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Analysis of Force, Time, Energy, Psychological demand and Safety of common kicks in Martial Arts

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Analysis of force, time, energy, psychological demand and safety of common kicks in martial arts

by

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Michael Dorneich
Stephen B Vardeman

The student author and the program of study committee are solely responsible for the content of this thesis. The Graduate College will ensure this thesis is globally accessible and will not permit alterations after a degree is conferred.

Iowa State University

Ames, Iowa

2017

DEDICATION

"It isn't a Master's Degree if it's without a thesis" is what my father Mr. Ashok Kumar R. Singh told me when I thought that doing research was not my cup of tea. Hence I dedicate this study to him along with my mother Mrs. Neela A. Singh, my brother Mr. Abhinav Singh and my sister Miss. Sneha A. Singh. Without your encouragement and push, this wouldn't have been possible. Proud to have you all as my family.

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NOMENCLATURE

MMA	Mixed Martial Arts
Kcal	Kilo Calories
Lbs	Pounds
HR	Heart Rate
ANOVA	Analysis of Variance
NASA	National Aeronautics and Space Administration
TLX	Total Load Index

ACKNOWLEDGMENTS

First and foremost, I would like to thank my Martial Arts instructor Sensai Lalith Salian for his guidance and coaching since the past 18 years, without him I would have never had the knowledge and expertise in the field of Martial Arts. Secondly I would like to thank my major professor Dr. Richard Stone for suggesting an area to work on by identifying my interest in Martial Arts and Human Factors. Without your support and guidance, I don't think it would have been possible for me to complete a thesis. Thank you to Dr. Michael Dorneich, my committee member, for introducing me to the world of cognitive field which eventually encouraged me to incorporate the psychological demand in the study. Also, I would like to thank Dr. Stephen Vardeman, my committee member, for providing his valuable input on the Statistical Data Analysis part which helped me produce more accurate results. In addition, a special thanks to Kevin Brownsfield for helping me with modifying the apparatus in his workshop.

In addition, I would also like to thank my family members, my partner Claire, her mom Lisa and my friends back home and in US for always being supportive and being there to help me.

ABSTRACT

Different forms of Martial Arts have become a popular sport and ways of being fit in the past couple of decades; Kick boxing, Taekwondo, Mixed Martial Arts, being some of them. Complex combinations of punches, kicks and both have been developed over the years. This study focuses on kicks and the aim was to find the best kick with regards to force, time of kick, energy consumption, force/energy, heart rate, safety and psychological demand which was in terms of mental demand, physical demand, temporal demand, effort, performance and frustration. A study was conducted in which 16 participants (5 females and 11 males) participated who were between 18 and 35 years of age with at least 2 years of experience. Each participant performed 10 kicks each of Front Kick, Roundhouse Kick, Side Kick and Spin Kick. Force was measured from the force sensor, time of kick from the video using a stop watch, energy consumption and heart rate were measured from the bio harness, safety and psychological demand were measured from the response of the participants to a pain scale and NASA TLX survey respectively. It was found that the Roundhouse and Front Kick were superior to the Spin and Side kick for most of the variables except force. However, even though the force obtained from these two kicks was lesser than Spin and Side kick, it was enough to knock the opponent down if hit at the right spot. Among front and roundhouse kick, the front kick was safer due to the fact that it's striking with the ball of the foot than the instep which is much delicate as compared to the former. The interesting point was even though the front kick was not favorite among the participants as compared to the roundhouse kick, it was better than the roundhouse kick for few variables and equal for the rest. This shows the tremendous

potential front kick has if given enough importance instead of disregarding it as a kick that is not visually impressive.

CHAPTER I

INTRODUCTION

What is Martial Arts?

In the past decade or so, Martial Arts has flourished largely in terms of being a form of sport or a recreational activity such as kick boxing, cardio kick boxing, ultimate fighting championship, world wrestling entertainment, etc. These being activities performed by human beings are a source of injuries, which could result in outrageous medical expenses, pain and suffering, bed rest, etc. Thus, it is very essential for such activities to be performed with the least possibility of injuries and obtaining the optimal results or effects. This study uses the knowledge from Physics, Human Factors Engineering and Cognitive Science to make these activities safer with regards to basic kicks.

