

EFFECT OF PRACTICE ON PATTERN CHANGES:  
ROUNDHOUSE KICK IN TAEKWONDO

By

Youngkwan Kim

Master of Science, 1996  
Korea Advanced Institute of Science & Technology  
Taejon, KOREA

Submitted to the College of Health and Human Science  
Texas Christian University  
In partial fulfillment of the requirements  
For the degree of

Master of Science

August 2002

EFFECT OF PRACTICE ON PATTERN CHANGES:  
ROUNDHOUSE KICK IN TAEKWONDO

Thesis Approved:

---

Dan Southard, Ph.D.  
Major Advisor

---

Carol Pope, Ph.D.  
Committee Member

---

Deborah Rhea, Ph.D.  
Committee Member

## ACKNOWLEDGEMENTS

The Author wishes to thank the following individuals:

I really appreciate Dr. Southard's help. He has provided guidance for every detail of my thesis. I would have never been able to complete this thesis without his help. He has also taught me American idioms which help to understand American culture. I will keep in my mind the memory of Dr. Southard and TCU forever.

Richard Chow was my lab partner during this project. He was a lot of help concerning physical therapy and orthopedics issues. He was unique to my TCU life. I also appreciate the kindness and help from Michelle and Erin. They helped me to understand lab work and the master's program at TCU.

I am deeply thankful for my mother's prayers and encouragement. Without her effort, I could not finish this project. I really love my mom.

Hyun and James have watched my life and tolerated hard times with me. I really appreciate Hyun's support for my work and James's smile. They gave me strength to get through this project.

Finally, I owe God my achievement.

## TABLE OF CONTENTS

<b>ACKNOWLEDGEMENT</b> .....	iii
<b>TABLE OF CONTENTS</b> .....	iv
<b>CHAPTER 1:</b>	
<b>INTRODUCTION</b> .....	1
A.    Significance of the Study .....	6
B.    Purpose of the Study .....	7
C.    Hypotheses .....	7
<b>CHAPTER 2:</b>	
<b>REVIEW OF LITERATURE</b>	
A.    Mechanics of Roundhouse Kick .....	8
B.    Changing Motor Pattern .....	9
C.    Pattern Change, Practice, and Skill Acquisition .....	14
<b>CHAPTER 3:</b>	
<b>METHOD</b>	
A.    Participants .....	19
B.    Procedure .....	19
C.    Apparatus .....	20
D.    Analysis .....	22
1.    Pattern Change .....	22
2.    Velocity and Limb Segments .....	23
3.    Accuracy .....	23
4.    Statistical Analysis .....	23
<b>CHAPTER 4:</b>	
<b>RESULTS</b>	
A.    Quantitative Analysis : Pattern Change .....	25
B.    Quantitative Analysis : Peak Velocity .....	27
C.    Quantitative Analysis : Accuracy Data .....	28
D.    Qualitative Analyses .....	28

E. Correlations .....	30
<b>CHAPTER 5:</b>	
<b>DISCUSSION</b> .....	33
<b>REFERENCES</b> .....	38
<b>TABLES</b> .....	42
<b>FIGURE CAPTIONS</b> .....	43
<b>FIGURES</b> .....	45
<b>APPENDIX A</b> .....	58
<b>APPENDIX B</b> .....	59
<b>VITA</b> .....	60
<b>ABSTRACT</b> .....	62

## CHAPTER 1

### Introduction

Taekwondo is a form of Korean martial arts. It has gained popularity throughout the world as an excellent physical conditioning activity as well as a method of self-defense. Taekwondo's popularity has increased as a competitive sport to such an extent that it was performed as an official game at the 2000 Sydney Olympics. The word, "Taekwondo", is based on the meaning of Chinese characters "Tae" or "Kicking" and "Kwon" or "Fisting" and "Do" a "Way to do"(Kim, 1998). Even though Taekwondo is a martial art that uses mainly the hands and feet for defense and attack, its popularity is largely due to the use of various kicks in competitive sparring.

Several kicking skills exist in Taekwondo such as the front snap kick, roundhouse kick, side thrust kick, back kick, spin kick, stretch kick, and hook kick. Considering all the alternatives, the roundhouse kick is the most popular during sparring because of its fast speed and excellent accuracy. The roundhouse kick is primarily used for the initiation of attack and the continuation of a series of attacks. Lee (1998) showed that the frequency of the roundhouse kick used by male combatants was 50% of the total kicks. In addition, 89% of total points scored came from executing the roundhouse kick. The frequency of the roundhouse kick used by females during sparring was 79%

which demonstrates that both genders prefer this kick to score points (Kim & Kim, 1997).

Improvement in kicking skills is important to the successful performance of competitive Taekwondo. Improvement is directly related to practice. Therefore, structuring practice sessions in order to maximize learning is an important issue to any Taekwondo competitor or coach. How practice should be structured is a function of sound motor learning principles. Knowledge of results (KR) is a principle that is essential to motor learning. However, in order for knowledge of results to be effective it should convey relevant information to the performer. If coaches understand how kicking skills change naturally as a result of practice, they could better establish what information is relevant to help improve performance. Therefore, knowledge of how and why kicking patterns change is important to the development of an effective practice schedule and informative Knowledge of Results.

A recent approach to the explanation of why motor patterns change is dynamical systems theory. The Russian physiologist Nicolai Bernstein (1967) is credited with first viewing the problem of coordinating movement from the perspective that the mover and the environment are partners in movement control and coordination. The mover takes advantage of environmental conditions and may use external forces such as gravity to

complete movements and determine motor patterns. More recently, researchers who have utilized Bernstein's concepts have determined that motor patterns may change when variables sensitive to the pattern of movement are scaled up to a critical value (Thelen and Smith, 1994; Kelso and Schoner, 1988; Southard, 1998a). Such variables are called control parameters but do not have direct control over the pattern. For example, consider ice in a cooking pan. The ice will eventually liquefy at room temperature. That is, the solid phase will change to the liquid phase. If heat is added to liquid water by a stove, the water temperature will increase and eventually reach 100 degrees Celsius at which point water will evaporate to a vapor gas. Molecules of water have preferred phases at certain temperatures. When the temperature is below 0 degrees Celsius, molecules bond to each other closely because the energy levels of molecules are insufficient for disconnection. When the temperature of molecules increase, the connections lose strength and water exists in a liquid state. When water is heated above 100 degrees Celsius molecules disconnect their linkage and move freely as a gas. Dynamic system theorists would define those preferred phases as attractor states. Temperature drives the phase changes from one attractor state to another attractor state (solid to liquid or liquid to gas) and is defined as a control parameter. The

control parameter instigates a pattern or phase shift from one stable state to another new state. The control parameter is independent of the system and does not contain any sort of code for the emerging pattern. Rather, it invokes the system to be changed into other possible patterns or states (Kelso, 1999). Attractor states can be changed to alternate states only if the control parameter reaches a critical value. In the case of water molecules, 0 and 100 degrees Celsius are critical values for phase shifts. As each phase dictates and dominates the characteristics of fluid dynamics in certain conditions, the phase of a water molecule can be defined as the order parameter or collective variable. Order parameters or collective variables are functional variables that dominate the behavior of systems and enable dominant patterns of movement (Thelen and Smith, 1994; McGill, 1997). Collective variables must be clearly quantifiable actions and responses that index the cooperativity of a multidimensional system. Haken (1977) stated that order parameters slave all other modes of the system. A phase diagram for a water molecule is provided in Figure 1.

