward movement. The kick is initiated from a front stance position (Figure 1A.) and the striking surface for this kick is the heel. The head is turned toward the kicking side allowing the eyes to focus on the target. The body weight is shifted to the supporting leg and the kicking knee is raised in front of the body to waist level. The foot is tucked up close to the thigh. This is the chambered or cocked position (see Figure 1B.). As extension begins, the body leans forward slightly and the kicking foot is thrust straight back toward the target. As the leg extends, the anterior aspect of the kicking knee is kept below the level of the ankle of the kicking foot. This is referred to as the extension phase of the kick (Figure 1C.). The toes remain pointing toward the ground throughout the kick. After full extension the kicking knee is flexed and brought back beside the support leg to the chambered position (Figure 1D), (Anderson, 1980; Snyder, 1981).

Principles of Maximum Effective Kicking Force have been outlined by Snyder (1981). These principles are preparation of the kicking leg, hip rotation/projection, complimentary arm/shoulder movements, support leg flexibility/stability, extension/retraction of the kicking leg, line of force/attack and weight distribution.
FIGURE 1A. Front Stance

FIGURE 1B. Chambered position

FIGURE 1C. Full Extension

FIGURE 1D. Retraction
Preparation of the kicking leg refers to moving the leg into a position to most effectively use the large muscle groups. This position is a level where the knee is at least at waist level. Also a part of this preparatory action is keeping the knee and foot aligned throughout the kick allowing force to travel in a straight line.

Hip rotation as explained by Snyder refers to a rotary movement of the hips about an axis either counter-clockwise or clockwise, depending upon the kick selected. Hip projection refers to the linear movement of the hips in a thrusting action toward the target. Hip projection is apparent in the back thrust kick.

Complementary arm and shoulder movements cover three areas: rising/dropping, swinging and pushing/pulling. These arm and shoulder movements assist in counter-balancing the kicking leg and in protecting the kicker during the kick as well as increasing the force of the kick when done concurrently with the extension phase of the kick.

Flexibility of the support leg is important to maintaining balance during a kicking motion. The support leg must hold the weight of the kicker and act as a shock absorber during impact. Stability is maintained by not straightening or locking the knee during execution of the kick. The support leg must also be able to pivot in unison with the rotary movement of the hips.
In terms of the extension/retraction principle, Snyder concurs with the literature stating that impact should occur after 70% of the extension phase has been completed. In other words, the kicking leg should not have reached full extension at the time of impact. This principle also recognizes the need to minimize the time between the preparatory chambered position and the retracted chambered position in order to provide for the kicker's safety. Fighting an opponent while standing on one leg is a rather precarious position.

In terms of kicking techniques, line of force refers to the direction in which momentum is established. The line of attack is the trajectory a particular technique adopts in route to the target. The kicking techniques in which line of force and line of attack are in the same direction are those which produce the faster impact/target times.

In kicking, proper weight distribution is essential for effective results. Balance, momentum and recoil at impact are all dependent upon proper weight distribution throughout the kick. Maximum Effective Kicking Force is the goal of martial arts students and Snyder outlines seven principles which are influential in developing Maximum Effective Kicking Force.

The majority of the research literature associated with karate
techniques has focused on hand strikes and/or impact information. Methodology used to study karate techniques has included cinematography, electromyography, stroboscopic photography and force analysis. Unfortunately, only a limited amount of published research evaluating the force and velocity developed during execution of kicking techniques is currently available to the martial arts instructor and/or student.

Karate hand and foot techniques were the subject of a study done by Feld, McNair and Wilk (1977). Stroboscopic photography and high speed film taken at 1000 frames per second were used to record the roundhouse kick, wheel kick, front kick and side kick, as well as various hand techniques. Experienced karateka were used to perform these skills. The peak speeds recorded for the roundhouse and wheel kicks ranged from 9.5 to 11 m/sec. and 9.3 to 10 m/sec., respectively. The front thrust kick produced a peak speed of 14 m/sec. and a value of 14 m/sec. was recorded for the side thrust kick. Hand techniques were also examined in this research.

Gray (1979) studied the force and impact of three different kicks performed by one Korean karate expert in order to determine injury potential from kicks aimed at the chest. The types of kicks analyzed were not identified. In this study terminal velocity values were
recorded using high speed film. In addition, force generated by these kicks was also recorded using a padded load cell. Terminal velocity values ranged from 9.78 to 18.68 m/sec. Force values varied from 283.5 to 997.9 kg. Gray concluded that there is possibility of severe chest injury resulting from certain karate kicks. In full contact competitive karate situations such as professional kick boxing or Olympic Tae Kwon Do, it is the responsibility of the referee to insure the performers' safety. Gray's research provided pertinent information concerning the injury potential of the various kicks. This has implications for both the design of protective equipment used and the rules governing these events.