The origin of Martial Arts exists simultaneously with the origin of Human Beings since Human Beings have always needed to defend themselves. Considering the vast variety of different Martial Arts forms, it is difficult to trace back a specific instance when the first form of Martial Art was developed. These forms were specific to a culture or region and were practiced by those inhabitants. For example, Copoiera, Judo, Taekwondo and Muay Thai are from Brazil, Japan, Korea and Thailand respectively. As Green and Svinth indicate in their book 'Martial Arts of the Word' (Green & Svinth, 2010):

"Martial arts are considered to be systems that blend the physical components of combat with strategy, philosophy, tradition or other features, thereby distinguishing them from pure physical reaction." (P.16)

Every form of Martial Arts relies heavily on the use of hands and legs. Punching and kicking both require a specific body stance which do not complement each other. As a result, an effective fighter is the one who can switch grounds depending on the need of the situation (Kurban, 1979).

Introduction to Kicks

There are different types of kicks that range from attacking the shin to attacking the head, attacking with the shin or knee to attacking with the ball of the foot, attacking by standing on one leg to attacking by jumping in the air or falling on your hands. However, the most commonly and excessively used kicks that are in practice are the basic kicks which are Front Kick, Roundhouse Kick, Spin Kick and Side Kick roughly in all the different forms of Martial Arts. The study aims at finding the most efficient kick among the above five with regards to Force, Metabolic Burn, Time, Psychological Demand and Safety.

CHAPTER II

LITERATURE REVIEW

Basic Kicks in Martial Arts

A kicking technique can be used for attacking as well as self-defending and is much powerful than a punch because the legs carry a large bone and muscle mass as compared to the hands. Each leg constitutes to around 20% of the body mass while each arm is made up of 5% of total body mass (Leva, 1996). Due to this large difference in mass, a kick is much more powerful than a punch. Generally, a fighter resorts to kicks when the opponent is beyond the punching range or is within the kicking range but is beyond the punching range. As compared to punching, kicks are difficult to master since you can't maneuver your legs just like you do your hands thus making them difficult to control and requiring extra training (Kurban, 1979).

Kicks could find their application in either street fights for self-defense or in bouts for scoring points and one could either go for high kicks, mid kicks or low kicks. High Kicks are not recommended in street fights because they take longer to execute, require perfection and are readily detected by the opponent (Holder, 1994). An erroneous high kick could result into exposing the groin region and leaving you immobile. When it comes to bouts, different styles and sub styles have bouts in their own way but none allow a kick to the groin due to the detrimental consequences. Bouts from styles such as Muay Thai and Mixed Martial Arts allow kicks below the waist on the legs whereas Taekwondo and most Kick Boxing styles allow kicks only above the waist. Moreover, for low kicks, the only place where one can hit is the thigh. The reason being that knee, calf and shin of the opponent can easily injure the attacker and the groin is not easily accessible for kicking. In addition, for most forms, a martial arts

performer could use any portion of leg below their ankle to launch the impact. Thus, looking at the common requirements between Street Fights and Bouts, the mid-level kicks are the ones that are most commonly used since their applications are found in both the places. In addition to that, the front kick, side kick, spin kick and roundhouse kick are used by all levels and forms of martial arts.

Kicking Force

Various studies have been done that compare the kicking force of different types of kicks. In one of the episodes of Fight Science titled Stealth Fighters, four professional disciples from different styles of martial arts were asked to perform their best kick in two setups, first having a stable target and a stable platform and the second having a moving target as well as a moving platform (Bir & Sandler, 2008). The disciples from Karate, Muay Thai, Capoeira and Taekwondo performed the Front Kick, Round House Kick, Negative Magnetola (Roundhouse kick in a sitting position) and Roundhouse kick respectively all to the mid-section of the body. The study could determine the most powerful kick but not the most efficient kick because the experimental set up was way different from an actual bout or a street fight. The participants just performed one kick and also the target was much softer while the human body is much different due to the bones and muscles (Djurdevic, 2011). The study accounts for these aspects which were not taken into consideration. An efficient kick would be the one that consumes the minimum time and energy, provides a descent force, least mental demand and is safe.