Southard (1998a) provided evidence for control and order parameters during throwing movements. He manipulated the mass of the arm, forearm, and hand while throwing at different velocities. Southard found that when the tapering of limb segments

is interrupted by scaling up on mass of distal segments, the throwing pattern changed to a constrained motion. When mass was added to proximal segments, throwing patterns were facilitated and took advantage of the open kinetic chain. The same changes occurred when participants scaled up on velocity of throw. Southard concluded that relative mass of limb segments and throwing velocity are control parameters for throwing. He also stated that the open kinetic chain is the order parameter that dictates various alternative states for throwing.

Kelso and Schoner (1988) provided an example of a control parameter and a order parameter during index finger movements of both hands. They observed that when subjects were required to flex and extend the index fingers of both the right and left hands, fingers were in a “phase-locked” state. When the frequency of finger movement increased, both index fingers flexed and extended together into a new state. They concluded that the control parameter which instigated change was frequency of movement and the order parameter was the relative phase of both index fingers.

Thelen and Smith (1994) approached motor development from a dynamic system perspective. They studied the real-time and developmental-time dynamics of infant treadmill stepping to determine control parameters and order parameters for

walking. They measured infant treadmill stepping patterns after changing treadmill speed and split the belt with different speeds for each side of the treadmill. Results indicated that at 7 months infants reliably and consistently performed alternate treadmill steps throughout a range of speed, although faster speeds seemed to be more strongly preferred. In addition, an alternative stepping pattern was maintained regardless of the perturbation of the split-belt treadmill. They concluded that alternate stepping was a stable attractor state. They proposed that a change in the flexor-extensor balance of the leg muscles was the developmental control parameter and the phasing of the two limbs was the collective variable or order parameter for infant walking.

### Significance of the Study

Taekwondo coaches and players are in need of information concerning the performance of a roundhouse kick due to its popularity and preferential use with both males and females. Information concerning pattern change as a result of practice should help develop effective teaching strategies. In addition, information from this study should add to our understanding of why motor patterns change and provide information concerning control parameters and order parameters for a roundhouse kick.

### Purpose of the Study

The purpose of this study was to determine changes in pattern and accuracy of the roundhouse kick as a function of practice.

### Hypotheses

It was hypothesized that: (1) there would be no difference in peak velocity of leg segments and pattern of movement for the kicking and supporting leg as a result of practicing a roundhouse kick; and (2) there would be no change in accuracy of kick resulting from ten sessions of practice.

## CHAPTER 2

### Review of Literature

#### Mechanics of roundhouse kick

Kukkiwon(1995) defined the roundhouse kick as a flexion/extension motion of the knee and flexion of the hip joint while simultaneously rotating the trunk and abducting the hip joint. The hip joint of the supporting leg rotates externally while extending the knee joint of the kicking leg. The roundhouse kick starts in the sagittal plane and finishes in the transverse plane because the target (usually the trunk or face) has a vertical surface that is perpendicular to the ground. Recent studies concerning the roundhouse kick have increased our understanding of kicking biomechanics. Kim and Kim (1997) utilized three-dimensional data to determine that there is hyperextension, abduction, and external rotation of the hip joint prior to toe-off due to the trunk leaning back and the leg moving toward the target. Maximum internal rotation and maximum abduction occurred when the leg finally kicked the target. Bae (1992) showed that target impact occurred after the toe reaches maximum velocity. The period from toe-off to linear peak velocity of the knee took 60% of the total kicking time and the last 40% was used for knee extension to meet the target. Relative percentage periods for the peak linear velocity of the knee and extension to the target was the same as those of a soccer

kick (Putnam,1991). The roundhouse kick uses a proximal-to-distal sequence of segmental interaction in an attempt to maximize the linear velocity of distal segments. The proximal segments transfer angular momentum to the distal segments using the kinetic link principle (Kim & Kim, 1997; Putnam, 1991). The kinetic link principle is applied to motions requiring sequential segmental rotations such as throwing, kicking, or striking. Such movement patterns require the body to work like a flexible chain of links. The base segment starts movement that ends at the freely moving distal end. If the base segment (trunk) begins to rotate, it creates angular momentum that is conserved as distal segments lag behind proximal neighbors. The less massive distal segments increase velocity as the system attempts to conserve momentum. The resulting pattern is one of distal lag as the transfer of velocity terminates at the most distal and least massive segment. This whip-like activity occurs as a result of the system acting as an open kinetic chain. This sequence occurs link by link, from base to end, proximal to distal, until the end of the chain is reached (Kreighbaum and Barthels, 1985).

### Changing motor pattern

Although the mechanics of the roundhouse kick are well documented, there are no studies which explain changes in the roundhouse kicking pattern resulting from

practice. Dynamic systems use the concepts of attractor state, order parameter, control parameter, and critical value to provide a theoretical basis for understanding changes in patterns resulting from practice. Proponents of this theory believe complex systems have the ability to self-organize. Self-organization means systems tend to form patterns as a result of system elements organization without the help of an agent-like entity (i.e., programs, schema, and engrams) inside the system (Kelso, 1999). From a stability point of view, the pattern will not change unless a perturbation or a stimuli (control parameter) exceeds a critical value. If the control parameter exceeds a critical value the system becomes unstable. Instability allows the system to change or shift into another pattern or mode of stability. The order parameter determines the shape of the new pattern. Kelso (1994) described the relation of the order parameter (collective variable) and the control parameter as “yin and yang”. The control parameter is identified when its continuous variation induces qualitative change. And qualitative change is necessary to identify order parameters (collective variables) unambiguously. When the system changes its pattern, there is a preferable mode of behavior over all possible modes. This preferable mode is defined as an attractor state which is dynamically very stable against external perturbation (Kelso, 1999). Different degrees of stability exist in attractor states. Less

stable attractor states can be easily shifted into another attractor state by a small perturbation. Very stable attractor states cannot be disturbed even under extreme perturbation. When control parameters reach a critical value there is a decrease in the stability of the system and a shift to another attractor state. The new attractor state is determined by the order parameter.