Tae Kwon Do (TKD) front kicks with and without a target were studied by Hwang (1987) using high speed cinematography. Velocity patterns and muscular activity around the hip, knee and foot joints generated during the kick were examined. Results of this study showed significant differences in absolute speed, velocity patterns and muscular activity about the joints when impact and non-impact kick values were compared. Absolute speeds for the TKD front kick with impact were between 10.3 and 11.7 m/sec., while absolute speeds of .8 and 1.0 m/sec were recorded for the non-impact kick. The maximum
foot speeds for both kicks were 11.6 and 13.4 m/sec., respectively. It was also demonstrated that maximum foot speeds were reached prior to full extension in both kicking conditions.

Shaw and Bos (1982) analyzed the duration and angular velocity of the front snap kick (FSK). Eight martial artists ranging in experience from beginner to advanced participated in the study. Results showed FSK mean duration to be 1.17 sec. Mean peak angular velocity values for the knee were 1755 degrees/sec., while angular velocity values for the hip were 531 degrees/sec.. Advanced karateka exhibited higher angular velocity values at the knee while beginners showed higher values at the hip. Five of the eight subjects also exhibited a terminal knee hyperextension of more than 15 degrees. Shaw and Bos suggested the need for more research on the effect of repeated practice on knee joint integrity due to this hyperextension.

The following information concerning hand techniques is included to provide information regarding methodology used to study martial arts skills. It also provides a basis for comparing velocity and force values for foot and hand techniques.

Vos and Binkhorst (1976) examined velocity and force displayed during karate arm movements using photos illuminated by a stroboscopic lamp. The performances of three well-trained karateka
were compared to two moderately trained subjects. The punches performed were impact punches. Maximum linear velocity of the fingers and impact force were analyzed. Results of their study showed that skilled karateka produced finger velocities which were at least 25% higher than those produced by control subjects. However, the absolute force produced by the two groups did not differ significantly. Velocities produced ranged from 46 to 51 km/hr for the skilled group and from 39 to 40 km/hr for the control group. Force values for the skilled group varied from 47 to 89 kg and both control subjects had force values of 60 kg. The researchers identified speed of the striking limb as being a contributing factor to the success of a karate strike. This information suggests that martial arts instructors should design training activities to develop speed in order to obtain maximum results from their training.

Walker (1975) examined the karate principle of focusing a strike to terminate just inside the target body rather than the wide follow-through used by untrained street fighters and movie cowboys. The forward punch was selected to study the effectiveness of this principle. Walker, using a force analysis procedure and cinematography, found that karate black belts attain a maximum speed of about 7 m/sec. between 70% and 80% of the way through this
motion with the total duration of the punch being about .2 sec.. Contact should be made when the fist is traveling at its maximum speed.

Using cinematography, accelerometry and electromyography, Cavanaugh and Landa (1976) analyzed the pre-impact movements of a karate chop. Subjects performed karate chops intended to break pine boards. Kinematic analysis was made from film taken at 200 fps to measure and compare joint angles at the shoulder and elbow. There was found to be a sequential movement pattern taking place at the shoulder and elbow during this technique with shoulder extension approximately 70% complete before elbow extension began. Elbow flexion actually begins as shoulder extension is occurring. Angular velocities at the elbow ranged from 24.5 to 29.5 radians/sec for this particular karate strike.

Blum (1977) also analyzed the impact of a karate punch using boards from an energy produced perspective. The maximum speed recorded for each practitioner's punch ranged from 7 to 14 m/sec. This research supported Walker's (1975) conclusion that the hand should impact while it is moving at maximum speed in order to maximize the energy produced and result of the impact.

The karate counterpunch was analyzed by Nistico (1982) using high
speed film. The counterpunch was performed under two conditions: impact and non-impact. Film taken at 200 fps was used to record 10 trials, and the best 5 trials were analyzed. Nine experienced karateka were used as subjects. The researcher concluded that performance is condition specific and that impact and non-impact performances utilize different physical skills. These results were consistent with those more recently obtained by Hwang (1987). Nistico (1982) recommended that further study be done in order to develop objective criteria in evaluating technique and to assist in identifying components that contribute to effective technique.

SUMMARY OF LITERATURE

In summary, there appear to be a variety of viable techniques for analyzing the performance of karate skills, including stroboscopic photography, electromyography, accelerometry and use of static force analysis models. High speed cinematography seems to be the technique most commonly used. The speed for filming varied from 100 frames per second to 1000 fps, with 200 fps being selected most often.