Pedzich and his team compared the spin kick and side kick from the Taekwondo style and found that there was no difference in the stroke force of both the kicks and this force depended on the weight of the attacker. They also found that in the cases of the right leg being the dominant one, higher stroke force values were obtained (Pedizch, Mastalerz, & Urbanik,

2006). Another study was conducted that compared Side Kick, Round Kick, Spinning Back Kick and Reverse Punch from right and left side on the 1988 US Olympic Taekwondo Teams between men and women (Pieter & Pieter, 1995). Both, male and female athletes had roundhouse kick as the fastest and strongest in terms of force as compared to the side kick and spin kick (Pieter & Pieter, 1995). On another study conducted on elite male Taekwondo athletes that compared the basic techniques viz. Roundhouse Kick, Side Kick and Spin Kick. The speed recorded for the roundhouse kick was 19.2 m/s as compared to that of Side and Spin kick which were 10.3 m/s and 10.4 m/s respectively (Sung, Lee, & Joo, 1987). The force of the roundhouse kick was 2.7 times and 2.9 times more than that of the side kick and spin kick respectively. The unknown part of these results were whether the results would be the same if while kicking a target that closely represents the midsection of the human body.

Safety and Injuries in Martial Arts

Safety has always been a concern during fights among various forms of martial arts. Over the years, rules of various bouts have changed significantly to make the game safer than before. Mixed martial arts (MMA) which was first introduced in United States in 1993 did not have any rules and regulations, no time restrictions, was brutal and no-holds barred. However, the rules and regulations were changed dramatically which introduced weight class, established time limits and restricted the participants from attacking the opponent's throat, spine and back of the head. They were also forbidden to stomp or knee the opponent when grounded (Bledsoe, Hsu, Grabowski, Brill, & Li, 2006). This resulted in acceptance of the sport from two states to thirteen states in United States. A study was conducted that compared the incidence and distribution of injuries in the years 1997 and 2002, which were before and after the implementation of new rules by World Karate Federation in 2000. It was concluded that the

relative risk of leg injuries was significantly lower in 2002 in comparison to 1997 with a confidence interval of 0.09 to 0.28 (Macan, Bundalo-Vrbanac, & Romic, 2006).

Different forms of martial arts have different common regions of injuries and also there are different forms of injuries in martial arts. For instances, judo practitioners are injured more often on the upper extremities, karate on the head and face while taekwondo athletes are prone to injuries on lower extremities (Peter, 2005). The common areas of injuries on lower proximities are generally on the instep or the chin which are hurt by going off the target and kicking the opponent's hip bone, elbow bone, etc. (Macan, Bundalo-Vrbanac, & Romic, 2006). The percentage of these injuries of total injuries was 28.0-37.0% in Judo, 51.3-90.9% in Karate and 36.7-65.0% in Taekwondo (Peter, 2005). The major types of injuries in martial arts are contusions/abrasions, lacerations, strains/sprains, fractures/dislocations (Birrer & Halbrook, 1988). To prevent the martial artists from sustaining such injuries, various measures such as limiting the sparing in less experienced students, use of padding, headgear, mouth guards, eye and face protection are advised (Woodward, 2009). However, considering the different ways in which Front Kick, Roundhouse Kick, Spin Kick and Side Kick are executed, it would be interesting to know which of them is the safest to perform or use in fights.

Energy Consumption and Psychological Demand

With the physical part of martial arts, there is also the psychological part involved. While studying martial arts from different background, there was more to it just than the punches, kicks and throws and the martial arts performers had essential knowledge to contribute about the mental health in terms of energy (Seitz, Olson, Locke, & Quam, 1990). Chen and Cheesman looked into the difference in mental toughness of Mixed Martial Arts athletes at various levels of expertise in a competition and found that the ones taking part at

higher levels had a higher mental toughness which was in line with the previous literature (Chen & Cheesman, 2013). Similar studies have been done in different sports such as volleyball, rugby, etc. pointing to the fact that it is essential to have participants with similar expertise level in this study to find if all the kicks had the same psychological impact.