Diedrich and Warren (1995) used a dynamic system approach to explain gait transition. They completed two experiments to determine whether gait transition is a nonequilibrium phase transition between attractors and to determine control parameters which instigate gait transitions. Experiment 1 examined walking and running on a treadmill at varying speeds of travel. Subjects were asked to walk or run at a comfortable pace while speeds were increased and decreased. The data indicated that relative phase between limb and limb segments were order parameters which determine gait pattern. They predicted that stride frequency and velocity of gait were control parameters which instigate gait pattern change. Their prediction was confirmed when a bifurcated transition (defined as a sudden jump from one attractor to another without occupying intermediate states) from walking to running occurred at the speed of 2.09 m/s (SD=0.21 m/s). The pattern transition was a result of shifts in stride length and

frequency. There was a qualitative reorganization in the relative phasing of segments within a leg and a sudden jump in relative phase. In a second experiment speed, stride, and frequency were manipulated to determine potential control parameters. Stride length ( $s$ ) and stride frequency ( $f$ ) were strongly coupled and affected by velocity ( $v=sf$ ) of travel. Participants were asked to keep up with stride frequency at a given treadmill speed by following a metronome sound. Different speeds with different combinations of stride and frequency were examined with an increase in frequency. Results indicated that transitions occurred at significantly different values of stride length and frequency, but at a constant value of speed. They concluded that stride length or stride frequency alone is not sufficient as a control parameter. The single parameter of speed, composed of stride length and stride frequency served as a control parameter under natural conditions. In a more recent investigation, Diedrich and Warren (1998) manipulated the grade of the treadmill and loaded a weight on the ankle. Velocity was varied as a control parameter to determine changes to new attractor states. They indicated that the loaded weight induced the most stable walk shift and caused transition to lower stride frequencies. The uphill grade induced a stable walk accomplished by a shift into a shorter stride length. They concluded that attractor states and critical values arose from

the interaction of both the dynamics of the action system such as the moment of inertia, muscle stiffness, and perceptual information about forcing, as well as the dynamics of the environment such as support surface characteristics and external loads.

Kelso and Schoner (1988) explained pattern change and stability of bimanual rhythmic movement with the self-organizing ability of the motor system. They found that rhythmic finger patterns changed from out-of-phase (180 degrees) to an in-phase (0 degrees) pattern as result of increasing movement frequency. No pattern change was found when subjects started from in-phase pattern regardless of frequency. Kelso and Schoner concluded that frequency was a control parameter that initiated change at a critical value. The change in pattern was from an unstable condition (out-of-phase) to a stable condition (in-phase). The shift to a new pattern was the result of self-organization and not a function of hard-wired neural information from the mover.

Southard (In Press) examined the critical values for throwing attractor states. He manipulated the control parameter of velocity to determine critical values which instigate pattern change. Thirty-six subjects (6yrs – 12yrs) were asked to throw a ball at 10 different velocities from 10% of maximum to maximum in 10% intervals. He indicated that lower skilled throwers (level 1 and 2) changed patterns more frequently at lower

velocities than higher skilled throwers (level 3 and 4). In addition results indicated that higher skilled throwers have more stable patterns when compared with lower skilled throwers.

### Pattern change, practice, and skill acquisition

Skilled movement is generally recognized by demonstration of common characteristics such as spatio-temporal precision, adaptability, and consistency (Kelso, 1982). Spatio-temporal precision means that all elements of the movement are in the right place and at the right time. For coordinated movement to occur with spatio-temporal precision, degrees of freedom have to be controlled and regulated properly. Degrees of freedom are defined as decisions required by the motor system in order to successfully complete a movement. What muscles will contract, forces to contract with, and planes of motion are primary examples of degrees of freedom. In addition to primary degrees of freedom we also have context conditional variability. That is, the same muscles may accomplish different movements depending upon the context of the movement itself. The forces required to move limb segments may vary as the initial properties of limb change during movement. The motor system must also account for fatigue and neural variability during movements. In order to manage the many degrees

of freedom muscles may be constrained to act as a unit. Turvey, Fitch, and Tuller (1982) referred to these constraints as coordinative structures. Coordinative structures are defined as a functional group of muscles, often spanning multiple joints, which act as a single unit toward goal achievement. When muscles are constrained to act as a unit, information to one group of muscle would also serve as information to other muscles in the constraint, thereby reducing degrees of freedom.

Bernstein (1967) suggested two successive stages in the development of skilled behavior which are related to degrees of freedom. In the first stage, novices tend to solve the problem of coordination by initially freezing degrees of freedom. Novices utilize a coordinative structure which keeps joint angles rigidly fixed throughout movement. That is, there is a strong coupling or constraining of multiple joints. Joints are forced to move like a single “virtual” degree of freedom. Later in the learning process there is a release on degrees of freedom. The joints are incorporated into larger functional units of action and move fluently. During this second stage, the learner utilizes a coordinative structure which is better able to take advantage of passive (reactive, frictional, gravitational, and inertial) forces to enhance the efficiency of the active muscular forces.

Newell and van Emmerik (1989) investigated the acquisition of coordination

comparing the limb dynamics of dominant and nondominant limbs during hand writing. Subjects were asked to write both their signature and a repetition (10) of cursive e's with both their dominant arm and nondominant arm. Right-handed subjects were given extensive practice at writing both their signature (1,000 times) and cursive e's (1,000 times) for their nondominant arm over several days. Results regarding right-handed subjects provided support for Bernstein's idea that skill acquisition involved mastering degrees of freedom. The nondominant links were more tightly locked as a unit than the dominant limb. However, left-handed subjects did not show differences in phase-locking between the dominant limb and the nondominant limb. They concluded that structure differences in limb organization of writing could be influenced by a variety of sources of constraint, including past experience.

Southard and Higgins (1987) investigated the effects of practice and demonstration on a striking pattern. They divided subjects into 4 groups (control, demonstration, practice, and demonstration/practice). The demonstration group viewed a 10-minute video cassette of a professional racquetball player executing a forehand shot. The practice group hit forehand racquetball shots every 10s for 10 minutes (No demonstration). The demonstration/practice group watched the demonstration and

practiced. The control group did nothing for 3 weeks. Results indicated that the practice and practice/demonstration groups had a significant increase in segmental velocities and a significant change in relative limb position. Whereas, the control group and demonstration groups showed no significant changes in velocity or pattern. Southard and Higgins concluded that at the beginning of practice, subjects constrained the striking limb to act as a unit. With practice, there was a release on degrees of freedom to take advantage of the open kinetic chain.

Vereijken, van Emmerik, Whiting, and Newell (1992) investigated the effect of practice on a slalom-like ski movement to examine release of degrees of freedom. Subjects were asked to practice slalom-ski movements on a ski device for 7 consecutive days. Results indicated that joint angles of the lower limbs and torso had a limited range of angular motion at initial stages. High cross-correlations between joints were found. With practice, there were increases in all joint angles of the lower limb and torso and a decrease in cross-correlation between joints. Their findings support the initial freezing of degrees of freedom and final release of degrees of freedom as a result of practice.