In the studies examined, speed was considered to be of primary
importance to the production of maximum force values. The majority of the studies have dealt with the impact of karate strikes and the resulting effects on the impacted surface. Researchers concurred that for maximum effect to result from striking techniques the technique should impact after approximately 70% of the technique has been performed. This would support the karate principle of focusing a technique to end just inside the body rather than at impact with the surface. There was also consistent support for the body segments and muscle groups acting in sequential movement patterns, especially among more experienced practitioners.

In those studies that analyzed kicking techniques the results obtained for maximum velocity were between 9 and 14 m/sec. for most of the kicks, with one study recording a maximum velocity of 18 m/sec. Hand techniques produced velocity values ranging from 7 to 14 m/sec. with most values near the lower end of the range.

There is general agreement among the researchers that more study needs to be directed to identify the components that are required for effective technique, and the subsequent effects of these techniques on the intended impact surfaces. Finally, the effect of continual practice of these techniques on martial arts performers should be investigated further for the purpose of designing training activities that are
biomechanically efficient while reducing injury potential.
CHAPTER III

METHODS AND PROCEDURES

The primary purpose of this study was to describe the back thrust kick with references to movement sequencing, angular position of the trunk, thigh and leg, angular velocity of the thigh and leg, linear velocity at the ankle and duration of the kick. A secondary purpose was to examine the function of gender of these values.

PILOT STUDY

A pilot study was conducted to determine the most appropriate film speed for recording the kicking movements and the anatomical landmarks most visible during performance of the kick. A Redlake LoCam Camera was used to film one subject performing three trials with film speed set at 100 frames per second and then three additional trials with film speed set at 200 frames per second. These speeds were selected as the most commonly used speeds based on a review of current research performed on martial arts skills. The film was then analyzed using a CalComp 9100 digitizer. After viewing the film it was determined that 200 frames per second would be a more appropriate speed since 100 frames per second did not adequately record
Anatomical landmarks determined to be important were the joint centers of the shoulders and elbows. The joint centers of the hips were also determined to be important landmarks and were subsequently marked from both the anterior and lateral aspects. The knee and ankle joint centers were marked at the anterior, medial and lateral aspects in order to be visible throughout the kick.

SUBJECT INFORMATION

The subjects for the study were seven adult karatekas, four male and three female. All subjects were currently involved in training and in teaching the martial arts. The ranks of the subjects ranged from 1st degree black belt to 5th degree black belt. The mean age for the subjects was 35 years with the range being 28 to 39 years. All subjects had trained for at least nine years with the average being 13 years. The mean height was 175.26 cm. while actual values ranged from 160 - 190.5 cm. Weight ranged from 54.4 to 97.5 kg with the mean being 73.6 kg.

The subjects were from a varied background of Chinese, Korean, Japanese and American martial arts styles. These styles included Tae Kwon Do, American Kenpo Karate, Wy Ying Tao Karate, and Shotokan
Karate. All were familiar with the back thrust kick and its performance, as defined in this study. Several subjects also had trained performing this kick with slight variations. (See Appendix B for further subject information.)

PRE-EXPERIMENTAL PROCEDURES

Prior to the actual filming the investigator recorded the subjects’ ages, heights, weights, martial arts ranks, styles and years of experience. Informed consent forms (see Appendix A) were obtained from all subjects. Attire worn for the purpose of filming included shorts and tank tops. Predetermined anatomical landmarks were marked using both a black marking pen and tape. The specific joint centers marked were:

- Right & Left shoulders (anterior and lateral views)
- Right & Left elbows (anterior and lateral views)
- Right & Left hips (anterior and lateral views)
- Right & Left knees (anterior, medial and lateral views)
- Right & Left ankles (anterior, medial and lateral views)

These joint centers were marked according to the descriptions provided by Plagenhoef (1971).

Prior to filming, the mechanics of the back thrust kick were verbally
and visually reviewed with the subjects. Subjects were reminded of the necessity to perform the techniques correctly and to perform each kick as rapidly and forcefully as possible.

**EXPERIMENTAL SET-UP**

The data collection site for filming the seven subjects was a large indoor activity room. A 16 mm Redlake LoCam II Camera, Series 51-0062 was used to film all performances at 200 frames per second. The camera was positioned at a distance of 10 meters from the performing subject with the optical axis perpendicular to the primary plane of motion of the kick. The lens height was fixed at subject waist height. An "X" was taped on the floor and each subject positioned their support foot on this tape in order to standardize the position of the subjects. A meter stick was also included in the camera's field of view and served as a scale device.

A brief sparring workout was used as a warm-up for the subjects. This was followed by fifteen minutes of practice time during which subjects reviewed the performance of the back thrust kick. Subjects were allowed up to five minutes recovery time between kicks to allow for optimal performance. All kicks performed were non-impact
kicks with the subject kicking at a target set just out of critical distance (Figure 2). Subjects used their preferred leg to perform the kick. The target was set for each subject at a height equal to 60% of each individual subject's height.