The first study dealing with the caloric consumption in Martial Arts was done in 2002 and that too on a training drill on Novice Participants (Glass, Reeg, & Bierma, 2002). It was concluded that there existed substantial cardiopulmonary strain, energy expenditure and a large variation in calorie consumption. Another study established the experimental proof to state that the dominant source of energy in Martial Arts fights was anaerobic metabolism (Beneke, Beyer, Jachner, Erasmus, & Hutler, 2004). Other studies were also conducted that looked into the energy cost and energy systems while performing different activities in Martial Arts (Francescato, Talon, & di Prampero, 1995) & (Campos, Bertuzzi, Dourado, Santos, & Franchini, 2012). However, none established a direct relation of the calories consumed and heart rate between the four common kicks in Martial Arts.

Hypothesis

Thus, the purpose of this psychophysical study was to compare Front Kick, Side Kick, Spin Kick and Roundhouse Kick while kicking a target resembling the hardness of a human body for the following hypothesis:

Hypo. 1) There exists a difference between the relative forces on impact of each type of kick.

Hypo. 2) There exists a difference between the times taken to perform each type of kick.

Hypo. 3) There exists a difference in the kilo calorie consumption for each type of kick.

Hypo. 4) There exist a difference in the psychological demand of each type of kick.

Hypo. 5) There exist a difference in the level of safety for each type of kick.

CHAPTER III

ANALYSIS OF FORCE, TIME, ENERGY, PSYCHOLOGICAL DEMAND AND SAFETY FOR COMMON KICKS IN MARTIAL ARTS

Abstract

Different forms of Martial Arts have become a popular sport and ways of being fit in the past couple of decades; Kick boxing, Taekwondo, Mixed Martial Arts, being some of them. Complex combinations of punches, kicks and both have been developed over the years. This study focuses on kicks and the aim was to find the best kick with regards to force, time of kick, energy consumption, force/energy, heart rate, safety and psychological demand which was in terms of mental demand, physical demand, temporal demand, effort, performance and frustration. A study was conducted in which 16 participants (5 females and 11 males) participated who were between 18 and 35 years of age with at least 2 years of experience. Each participant performed 10 kicks each of Front Kick, Roundhouse Kick, Side Kick and Spin Kick. Force was measured from the force sensor, time of kick from the video using a stop watch, energy consumption and heart rate were measured from the bio harness, safety and psychological demand were measured from the response of the participants to a pain scale and NASA TLX survey respectively. It was found that the Roundhouse and Front Kick were superior to the Spin and Side kick for most of the variables except force. However, even though the force obtained from these two kicks was lesser than Spin and Side kick, it was enough to knock the opponent down if hit at the right spot. Among front and roundhouse kick, the front kick was safer since it is striking with the ball of the foot than the instep which is much delicate as compared to the former. The interesting point was even though the front kick was not favorite among the participants as compared to the roundhouse kick, it was better than the

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Introduction

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Every form of Martial Arts relies heavily on the use of hands and legs. Punching and kicking both require a specific body stance which do not complement each other. Thus, an effective fighter is the one who can switch grounds depending on the need of the situation (Kurban, 1979). There are different types of kicks that range from attacking the shin to attacking the head, attacking with the shin or knee to attacking with the ball of the foot, attacking by standing on one leg to attacking by jumping in the air or falling on your hands. However, the most commonly and excessively used kicks that are in practice are the basic kicks which are Front Kick, Roundhouse Kick, Spin Kick and Side Kick in all different forms of Martial Arts. Depending on the form of Martial Art and the athlete, people have different opinions on which kick amongst these is the best but there is no proof of comparison.

A kicking technique can be used for attacking as well as self-defending and is much powerful than a punch because the legs carry a large mass as compared to the hands. Each leg constitutes to around 20% of the body mass while each arm is made up of 5% of total body mass (Leva, 1996). Due to this large difference in mass, a kick is much more powerful than a punch. Generally, a fighter resorts to kicks when the opponent is beyond the punching range or is within the kicking range but is beyond the punching range. As compared to punching, kicks are difficult to master since you can't maneuver your legs just like you do your hands thus making them difficult to control and requiring extra training (Kurban, 1979).