Van Emmerik (1992) examined adaptation in drawing patterns as a result of unexpected perturbations. Subjects were asked to trace a template of the figure-eight

pattern on a writing surface. During the task, four unexpected perturbations were administered to the writing stylus. Results indicated that the non-dominant limb was not affected by the application of a sudden increase in friction levels because the limb segments were tightly locked. However, dominant limb segments showed significant differences in joint angular motion due to a weaker coupling of limb segments. Van Emmerik attributes results to the adjustment of degrees of freedom by each limb to accommodate perturbations. Results also indicated that the control problem is simplified by freezing degrees of freedom early in practice. However, the well practiced dominant limb was free to decouple highly coupled joints.

## CHAPTER 3

### Method

#### Participants

Ten volunteer students (range = 20 - 23 years) from Texas Christian University were participants for this study. All participants were right-foot dominant and beginners at Taekwondo. Beginners were defined as individuals who have never received formal martial arts training. Each participant was required to sign a university approved informed consent form prior to participation (APPENDIX A). Participants were told that the purpose of the study was to determine the relationship between practice and motor pattern change.

#### Procedure

Participants were required to perform a right-foot roundhouse kick with maximum velocity and to be as accurate as possible to a target. The only instruction provided to participants was to set stance with the right foot back and to kick the target with the instep of the right foot. The target was an X mark on a kicking dummy at the height of the xiphoid process. Augmented information concerning foot strike position was provided only if the participant did not strike the kicking dummy with the instep of the foot. Participants were shown proper foot strike within their own kicking style. No model

and no augmented information was provided concerning kicking patterns. Participants were provided foot velocity and accuracy data from the former session prior to each successive session. Participants were encouraged to increase velocity and accuracy during each of the ten sessions over a period of five weeks (two sessions per week). Each session consisted of 10 trials or roundhouse kicks. Participants were allowed a warm-up of three practice kicks before each session. Bare foot kicks were required during trials.

### Apparatus

Participants kicked an up-right sponge bag kicking dummy (16 inch diameter) with a water-filled base. Accuracy was determined by measuring the contact of the cuneiform portion of the foot relative to the center of an X mark placed on a kicking dummy. To aid the measurement of accuracy the participants' foot was colored with a red marker which left a mark on the dummy that was easily measured relative to the target.

Kinematic data (displacement and velocity) of body segments were determined using a three dimensional infrared motion analysis system (WATSMART). Two cameras mounted on tripods detected movement of infrared emitting diodes (IREDs) placed on

participants. Nine infrared emitting markers (IREDs) were attached to specific anatomical landmarks to provide kinematic data. IREDs were placed at the following locations: (1) the right foot (distal head of fifth toe), (2) the right ankle (lateral malleolus), (3) the right knee (lateral epicondyle), (4) the right hip (iliac crest), (5) the right lateral side of trunk (7 inches away from iliac crest), (6) the left foot (distal head of first toe), (7) the left ankle (medial malleolus), (8) the left knee (medial epicondyle), and (9) the medial side of left thigh (middle of vastus medialis). Detailed IRED locations may be found in Figure 2.

Data were collected at a sampling rate of 100 Hz and filtered using a double pass Butterworth process with a cutoff frequency of 10 Hz. The placement of IREDs permitted the derivation of segmental linear velocities. X-axis motion was defined as horizontal movement parallel with cameras. Y-axis motion was defined as vertical. Motion toward or away from the cameras was Z-axis motion. Movement in the X and Y axes simultaneously was equal to the sagittal plane. Movement in the transverse plane was composed of simultaneous X and Z movement. Calibration of the system was performed using a steel frame of known dimensions prior to data collection.

## Analysis

Commercially prepared software (Northern Digital Inc.) was used to digitize each trial. The following dependent measures served as basis for analysis.

Pattern change. Time to Peak Velocity (TTPV) was determined by measuring the period from a common starting position to the point at which each segment reaches peak velocity. The common starting point was determined by the movement of any segment in the X-axis. The starting point for analysis of the Z-axis was synchronized with the same starting point for X-axis analysis. In addition, segmental lag was used to determine the quantitative pattern changes. Segmental lag was defined as the difference in time to peak velocity (distal to proximal) between adjacent segments.

Qualitative change in pattern was represented by trajectory graphs and scatter graphs. Trajectory graphs were determined by velocity profiles (ordinate) of each IRED according to time variation (abscissa). Scatter graphs of segmental lag were determined by the difference in lag value by session displayed in three dimensional space. Error scatter graphs were determined by data points representing variable error (ordinate) and constant error (abscissa).

Velocity of limb segments. Peak velocity (PV) of limb segments was determined by digitizing the peak values from trajectory graphs in both X and Z axes.

Accuracy. Kicking accuracy was represented by total constant error (TCE) and total variable error (TVE) about the target. Total constant error was determined by measuring the distance in both X-axis and Y-axis from impact location of the foot to target center ( $TCE = \sqrt{(CE_x)^2 + (CE_y)^2}$ ). Positive X-axis error is away from the subject relative to target. Positive Y-axis error was any value above the target. Variable error is the standard deviation of constant error. The equation for variable error is:

$$VE_x = \sqrt{\sum \frac{(CE_x - \overline{CE_x})^2}{N}}, \quad VE_y = \sqrt{\sum \frac{(CE_y - \overline{CE_y})^2}{N}}. \quad \text{Total variable error is: TVE} \\ = \sqrt{VE_x^2 + VE_y^2}.$$

Statistical analysis. Dependant measures for pattern change and velocity were analyzed separately according to kicking leg and supporting leg. Three-way analyses of variance (session X segment X axis) for time to peak velocity, timing lag, and peak velocity were performed to determine any main effects and interactions relative to independent factors. An alpha level of .05 determined significance. Tukey post hoc procedure determined significance between specific means. A Huynh-Feldt adjustment to degrees of freedom protected against sphericity violation. Analysis of accuracy was

determined by a one-way ANOVA for TCE and TVE with sessions as the independent factor. Pearson product correlation by session determined relationships between dependent measures of pattern change and accuracy variation.

## CHAPTER 4

### Results

The results are organized according to quantitative and qualitative analyses. The quantitative analyses relate to pattern change, peak velocity, accuracy and correlational data. The kicking leg and supporting leg are treated separately. The qualitative results are represented by trajectory graphs and scatter graphs which are intended to support the quantitative analyses.

#### Quantitative Analysis : Pattern Change

Kicking Leg. The three way ANOVA (session X segment X axis) of segmental lag indicated significant main effects for session ( $F(9, 7391)=2.675, p<0.01$ ), segment ( $F(3, 7391)=941.9, p<0.01$ ), and axis ( $F(1, 7391)=12.74, p<0.01$ ) with a significant three-way interaction ( $F(27, 7391) = 1.541, p<.05$ ). Huynh-Feldt adjustment did not affect significance. Figure 3 represents mean values for the three-way interaction.