![FIGURE 2. Experimental set up.](image)

Each subject performed three consecutive back thrust kicks from a front stance using the preferred leg. Six subjects used their right legs while one subject used the left leg. If a subject performed a kick that did not conform to the accepted description the trial was repeated. No subjects were required to repeat any trials. It was discovered upon development of the film that due to malfunction in the lighting system, one trial for one female subject was insufficiently illuminated.
for digitizing. Filming started before the kick began and continued until the kicking leg returned to its original position. Two rooms were provided, one for filming and one in which subjects waited. The filming was accomplished in one session lasting approximately two and a half hours.

ANALYSIS OF DATA

The trials were analyzed using a CalComp 9100 digitizer interfaced to an IBM PC-AT. Coordinates were taken for each anatomical landmark frame by frame and stored in data files. The digitizing process began three frames prior to the frame showing initial movement of the kicking leg and continued until five frames after full extension of the leg was completed. The coordinate data files were then accessed by a computer program which calculated linear and angular kinematic quantities on a frame-by-frame basis for each kick.

Using the data derived from the film analysis, the following variables were examined:

1) movement sequencing of the back thrust kick
2) angular position of the trunk at the end of the extension phase of the kick.
3) maximum angular velocity of the thigh and of the leg
4) linear velocity of the ankle
5) duration of the kick

The calculated values of these variables for the kick were compared as a function of gender.

Due to the small sample size, a two-sample t-test and a non-parametric test were used. The Mann Whitney Comparison of Two Samples formed the non-parametric test used. This test does not require either a large sample size or normal distribution and can be used when the data is from two independent samples of different sample size (Velleman & Hoaglin 1981). The t-test and non-parametric test compare favorably with regard to efficiency (Lehmann & D'Abrera 1975). The two sample t-test was selected in preference to the Analysis of Variance procedures because of the small sample size and the highly select group of subjects tested. The acceptable level of significance was set at <.01 prior to data collection.

Graphs also were used as a means of reviewing the data. The following graphs were compiled:

1. Linear velocity of ankle as a function of time.
2. Angular velocity of thigh and leg as a function of time.
3. Angular position of the thigh and leg as a function of time.
A simple moving average process was used to smooth out the velocity and angular position curves and allowed comparison between subjects and between gender. This involved smoothing out the data curves by averaging each point on the curve with two points before and two points after its occurrence. This produced curves representing the general movement of the kick as performed by that subject without small scale fluctuations.

A qualitative analysis was also performed to determine the common components of the kick. This qualitative analysis examined two phases of the kick: preparatory and extension; and the factors that were apparent in the majority of the trials.
CHAPTER IV

ANALYSIS OF RESULTS

This study described the kinematic variables involved in a skilled performance of the karate back thrust kick. The parameters described included movement sequencing, angular position of the trunk, thigh and leg, angular velocity of the thigh and leg, linear velocity at the ankle and duration of the kick. A secondary purpose was to determine whether any differences in performance existed as a function of gender.

QUANTITATIVE DATA

The back thrust kick is primarily a defensive technique which is executed in response to an attacker's forward momentum. It is therefore important to execute the kick as rapidly as possible and with maximum force. The first hypothesis tested was that males would perform the kick with a higher linear velocity at the ankle when compared to values for females. For the males, the mean maximum linear velocity value attained at the ankle was 18.1 m/sec. with a range of 15.3 to 21.3 m/sec. and a standard deviation of 1.1 m/sec. The mean value for females was 13.8 m/sec. with a range of 10.1 to 17.0 m/sec.
and a standard deviation of 2.8 m/sec. The mean values obtained for male and female karatekas were analyzed using the two sample t-test and the Mann-Whitney comparison of two samples based on pairs. Neither the t-test (p>.02) nor the Mann-Whitney analyses (p>.04) indicated significant gender differences at the .01 significance level.

It was also hypothesized that males would generate a higher linear velocity over a shorter duration of time when compared to female martial artists. Two aspects of the duration measure were examined, the actual time it took to perform the kick and the time it took to achieve maximum linear velocity at the ankle. The average duration value, time to complete the total kick, for the women was .28 seconds with a range of .21 to .37 s and a standard deviation of .06 s. The mean value for males was .25 s and ranged from .22 to .28 s with a standard deviation of .04 s. The results of both the Mann-Whitney and two sample t-test analyses showed no significant difference in duration of the kick as a function of gender. The probability levels obtained were p>.3 and p>.4, respectively. Similarly, analysis of the percent of the kick completed at the point of maximum linear velocity at the ankle revealed no significant differences as a function of gender. The probability level for the t-test was p>.03 and the Mann-Whitney
comparison value was $p > .04$. Males produced maximum linear velocity at the ankle after approximately 71% of the kick was completed. The values ranged from 61-93% with a standard deviation of 5%. Females produced maximum linear velocity at the ankle after approximately 60% of the kick was completed with a range of 46-86%. The standard deviation for females was 5%.