Kicks could find their application in either street fights for self-defense or in bouts for scoring points and one could either go for high kicks mid kicks or low kicks. High Kicks are not recommended in street fights because they take longer to execute, require perfection and are readily detected by the opponent (Holder, 1994). An erroneous high kick could result into exposing the groin region and leaving you immobile. When it comes to bouts, different styles

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Hypo. 1) There exists a difference between the relative forces on impact of each type of kick. Hypo. 2) There exists a difference between the times taken to perform each type of kick. Hypo. 3) There exists a difference in the kilo calorie consumption for each type of kick. Hypo. 4) There exist a difference in the psychological demand of each type of kick. Hypo. 5) There exist a difference in the level of safety for each type of kick.

Method

Participant selection

The experiment comprised of 16 participants that were recruited from different martial arts clubs at Iowa State University and 14 of them were from the Taekwondo style. Male and female participants between the age group of 18 to 45 years and 18 to 55 years respectively and with at least 2 years of experience were allowed to participate. This would prevent martial artists with lesser experience from participating in the study and injuring themselves. There were 5 females and 11 male participants making it a total of 16 participants. All the participants were pursing Martial Arts as a hobby or an activity for remaining fit and were well familiar with the kicks since they had at least 2 years of experience. Since the study involved physical exercise and wearing a heart rate monitor, participants with surgically fitted heart pacemakers or automatic defibrillators, or persons with prior evidence of skin irritation in locations where the chest strap made contact with the subject were disallowed to participate.

Materials and Equipment

The devices used were a Zephyr Bio harness, FGV SHIMPO, Hard Cushioned Pad, Tread mill. The Zephyr Bio harness was used to record different body parameters of the participant such as Heart Rate, Breathing Rate, Calories Burnt, etc. The FGV SHIMPO, a force measuring device with a range of 0 to 1000lbs was used to measure the force. Due to the fact

that the absolute kicking forces could easily go above 1000lbs and to prevent the sensor from getting damaged, the cushioned pad was modified with additional springs to dampen the forces. Initially it had 4 springs each of a stiffness of around 10lbs as shown in figure 2. Later it was modified and fitted with 5 springs each with an approximate stiffness of 100lbs as show in figure 3. Even though this set up didn't provide the absolute value, because all the kicks were performed on the same pad, the readings were reliable to be compared with each other.

Figure 1. Kicking Pad

Figure 2. Before modification

Figure 3. After modification

The cushioned pad was deliberately made a little harder to replicate the hardness of human body which is where one has to attack in bouts or fights and not on a soft punching/kicking bag. This was way different than what the participants were used to kicking in everyday practice. Such a kind of target setup ensured that the participants kicked at the same spot every time and also have a steady target which doesn't sway on striking. Another

important feature of the target was that it provided the instant reaction force and was restored back to its initial position unlike the heavy bags or other soft striking pads. The software used for recording data from the heart rate monitor was OmniSense Live and OmniSense Analysis was used for analyzing the data.

Kick Description

Every participant was read a training manual that had instructions and graphical representation of different steps involved in executing a successful kick. Since the participants had a prior experience of at least 2 years, all of them were familiar to the four types of kicks. The training manual had every kick broken down into its fundamental steps as follows:

1) Front Kick

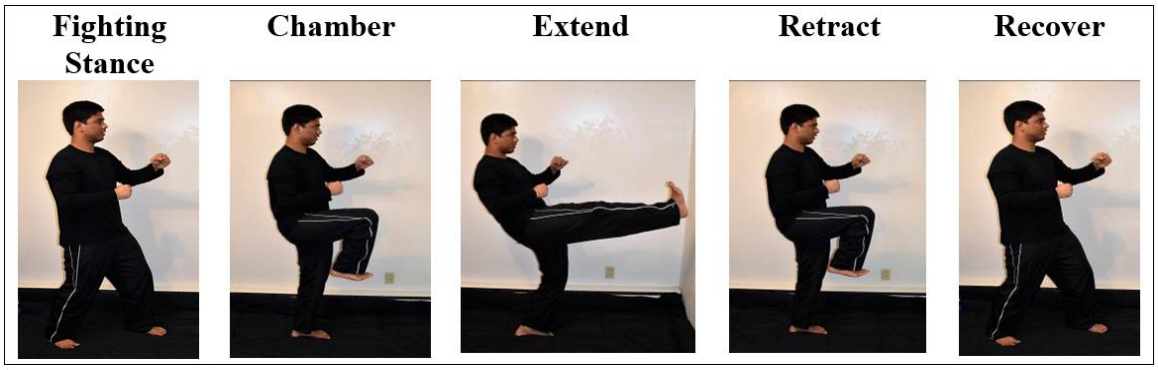


Figure 4. Steps to perform the Front Kick

This kick is usually executed by the rear leg while in the fighting stance called the guard. The knee is lifted in a way that the angle between the thigh and the calf is roughly 90° called the Chamber and then later extending the leg to strike the target without lowering the knee position. As the foot approaches the target, the toes are pulled back in order to strike the target with the ball of the foot. However, in a fight the knee lifting and the leg extension movements are performed in harmony such that by the time the knee reaches the desired height, the foot is almost near the target. Upon hitting the target, the extended leg needs to be retracted and the

leg placed back in the initial stance as soon as possible to allow a follow up technique and also to prevent the opponent from blocking it.

2) Side Kick

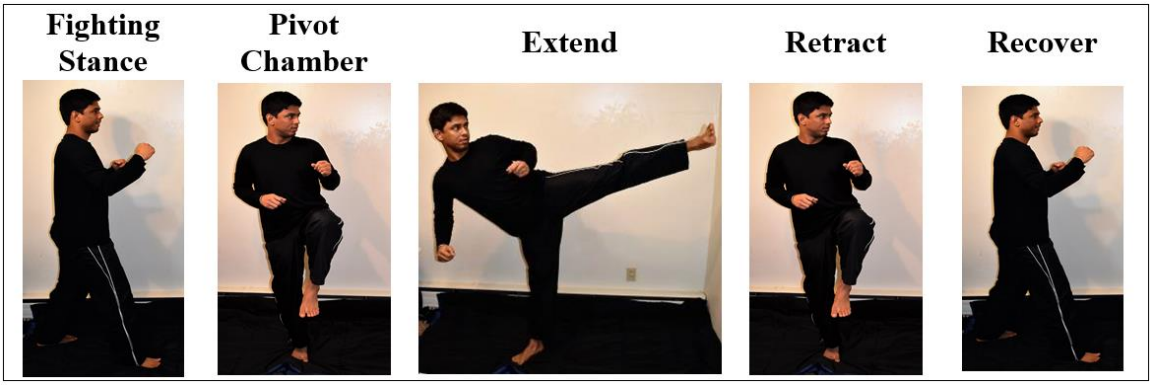


Figure 5. Steps to perform the Side Kick

This is also preferred with the rear leg when in the fighting stance and starts with raising the knee to a height such that the angle between the thigh and the knee is approximately 90°. As the name goes, 'Side' Kick, the body is turned side-ways before executing the kick. In order to do so, the heel of the grounded leg is lifted and the ball of the foot and the toes are used as a pivot point to turn the body to the required position such that the heel of the kicking leg faces the target. After that the leg is extended to strike the target with the heel. Some forms of Martial Art focus on striking with the edge of the foot. Once the target has been struck, the extended leg is retracted, the body turned and the leg brought back in the defensive stance.