The toe – ankle lag was positive in the X axis across sessions but was negative in the Z axis across sessions. The remaining lag values were positive across axes and sessions. Post-hoc analysis of the interaction indicated that the knee – hip lag was less than the hip-trunk lag in the X axis across sessions but was greater than the hip – trunk lag for sessions 1, 4, 6, 8, 9, and 10 in the Z axis. The data indicate that leg segments

likely take advantage of the open kinetic chain in both axes, however, a lack of segmental lag indicated there was no transfer of angular momentum from toe to ankle in the Z axis.

Supporting Leg. Three way ANOVA (session X segment X axis) for TTPV of the supporting leg indicated significant main effects by session ( $F(9, 5941)=10.9, p<0.01$ ), segment ( $F(3, 5941)=20.1, p<0.01$ ), and axis ( $F(1, 5941)=10.43, p<0.01$ ) with a significant segment by axis interaction ( $F(3, 5941)=72.861$ ). Huynh-Feldt adjustment did not affect significance. Equipment error prevented the recording of data for session 4. Therefore, session 4 was missing from the analysis.

Post hoc analysis of the two-way interaction indicated that the toe and ankle segments reached peak-velocity sooner than the knee and thigh in the X axis but were generally greater than the knee and thigh in the Z axis. The data indicate that movement progresses distal to proximal in the X axis with segments moving simultaneously in the Z axis for sessions 1 and 5. The remaining sessions indicated that the thigh and knee reach peak velocity first followed by the ankle and toe in the X axis. The supporting leg is not a candidate for use of the open kinetic chain since the distal segment is in contact with the floor. Figure 4 represents the segmental means for TTPV by axis and sessions.

### Quantitative Analysis : Peak Velocity

Kicking leg. The three-way ANOVA (session X segment X axis) for PV indicated main effects by session ( $F(9,9374)=55.6$ ,  $p<.01$ ), segment ( $F(4,9374)=5622.5$ ,  $p<0.01$ ), and axis ( $F(1,9374)=287.2$ ,  $p<0.01$ ) with a significant three way interaction ( $F(36, 9374)=2.1$ ,  $p<0.01$ ). Huynh-Feldt adjustment did not affect significance.

Post hoc analysis of the interaction indicated that the ankle and toe were similar in velocity across sessions in the X axis with the toe being significantly greater than the ankle across sessions in the Z axis. There was progression in segment velocity from proximal to distal segments (trunk to knee) in the X axis with the hip and knee attaining similar velocities in all but session 1, 4, and 10 in the Z axis. Figure 5 is a representation of means by session, segment, and axis.

Supporting leg. Three-way ANOVA (session X segment X axis) for PV indicated main effects by session ( $F(8,5432)=15.8$ ,  $p<.01$ ), segment ( $F(3,5432)=537.4$ ,  $p<0.01$ ), and axis ( $F(1,5432)=403.2$ ,  $p<0.01$ ) with significant session by segment ( $F(24, 5432)=3.36$ ,  $p<0.01$ ) and segment by axis interactions ( $F(3, 5432)=83.8$ ,  $p<0.01$ ). Huynh-Feldt adjustment did not affect significance.

Post hoc analysis of session by segment interaction indicated that PV of the thigh was greater than remaining segments with the exception of the knee during session 7. The proximal segments attained greater peak velocity since the foot was in contact with the floor. Post hoc analysis of the segment by axis interaction indicated that toe and ankle attained greater velocity in the Z axis than in the X axis. Figure 6 represents peak velocity graphs for the supporting leg.

#### Quantitative Analysis : Accuracy Data

One-way ANOVA for constant error and variable error indicated no significant differences by session. Figure 7 represents means and standard deviations by session.

#### Qualitative Analyses

Trajectory graphs for kicking leg. Figures 8 and 9 contain trajectory graphs of the kicking leg in the X and Z axes respectively. The toe, ankle, and knee in the X axis were relatively consistent. That is, the segmental data retain the same relative position and velocity over sessions. The trajectory graphs demonstrate the positive lag indicated by quantitative analysis for the X axis. The trunk reaches peak velocity consistently before the hip creating positive lag, however, the degree of positive lag for the hip and trunk relative to the knee is variable over sessions. The consistent negative lag for the toe and

ankle in the Z axis is likely due to plantar flexion at the moment of contacting the target. Note the close proximity of the distal segments (toe and ankle) and proximal segments (hip and trunk) across sessions. This indicates that the proximal segments are constrained and together transfer velocity to constrained distal segments.

Trajectory graphs for supporting leg. Figures 10 and 11 contain trajectory graphs for the supporting leg in the X and Z axes respectively. The trajectory graphs support the distal to proximal sequence for segments reaching peak velocity. Note the appearance of increased variability in pattern for both TTPV and PV for the supporting leg in comparison to the kicking leg in both X and Z axes.

Scatter graphs for segmental lag. Figure 12 is a representation of segmental lag between adjacent segments for the kicking leg by session. Each dot represents a trial for the designated session. When data points are condensed it indicates a consistent pattern. When data points are dispersed it indicates that patterns varied over trials. There is variability by trial but no major shifts in position of data points over sessions. Note how the kicking pattern appears more consistent in the X axis compared to the Z axis across sessions.

Scatter graphs for accuracy. Figure 13 represents absolute errors of X and Y

axes for each trial by session. Condensed data about the zero point represents consistently accurate kicks. Data points are similar in dispersion across sessions which supports the quantitative analysis (one-way ANOVA by session).

### Correlation

Pearson product correlation was utilized to determine the relationship between : (1) pattern of kick and accuracy; (2) velocity of segments and accuracy; (3) changes in pattern and velocity of segments.

Pattern of Kick and Accuracy. There were no significant correlations between segmental lag (representing pattern of kick) and kicking accuracy.

Velocity of Segments and Accuracy. There were no significant correlations between the velocity of segments (both kicking leg and supporting leg) and accuracy of kick across sessions.

Pattern of Kick and Velocity. Analysis indicated significant correlations between segmental lag and velocity of segments across sessions. Positive lag between the ankle and the knee of the kicking leg in the X axis was significantly correlated with peak velocity of the kicking leg ankle in the X axis for session 7 (  $r = -.594$ ,  $p < .01$ ;  $R^2 = .35$ ), session 8 (  $r = -.562$ ,  $p < .01$ ;  $R^2 = .32$ ), and session 9 (  $r = -.603$ ,  $p < .01$ ;  $R^2 = .36$ ). The

correlation of timing lag between the ankle and knee of the kicking leg (X axis) was significantly correlated with peak velocity of the kicking leg ankle in the Z axis for all sessions except 1 and 2 (Session 3,  $r = -.587$ ,  $R^2 = .34$ ,  $p < .01$ ; Session 4,  $r = -.622$ ,  $R^2 = .39$ ,  $p < .01$ ; Session 5,  $r = -.676$ ,  $R^2 = .46$ ,  $p < .01$ ; Session 6,  $r = -.667$ ,  $R^2 = .44$ ,  $p < .01$ ; Session 7,  $r = -.711$ ,  $R^2 = .51$ ,  $p < .01$ ; Session 8,  $r = -.671$ ,  $R^2 = .45$ ,  $p < .01$ ; Session 9,  $r = -.583$ ,  $R^2 = .34$ ,  $p < .01$ ; Session 10,  $r = -.736$ ,  $R^2 = .54$ ,  $p < .01$ ). This result indicates that decreasing lag time between the ankle and knee significantly affects kicking velocity of the ankle in Z axis. That is, fast knee extension of the kicking leg in the X axis is important to increasing kicking velocity.