It was also hypothesized that there would be a significant difference in terminal trunk position attained between males and females. The female average was 253.7 degrees with a standard deviation of 54.2 while the male average was 228.3 degrees with a standard deviation of 3.7. The female values ranged from 219 to 316 degrees while the values for the males ranged from 226 to 233 degrees. The t-test probability level for this variable was $p > .3$ and therefore did not provide support for the hypothesis forwarded. The Mann-Whitney analysis yielded a probability level of $p > .7$ which also failed to reach the established significance level of .01.

Although no formal hypotheses were forwarded to address the variables of angular velocity and position of the thigh and leg, data was recorded and gender values compared. The mean maximum angular velocity of the thigh for the males was 1933 degrees/sec. and 3230 degrees/sec. for the females. The range for these values was 1239 to
2556 deg./sec. for the males with a standard deviation of 549 deg./sec. The females ranged from 1261 to 6203 deg./sec. The standard deviation for the females was 2620 deg./sec. The t-test (p>.3) and the Mann-Whitney (p>.60) analyses indicated no significant differences between males and females. The maximum angular velocity for the leg was also not significantly different between genders, according to t-test (p>.4) and Mann-Whitney (p>.8) analyses. Female values ranged from 473 to 3001 deg./sec. with a mean of 1498 deg./sec. and a standard deviation of 1330 deg./sec. Male values ranged from 742 to 1375 deg./sec. with a mean of 929 deg./sec. and a standard deviation of 301 deg./sec.

QUALITATIVE DATA

The following discussion is based on information derived from qualitative analysis of graphs depicting the angular velocity and position of the thigh and leg and the linear velocity of the ankle. Certain qualitative information was also obtained from visual analysis of the research film.

All subjects achieved maximum angular velocity of the thigh in the last frame of the extension phase of the kick analyzed. There was an
initial increase in angular velocity during the preparatory phase of the
kick, as the thigh and leg were being lifted into the chambered position.
This was followed by a decrease in velocity as the transition from hip
flexion to extension occurred. Subsequently, a relatively sharp rise to
maximum angular velocity of the thigh was observed following the
start of the extension phase. The angular velocity values for the thigh
did not decline as the final stage of the extension phase was reached,
but instead appeared to increase (Appendix D).

Subjects consistently produced maximum angular velocity values
for the leg prior to attaining maximum angular velocity at the thigh.
When values were collapsed across groups, it appeared that maximum
angular velocity for the leg was achieved during the preparatory phase
of the kick. This is consistent with the description of the technique
which requires the lower leg to be lifted into a chambered position
before the extension phase begins with hip extension. There is a
second peak in the velocity curve for the leg for all subjects. It occurs
during the extension phase, approximately 1/2 to 2/3 of the way
through the kick. Five of the subjects exhibited this second peak
slightly before attaining maximum linear velocity at the ankle. The
remaining two subjects exhibited this peak simultaneously with the
production of maximum linear velocity at the ankle. This is consistent
with the principle of summation of force as described by Schroeder and Wallace (1976). Summation of force refers to the concept of each succeeding force starting at the point of greatest velocity resulting from the preceding force. This allows for the most efficient movement.

Graphs (Appendix D) demonstrating the angular position of the thigh and leg suggest that the initial movement of the kicking leg involves simultaneous flexion of the hip and knee. This is done to bring the leg into the chambered position in preparation for the extension phase of the kick. Hip extension began before knee flexion ended. After hip extension began, knee extension was initiated to bring the hip, knee and foot into alignment with the target. Extension toward the target began with the hip and continued with the knee and then the foot. This is congruent with the principle of summation of forces.

Throughout the kick, the females filmed were able to maintain the vertical foot position described by Ingber (1981). Male subjects had difficulty maintaining this foot position and also exhibited abduction of the thigh during the extension phase of the kick. In order to return the foot to the vertical position prior to impact and to keep the knee below the hip, males tended to rotate the hip externally at the end of the
extension phase.

All subjects showed slight differences in angular position of the trunk at the beginning of the kick when compared to trunk position at the end of the kick. The mean value for males and females was 269 degrees at the beginning of the kick and 239 degrees at the end of the kick. Six of the subjects exhibited a decrease in angular position of the trunk at the end of the kick. Conversely, one subject showed an increase in angular position of the trunk, from 271 degrees to 316 degrees, or a backward curvature of the trunk in the direction of the kicking foot.

In summary, the qualitative analysis of the back thrust kick illustrates slight differences in form between males and females. Males in this study showed a variation in thigh and foot position during the extension phase of the kick. This would suggest that instructors need to keep in mind structural differences between genders when providing teaching cues and descriptions of the technique.

Movement sequencing followed a consistent pattern for both males and females. Hip and knee flexion occurred simultaneously during the preparatory phase of the kick. This was followed by hip extension and subsequent knee extension. Instructors can make use of this
information in teaching the basics of this technique by emphasizing the sequential nature of the kick.

The increase in angular velocity of the thigh at the end of the extension phase of the kick implies that instructors consider limiting practice of the back thrust kick to impact settings. This would allow the body segments involved in the kick to use impact to help decelerate. Practicing with just impact kicks could reduce the possibility of injury to the lumbar region and decrease hyperextension of the knee as mentioned by Shaw and Bos (1982).
CHAPTER V

SUMMARY AND CONCLUSIONS

The primary purpose of this study was to describe the karate back thrust kick with reference to movement sequencing, angular position of the trunk, thigh and leg, angular velocity of the thigh and leg, linear velocity at the ankle and duration of the kick. A secondary purpose was to compare these values as a function of gender.

Seven black belt subjects, three women and four men, were filmed at 200 frames/second as they performed three trials of the karate back thrust kick. The trials were digitized and analyzed using a Calcomp 9100 Digitizer. A two sample t-test and the non-parametric Mann-Whitney comparison of two samples analyses were used. A significance level of .01 was established prior to commencement of the study.

On the basis of the statistical analyses conducted, males and females do not differ significantly on the performance variables of the back thrust kick measured in this research. There were slight, but non-significant, differences in maximum linear velocities produced at the ankle and in the percentage of kick completed when these peak speeds were reached. Males attained peak velocity after completion of 71% of
the kick was completed, while females achieved this peak value after 60% of the kick was completed.

Males demonstrated a higher mean maximum linear velocity at the ankle (18 m/sec.) when compared to females (13.8 m/sec.). However, the pooled value of 16.3 m/sec. is within the range of values reported in studies of other thrust kicks. Feld, McNair and Wild (1977) reported values of 14 m/sec. for both the front thrust kick and the side thrust kick in a group of male subjects tested. Achievement of such a high velocity would appear to make the back thrust kick a viable defensive technique, since prior studies have identified speed as being a contributing factor to the success of karate techniques. Keeping in mind the limited sample size, the back thrust kick would seem to produce a higher linear velocity than other thrust kicks, such as the front thrust kick (14 m/sec.) and side thrust kick (14 m/sec.). The back thrust kick results in velocities high enough to consider this kicking technique as having the potential for severe injury, whether it is performed by males or females.

Previous investigators have recommended that impact should occur after approximately 70% of the kick has been completed or at the point at which maximum velocity of the striking surface has been
attained (Snyder, 1981 and Hwang, 1987). When mean values for percent of kick completed at achievement of maximum velocity were collapsed across groups in the present study, maximum velocity values were achieved after 66% of the kick was completed. Males reached this value after 71% of the kick was completed while females reached this maximum velocity after 60% of the kick was completed. This data is in agreement with Snyder's (1981) principles concerning Maximum Effective Kicking Force.

The angular position of the trunk varied approximately 30 degrees from the beginning of the kick to the end of the extension phase of the kick. This slight forward lean of the trunk was necessary to allow the foot to travel in a direct line toward the target and to assist in distributing the weight appropriately to maintain balance. There was no significant difference on this variable between males and females. Males, however, demonstrated a tendency to allow the kicking hip to rotate outward, the thigh to abduct and the foot to drift from its vertical position. This tendency could be due to the difference in hip structure between males and females or to a difference in flexibility between genders. Further research is necessary to determine the reason for these form differences.

Mean values obtained for the male group were very consistent
among subjects, despite differences in height and weight. Conversely, mean values between the female subjects were more variable. One subject produced mean angular velocity values which were much higher than all other subjects - both male and female. This might have been due to her much smaller height (160 cm.), and lighter weight, (48 kg.) when compared to all other subjects. The extensive training time of the subjects could account for the consistency of the form between all subjects. With the exception of the males' tendency to externally rotate the hip and the resultant change in foot position during the extension phase of the kick, all subjects performed the kick in an almost identical fashion.

The short duration of time required to execute the kick makes it a very efficient technique to use in a defensive situation. With a mean duration of .27 seconds from initiation of the kick to full extension, this technique is one of the most rapid leg techniques studied.