For the supporting leg, segmental lag between the ankle and knee and knee and thigh resulted in significant correlations with segmental peak velocities. Specifically, in session 1 lag between the ankle and knee of the supporting leg (Z axis) was correlated with peak velocity of the supporting leg ankle in the X axis ( $r = .570$ ,  $p < .01$ ;  $R^2 = .32$ ). In session 2 ankle-knee lag (supporting leg, Z axis) was correlated with peak velocity of the kicking leg toe in the X axis ( $r = -.550$ ,  $p < .01$ ;  $R^2 = .30$ ). Lag between the ankle and knee in the Z axis was correlated with peak velocity of the supporting leg knee in the X axis during session 3 ( $r = .508$ ,  $p < .01$ ;  $R^2 = .26$ ) and session 5 ( $r = .715$ ,  $p < .05$ ;  $R^2 = .51$ ).

Timing lag between the knee and thigh of the supporting leg (X axis) was significantly correlated with peak velocity of the kicking toe (Z axis) during session 3 (  $r = -.530$ ,  $p < .01$ ;  $R^2 = .28$ ). Timing lag of the knee and thigh was also correlated with the supporting knee velocity (X axis, session 5,  $r = .683$ ,  $p < .01$ ;  $R^2 = .47$ ) and peak velocity of the kicking ankle (Z axis, session 7,  $r = .540$ ,  $p < .01$ ;  $R^2 = .29$ ).

## CHAPTER 5

### Discussion

The results of this study indicate that the hypothesis regarding differences in peak velocity and pattern of kick is not supported. The data indicate significant change in segmental velocity and kicking leg pattern during 10 practice sessions. The changes in pattern were mainly due to fluctuation of proximal segmental lag (knee – hip and hip – trunk) by session and axis. The data indicate positive lag for segments in the X axis which reflects a transfer of velocity between segments that is supported by the accompanying increases in peak velocity from proximal to distal segments. Fluctuation in the degree of lag is likely an attempt by participants to find an ideal attractor state for kicking (Figure 3). Southard (In Press) has shown that lag values, when performing an activity with the same collective variable (throwing), may fluctuate within a positive value as performance moves toward a stable attractor state. It appears that taking optimal advantage of the open kinetic chain may require change within positive lag values.

Distal segments (toe – ankle and ankle – knee) indicate consistent patterns over sessions but inconsistent patterns by axis. From a developmental perspective, participants (adults) are at a global state for fundamental kicking (Thelen and Smith, 1994). A global attractor state represents maximizing the collective variable and

reaching a higher level of proficiency. Development of a global state for activities utilizing the open kinetic chain occurs in a distal to proximal order (Southard, 1998, 2001, In Press). This may explain why participants have consistent distal patterns with fluctuation in the proximal segments when executing the roundhouse kick. The difference in pattern by axis is emphasized by the negative direction of movement (Toe – Ankle) in the Z axis (Figure 3). The negative lag between toe and ankle is likely due to plantar flexion of the kicking foot prior to contact in the Z axis (Bae, 1992). Positive lag for remaining segments in the Z axis indicates transfer of velocity but only for session 1, 2, 7, and 10. Positive timing lag is not necessarily indicative of the transfer of velocity as indicated by similar velocities of the hip and knee during sessions 3, 4, 5, 6, 8, and 9. Positive lag for timing of segments must be accompanied by a distal increase in velocity in order to indicate a transfer of velocity. The peak velocity of segments for sessions 1 and 2 are lower for both axes because participants did not fully utilize the open kinetic chain during the kicking task. It appears that participants conformed with Bernstein's idea for learning and constrained proximal and distal segments during initial stages of learning. The stability of the supporting leg (contact with the floor) reduces the possibility for significant changes in kinematics and explains the lack of change over sessions.

Recent research indicates that pattern change occurs when control parameters exceed a critical value (Kelso and Schoner, 1988; Southard, In Press). For this study, assuming velocity is the control parameter, velocity may not have increased sufficiently to instigate pattern change for the kicking task. Variation in proximal segmental lag indicates that participants were approaching a critical value for the control parameter and could be on the verge of pattern change. Ten practice sessions over 5 weeks may not have been enough practice to increase velocity to a critical value and effectively change kicking pattern. The established patterns for standard kicking may have influenced the value of critical values and made pattern change more difficult to accomplish (Thelen and Smith, 1994).

The hypothesis that accuracy will not increase with practice is supported. There were no significant changes in TCE and TVE by session. Correlational data indicated that changes in pattern created by fluctuational lag in proximal segments did not affect accuracy of kick. Interestingly, correlational data does not support the traditional speed – accuracy relationship. There were no significant correlations between increasing peak velocity and TCE. In fact, results indicate the opposite of the traditional speed – accuracy trade off. That is, the first two sessions (session 1 and 2) show low peak

velocity and high TCE and the last two sessions (session 9 and 10) indicate high peak velocity and improved TCE. This finding supports the contention that the basic kicking pattern was established for participants prior to practice which allows for increases in velocity and improvement of accuracy. Southard (1998b) found similar results when beginners practiced a golf swing. There was a decrease in accuracy until a pattern was established after which time accuracy and speed of swing were positively correlated.

Results have practical implications for Taekwondo instructors and students. Correlational data indicates that lag between the ankle and knee of the kicking leg in the X axis contributes to peak velocity of the ankle in the Z axis. It follows then that, in order to reach a high peak velocity, beginners need to extend their knee as soon as possible (reducing time lag) after knee flexion. Such distal lag allows the kicker to take advantage of the open kinetic chain and transfer velocity from proximal to distal segments. A strong quadriceps muscle along with good timing may be the key to taking advantage of the open kinetic chain and producing a forceful kick. As the energy of kicking is generated and transferred by the activation of flexor and extensor muscles, the coordination of muscle contractions (timing of turning-on and -off between hip flexor/extensor and knee flexor/extensor) is important to take advantage of the open kinetic chain. Practice should

encourage good timing of muscle contraction for the task. If participants scale up on the control parameter and are provided appropriate augmented information, they should eventually reach a global state for the roundhouse kick. The roundhouse kick is likely to be governed by the order parameter (open kinetic chain principle) so that instructors need to observe sequencing of segmental movement and provide such information to the kicker.