Consistency was demonstrated across the subject sample with respect to angular velocity produced by the leg, with the initial peak value reached during the preparatory phase and the second peak occurring approximately 1/2 to 2/3 through the kick. This was just prior to achievement of maximum linear velocity of the ankle and is
consistent with the mechanical principles related to efficient production of velocity. Angular velocity of the leg decreased during the final stages of the extension phase demonstrating a braking effect prior to full extension of the knee.

Graphs representing angular velocity of the thigh versus time also showed consistency (Appendix D). Maximum angular velocity of the thigh was reached at completion of the extension phase of the kick for all subjects. A low value for velocity occurred at approximately the time the thigh moved from flexion to extension, with velocity steadily increasing until the maximum value was obtained. The velocity curve for the thigh did not demonstrate a decrease in velocity at the end of the extension phase of the kick. This could possibly account for some of the external hip rotation evident on the film after subjects reached full extension of the kicking leg.

Linear velocity of the ankle increased during the extension phase of the kick. As the kick neared full extension this velocity value decreased as did the angular velocity of the leg. These decreases in velocity were due to a braking effect needed in the performance of non-impact kicks to prevent injury to the joints and muscular structure.

Analysis of the angular position of the thigh and leg showed that initial movement for this kick occurred with hip and knee flexion
bringing the kicking leg into a chambered position. This was followed by extension of the hip, propelling the foot toward the intended target. Knee extension followed and moved the hip, knee and foot into a straight line at point of impact.

Using both the quantitative and qualitative data obtained, the back thrust kick can be described using Snyder's (1981) Principles of Maximum Effective Kicking Force. The principles described include preparation of the kicking leg, hip rotation/projection, complementary arm/shoulder action, support leg flexibility/stability, extension/retraction of the kicking leg, line of force/attack and weight distribution.

During preparation of the kicking leg for a kick with the right leg, the knee and hip were flexed, drawing the foot up toward the buttocks and the thigh toward the chest. The ankle was flexed with the foot turned into a vertical position. Males exhibited differences in the amount of hip flexion and in the position of the kicking foot, leg and thigh. Rather than maintaining the vertical position of the knee and foot, males exhibited more initial abduction of the thigh and outward rotation of the foot.

There was a definite projection of the hips toward the target but
little hip rotation. Males exhibited a clockwise rotation of the hips during the preparatory phase accompanied by abduction of the thigh. Toward the final stage of the extension phase of the kick males demonstrated a counter-clockwise rotation of the hips to bring the foot, knee and hip into alignment before impact. This hip rotation among the male subjects could have been due to differences in anatomical structure of the pelvis and flexibility in the hip flexors and muscles stabilizing the trunk.

As the head turned to look at the target the shoulders also rotated slightly clockwise in direction. This shoulder rotation was more pronounced among male subjects as the extension phase of the kick began. Several subjects demonstrated a lowering of the hands and movement of the arms in a direction away from the intended target while still maintaining a guard position. This action helped the performer maintain balance while executing the kick swiftly and forcefully and also assisted in counter-balancing the extension of the kicking leg.

All subjects demonstrated flexion of the support knee prior to beginning the kick and slight extension of the support knee during the extension phase of the kick. The support leg was never fully extended at any point throughout the kick. There was minimal
rotation of the support foot in a counter-clockwise direction in conjunction with the thrusting action of the hips during the extension phase of the kick. This assisted in stability and force production.

This research dealt only with the preparatory and extension phase of the kick and did not analyze the retraction phase. The mean duration of the kick was .27 seconds making this kick a very swift kick. This would make it a viable choice in a self defense situation. The mean percentage of the kick completed before achievement of maximum velocity was 66%. This would have the karateka reaching full extension after impacting the target and is conducive to maximizing results of the impact. Extension of the joints occurred in a successive and complementary manner providing maximum production of velocity.

The line of force and line of attack in a back thrust kick were the same. By efficient use of summation of forces the karateka was able to have the hip, knee and foot in alignment at impact. This increased the effect of the kick on the impact surface.

Weight distribution was demonstrated by the forward lean of the body and a shifting of weight from the kicking leg to the support leg. This slight lean of the trunk away from the target, accompanied by the
arm movements, functioned as a counter balance to the extended kicking leg allowing the karateka to maintain a stable position. The support leg remained in a flexed position and helped assist with redistributing weight throughout the kick.

RECOMMENDATIONS

Recommendations for further study include more research comparing male and female performance variables associated with karate techniques, since the review of prior literature produced no other studies that included female subjects. While the parameters analyzed in this study did not differ significantly between males and females, it would be important to also analyze the force generated by this technique and compare that value as a function of both gender and type of kick executed. Including body segment measurements as a part of the comparison between genders could be beneficial in terms of identifying reasons for possible differences. Analyzing the changes kinematically, as a function of practice and instruction, on subjects' joints and musculature, particularly the lower back and kicking knee would also be beneficial in determining possible long term structural effects. This would seem especially beneficial given the lack of deceleration by the thigh at the termination of the extension phase of
the kick and the resultant effect on the lower back. On this same note, it would be appropriate to study the back thrust kick through the retraction phase to determine the velocity and angular position patterns occurring after full extension. It would also be recommended to study the differences in these parameters between impact and non-impact kicks and compare the results to Hwang's (1987) study of front snap kicks.


and Exercise. 14(2), 162.


APPENDICES
APPENDIX A

APPLICATION FOR APPROVAL OF THE
HUMAN SUBJECTS BOARD

DESCRIPTION OF METHODS AND PROCEDURES

The purpose of this study is to investigate, using two-dimensional high speed cinematography, the kinematic variables involved in executing the back thrust kick. Three consecutive trials of each kick will be performed by each subject. These will be non-impact kicks aimed at a target just out of striking distance. Various anatomical landmarks will be marked on each subject's skin with a felt pen to aid in analysis procedures.

RISKS/BENEFITS TO SUBJECTS

This study involves no perceived risk to the subjects. A potential benefit is that the results of the study may provide useful information related to individual performance.

INFORMED CONSENT FORM

A copy of the Informed Consent Form is attached. Subjects will be given a copy of the Informed Consent Form prior to the data collection session and will be asked to return it to the investigator before participating in the data collection session.

ANONYMITY

Data will be recorded and analyzed by subject number. The films will be used solely for data analysis.

QUESTIONNAIRE

A questionnaire will be used to obtain information pertinent to the study. A copy of this questionnaire is attached. Subjects' heights and weights will be measured prior to the kicking trials.

This project is not a part of a proposal to an outside funding agency.
The purpose of this study is to investigate, using two-dimensional high speed cinematography, the kinematic variables involved in executing the back thrust kick. Three consecutive trials of the kick will be performed by each subject. These will be non-impact kicks aimed at a target just out of critical distance. Various anatomical landmarks will be marked on each subject's skin with felt pen to aid in analysis procedures. This study involves no perceived risk to the subjects. It is believed that this study may provide information useful in devising more effective training methods for this kick. The principle investigator will be present at all data collection sessions and will answer any inquiries subjects may have concerning the procedures.

I have read and understand the procedures to be used in this study. I also understand that I may withdraw from participation at any time during the course of this investigation. I agree to participate as a subject in all phases of the study described above.

Signed____________________

Dated____________________
QUESTIONNAIRE

1) Full Name:

2) Birthdate:

3) Height:

4) Weight:

5) Number of years in the martial arts:

6) Style(s) studied:

7) Number of years as a black belt:

8) Current rank:
# APPENDIX B

**SUBJECT BACKGROUND INFORMATION**

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| 4         | M      | 177.8 | 74.8  | 37      | 15        | 13     |
| 5         | M      | 190.5 | 93.0  | 37      | 13        | 7      |
| 6         | M      | 175.3 | 77.1  | 35      | 14        | 2      |
| 7         | M      | 170.2 | 70.3  | 37      | 15        | 12     |
|           |        |       |       |         | Means (Males) | 178.4 | 78.8 | 36.5 | 14.3 | 8.5 |
### APPENDIX C

#### DURATION OF KICK

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**MEAN VALUE**

- **FEMALES** = .29
- **MALES** = .25
- **GROUP** = .27

*Unable to digitize complete kick due to lighting malfunction.
### MAXIMUM LINEAR VELOCITY OF THE ANKLE

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**MEAN VALUES**

- FEMALES: 13.8 m/s, 60%
- MALES: 18.1 m/s, 71%
- GROUP: 16.3 m/s, 66.3%

* Unable to digitize complete kick due to lighting malfunction.
<table>
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* Unable to digitize complete kick due to lighting malfunction.
APPENDIX D

LINEAR VELOCITY AT THE ANKLE - MALES

x-axis = Frame #
y-axis = Meters/second
LINEAR VELOCITY AT THE ANKLE - FEMALES

x-axis = Frame #

y-axis = Meters/second
ANGULAR VELOCITY OF THE THIGH - MALES

x-axis = Frame #
y-axis = Angular velocity (degrees/second)
ANGULAR VELOCITY OF THE THIGH - FEMALES

x-axis = Frame #
y-axis = Angular velocity (degrees/second)
ANGULAR VELOCITY OF THE LEG - MALES

x-axis = Frame #
y-axis = Angular velocity (degrees/second)
ANGULAR VELOCITY OF THE LEG - FEMALES

x-axis = Frame #
y-axis = Angular velocity (degrees/second)