Following are suggestions for future studies. First, increase the number of practice sessions and increase the number of trials per session. More practice sessions and trials may allow participants to reach the necessary critical value for change in pattern. Second, offer participants an incentive to keep them motivated throughout practice sessions. Motivated participants are more likely to increase velocity with practice. Third, collect electromyography (EMG) for muscles of the leg which may provide additional information concerning the timing of muscular contractions and assist in understanding both the mechanics and control of the movement.

## References

Bae, Y.-S. (1992). Biomechanical studies on characteristic and estimation of kicking velocity in Taekwondo. Korean J. of Phy Edu., 31, 219-227.

Bernstein, N. (1967). The coordination and regulation of movements. New York: Pergamon Press.

Diedrich, F.J. & Warren, W.H. (1995). Why change gait? Dynamics of the walk-run transition. Journal of Experimental Psychology: Human Perception and Performance, 21, 183-202.

Diedrich, F.J. & Warren, W.H. (1998). The dynamic of gait transitions : Effects of grade and load. Journal of Motor Behavior, 30, 60-78.

Haken, H. (1977). Synergetics : An introduction. Heidelberg : Springer-Verlag.

Kelso, J.A.S. (1982). Concepts and issues in human motor behavior: Coming to grips with the jargon. In J.A.S. Kelso (ed.), Human Motor Behavior (pp.21-58). Hillsdale, N.J.: Lawrence Erlbaum Assoc. Inc.

Kelso, J.A.S. (1994). The informational character of self-organized coordination dynamics. Human Movement Science, 13, 393 – 413.

Kelso, J.A.S. (1999). Dynamic patterns : The self-organization of brain and

behavior. Cambridge, Massachusetts: MIT Press.

Kelso, J.A.S. and Schoner, G. (1988) Self-organization of coordinative movement patterns. Human Movement Science, 7, 27-46.

Kim, K.-P. (1998). A study on development upon the age and globalization of Korea Taekwondo. Korea J. Sports Science, 7, 21-38.

Kim, S.-B., & Kim, J.-S. (1997) . Analysis of the anatomical kinematics at the joints during the roundhouse kick in Taekwondo. Korean J. of Phy Edu., 36, 348-360.

Kim, Y.-I., & Kim, H.-R. (1997). A study of kicking techniques of female Taekwondo players. Korea J. Sports Science, 6, 89-100.

Kreighbaum, E. & Barthels, K.M. (1985). Biomechanics: A qualitative approach for studying human movement. Minneapolis, MN: Burgess Publishing Company.

Kukkiwon (1995). The Manual of Taekwondo. Seoul, Korea: Korea Taekwondo Association

Lee, J.-B. (1998). A study of kicking techniques of advanced Korea Taekwondo players. Coach Field Reports. Seoul, Korea: Korea Sports Research Institutes.

McGill, R.A. (1997). Motor learning : concepts and applications. Boston, Massachusetts : McGraw-Hill.

Newell, K.M. & van Emmerik, R.E.A. (1989). The acquisition of coordination: Preliminary analysis of learning to write. Human Movement Sciences, 8, 17-32.

Putnam, C. (1991). A segment interaction of analysis of proximal-to-distal sequential segment motion patterns. Med. Sci. Sports Exerc. 22, 130-144.

Southard, D. (1998a). Mass and velocity : control parameters for throwing patterns. Research Quarterly for Exercise and Sport, 69, 355-367.

Southard, D. (1998b). Change in attractor state. Journal of Sport and Exercise Psychology, 29, 73.

Southard, D. (2001). Control parameter for the development of throwing. In J. Clark & J. Humphrey. (Eds). Motor Development : Research and Reviews Volume 2. Reston, Virginia, NASPE publications.

Southard, D. (In Press). Change in throwing pattern : Critical values for control parameter of velocity. Research Quarterly for Exercise and Sport.

Southard, D. & Higgins, T. (1987). Changing movement patterns: Effects of demonstration and practice. Research Quarterly for Exercise and Sport, 58, 77-80

Thelen, E. & Smith, L. (1994). A dynamic systems approach to the development of cognition and action. Cambridge, Massachusetts: MIT Press.

Turvey, M.T., Fitch, H.L., & Tuller, B. (1982). The Bernstein perspective: I. The problems of degrees of freedom and context-conditioned variability. In J.A.S. Kelso (Ed.), Human Motor Behavior (pp.239-252). Hillsdale, N.J. : Lawrence Erlbaum Association, Inc.

Van Emmerik, R.E.A (1992). Kinematic adaptations to perturbations as a function of practice in rhythmic drawing movements. J. of Motor Behavior, 24, 117-131.

Vereijken, B., van Emmerik, R.E.A., Whiting, H.T.A., & Newell, K.M. (1992). Freezing degrees of freedom in skill acquisition. Journal of Motor Behavior, 24, 133-142.

Wark, K. (1988). Thermodynamics. New York: McGraw-Hill.

## APPENDIX A

## Consent Form

Project Title : The Effect of Practice on Pattern Changes of the Roundhouse Kick in Teakwondo.

Investigator : Youngkwan Kim

I, \_\_\_\_\_, hereby certify that I have been told by Youngkwan Kim of the Department of Kinesiology about research procedures and benefits regarding changing motor pattern for a roundhouse kick. I understand the possible discomforts and risks involved with participation.

A written summary of what I have been told is attached. I have been given adequate opportunity to read it and ask questions. I understand that I have the right to ask further questions about procedure and to withdraw my consent and participation in this project at any time without prejudice to me.

I hereby freely consent to take part in this project.

\_\_\_\_\_  
Signature

\_\_\_\_\_  
Date

If you have any questions at any time concerning this project or your right as a participant, please call :

Youngkwan Kim, Principal Investigator,  
Dr. Dan Southard, Research Supervisor,

257-6859  
257-7665

## APPENDIX B

### Written Summary

This experiment is designed to help kinesiologists understand why motor patterns change and how we learn motor skills. In addition to providing data which will address pattern changes and learning, participants will have an opportunity to view and interpret kinematic data and gain an appreciation for the analysis of human movement.

Should you provide your consent, you will be required to perform a right-foot roundhouse kick as fast and accurately as possible to a padded kick dummy. You will be given instruction concerning initial stance and foot placement when contacting the kicking dummy. No other instruction concerning kicking procedures will be provided. You will be required to kick the dummy 10 times per session for 10 sessions. Sessions will be on different day for two days per week for a total of five weeks. Prior to each session the experimenter will provide you with velocity and accuracy data concerning the previous session. You will be encouraged to increase your velocity but not at the expense of accuracy. Kicking will be in bare foot. You will be allowed to stretch as well as perform three practice kicks for warm-up prior to each session.

For each session the experimenter will place infrared emitting diodes (IREDs) to your body in order to obtain data concerning the movement of your limb segments. IREDs will be placed at toe of your right foot, right ankle joint, right knee joint, right hip joint, right side of trunk, left foot toe, left ankle joint, left knee joint, and middle of left thigh. The infrared light emitted by IREDs is completely harmless and all IREDs are secured with small double-back adhesive tape.

The total time of each session is about 20 minutes. There is minimal risk involving muscle strain and joint sprain during kicking trials. If you notice any pain or sprain during kicking trials, let me know and I will discontinue data collection.

Participants are free to withdraw their consent and discontinue participation at any time without penalty or prejudice. If you have any questions regarding procedures, I will be happy to address them.

I have discussed the above points with the participant. It is my opinion that the participant understands the risks, benefits, and obligations involved with this project.

---

Investigator

## VITA

CURRENT ADDRESS

5229 Cameron Creek Ct.#401  
 Fort Worth, TX 76132  
 E-mail : ykkim01@yahoo.co.kr  
 Phone : 817-361-8526

PERMANENT ADD.

601-603 Hanson APT, Jungja-Dong, Pundang-Gu,  
 Sunghnam, Kyunggi, South Korea 463-010  
 Phone : 82-31-711-0907

EDUCATION

Master of Science  
 (July 2000 ~ Aug 2002)

Texas Christian University  
 Department of Kinesiology  
 Graduation Date : Aug 2002  
 Concentration : Motor Control and Learning  
 Thesis : "The Effects of Practice in Pattern Changes of the  
 Roundhouse Kick in Taekwondo"  
 Advisor : Dan Southard, Ph.D.

(Jan. 2000 ~ May 2000)

Texas Christian University  
 Department of Kinesiology  
 Undergraduate Study on Kinesiology

Master of Science  
 (Mar. 1994 ~ Feb. 1996)

Korea Advanced Institute of Science and Technology  
 (Taejon, Korea)  
 Department of Aerospace Engineering  
 Graduation Date : Feb. 1996  
 Concentration : Radiative Heat Transfer  
 Secondary Area : Propulsion and Combustion  
 Thesis : "Experimental Study of Solid Fuel Ignition in a  
 Confined Enclosure"  
 Advisor : S.-W. Baek, Ph.D.

Bachelor of Science  
 (Mar. 1989 ~ Feb. 1994)

Korea Advanced Institute of Science and Technology  
 (Taejon, Korea)  
 Department of Aerospace Engineering  
 Graduation Date : Feb. 1994  
 Emphasis : Aircraft Structure

EMPLOYMENT

Aug. 2000 ~ May 2002

Teaching/Research Assistant at Texas Christian University,  
 Department of Kinesiology  
 - Teaching physical activities courses : Weight training and  
 Taekwondo

- Assisting Adapted physical education clinic activity
  - Researching at Motor Control Lab. under Dr. Southard. Helping data collection and digitizing and contributing biomechanical analysis.
- Oct. 1999 ~ Dec. 1999 Aerospace Engineer at Korea Aerospace Industries, Ltd.(KAI) (Samsung Aerospace Industries, Ltd. was changed into KAI. Due to M&A.)
- Mar. 1996 ~ Sep. 2000 Aerospace Engineer at Samsung Aerospace Industries, Ltd. Special propulsion engineer for integration between aircraft engine and subsystems.
- Engine control system electrical interface design
  - Engine monitoring system algorithm & aircraft interface design
  - Steady state engine performance analysis of F404-GE-102 with engine manufacturers' computer cycle models.

### PUBLICATIONS & PRESENTATIONS

Southard, D. and **Kim, Y.** (2001). Why can't we throw as well with the non-dominant arm, Presentation at North American Society for the Study of Sport Psychology and Physical Activity, . St. Louis.

Southard, D. and **Kim, Y.** (2002). Disruption of throwing pattern at maximum velocity for skilled throwers: A preliminary EMG study, NASPSPA, Baltimore.

**Kim, Y.** and Baek, S. (1996). Experimental Study of Solid Fuel Ignition in a Confined Enclosure. *Journal of Korea Society of Mechanical Engineering*, 36: 10.

### COMPUTER SKILLS

Very well knowledge in PC based system and software of MS Office, Fortran, and SPSS  
Some knowledge in Unix systems and software of C++

### CAREER RELATED COURSES

Biomechanics, Human Motor Development, Motor Behavior, Exercise, Exercise Physiology, Applied Sport Psychology, Anatomical Kinesiology, Fundamental Neuroscience, Statistics, Fundamental of Aerodynamics, Aircraft Design, Heat Transfer, Computational Fluid Dynamics, Finite Element Method, FORTRAN Programming, Fluid Dynamics, Solid Mechanics

## ABSTRACT

EFFECT OF PRACTICE ON PATTERN CHANGES:  
THE ROUNDHOUSE KICK IN TAEKWONDO

By Youngkwan Kim, M.S. 2002  
Department of Kinesiology  
Texas Christian University

Thesis Advisor : Dan Southard, Ph.D.

The purpose of this study is to determine changes in pattern and accuracy of the roundhouse kick for beginners as a function of practice and provide Taekwondo instructors and students with meaningful information concerning pattern changes and skill learning. Ten college age students (beginners) voluntarily participated in this study. The task was to perform a right-foot roundhouse kick with maximum velocity and accuracy to a target. The only instruction provided to participant was to set stance with the right foot back and to kick the target with the instep of the right foot. No model and no augmented information concerning kicking pattern was provided to participant. However, participants were provided foot velocity and accuracy data from the former session prior to each successive session. Participants completed ten sessions over a period of five weeks (two sessions per week). A motion analysis system recorded the movement of limb segments using infrared emitting diodes (IREDS) on anatomical locations. Time to peak velocity (TTPV) and peak velocity (PV) were digitized for pattern changes analysis. Accuracy (total constant error) was also determined by the impact spot on a target. ANOVA was performed on TTPV, segmental lag, and PV for pattern change analysis. Following Tukey post hoc procedure determined significance between

specific means. In addition, analysis of accuracy was determined by a one-way ANOVA for total constant error and total variable error with sessions as the independent factor. Analysis of variance indicated significant interaction on segmental lag of kicking leg (session X axis X segment) but not on supporting leg. The fluctuational lag for proximal segment and consistent lag for distal segment for kicking leg indicated participants took advantage of open kinetic chain principle for kicking and were about to move toward next stable attractor state for kicking. Peak velocity was improved by session due to release of degrees of freedom of proximal segments. There was no significant difference in TCE and TVE across session. However, traditional speed – accuracy relationship was not supported. Significant correlation between PV of ankle (Z axis) and the lag of ankle – knee for kicking leg (X axis) indicated the fast knee extension after knee flexion was recommended to take well advantage of open kinetic chain. Trajectory graphs and scattering graphs indicated a qualitative change in pattern over the practice sessions. It was concluded that practice with appropriate information scales up the control parameter (velocity) and eventually allows participant to reach a global state in the roundhouse kick.

Key Words : Dynamic System, Roundhouse Kick, Practice