3) Spin Kick

Just like the first two kicks, even the Spin Kick begins with the fighting stance and is generally preferred with the rear leg. However, it involves a 360° spin. The body is spun 180° initially such that the back faces the target. This can be done either by moving the rear leg behind the front leg or by moving the front leg from the front of the rear leg. While turning,

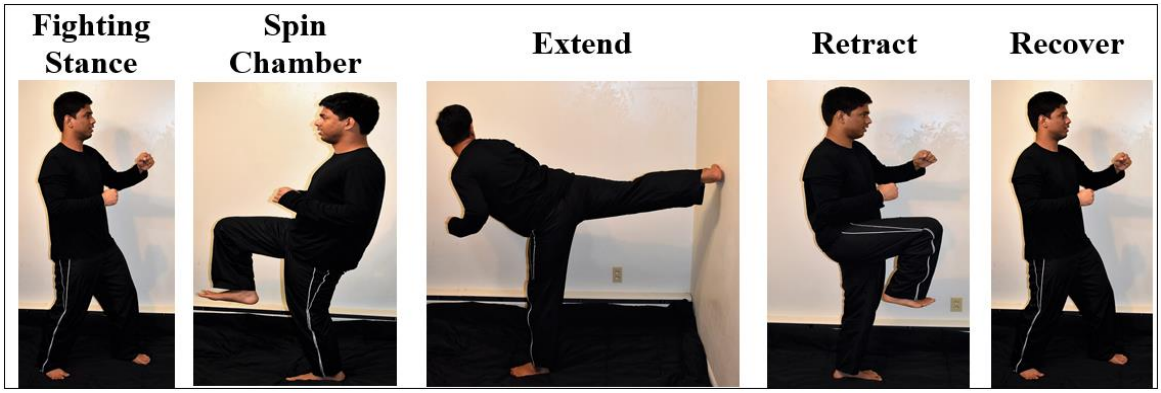


Figure 6. Steps to perform the Spin Kick

the knee is brought up such that the angle between the thigh and the calf is 90˚. Once in this position, then the kick is ready to be launched and the leg is extended to strike the target. After completing the strike, as the kicking leg is retracted, the body is turned in the direction as it was turned previously in order to come back to the fighting stance.

4) Roundhouse Kick

Figure 7. Steps to perform the Roundhouse Kick

The roundhouse kick is like the front kick, only difference being that the kick comes in a circular side-ways. The attacker lifts his rear leg knee from the fighting stance. Then the heel of the grounded leg is lifted and rotated in a direction towards the target and while doing so, the kick is extended to strike the target with the instep. After the attack, the extended leg is retracted and the body rotated back to the fighting stance facing the target.

The front kick is the basic first kick that any martial artist is taught and is not visually appealing as compared to the remaining 3 kicks. As a result, it is shadowed by other fancy kicks in the long run and barely used in fights.

Task

Every participant had to perform 10 kicks each of Front Kick, Side Kick, Roundhouse Kick and Spin Kick. The order of the kicks was randomly assigned to the 16 participants. After every set of 10 kicks, the participant had to complete 2 forms from which one was the Appendix C National Aeronautics and Space Administration Total Load Index (NASA TLX) (Human Performance Research Group (NASA), 1986). The other form was the Appendix B Pain Scale survey which asked the participant to mark the body parts where they felt the pain, state whether the pain is internal or external and then rate it on a scale of 0 to 10 with 0 being the least and 10 max (McCaffery & Pasero, 1999) (Melzack, 1975).

Experimental procedure

The study took around an hour per participant. Before beginning with the task, the participant had to sign the consent form and then fill up the Appendix D Pre-trial survey. The survey collected anthropometric measurements and personal questions (age, height, weight, reach (if known), gender, years of experience and the dominant leg (right or left) with which they will be performing the kick and also the ranking of their preference for the four kicks. Depending on their reach, the participants were placed at a certain distance from the kicking pad. This was followed by buckling the participant with the Zephyr Bio harness for collecting heart rate, breathing rate, etc. The participants were also asked to get an idea about the hardness of the target since it was designed to replicate the human body hardness and thus was harder than what people use during normal practice. Then the participants were given instructions on

the type of kick that they had to perform. After all this was done, the participants were asked to warm up and then placed on a tread mill and asked to job until their heart beat reached 65% to 70% of their maximum heart rate. The equation used to calculate the maximum heart rate was 220 – Age (Tanaka, Monahan, & Seals, 2001). Once the target heart rate zone was achieved while running, the participant was asked to step down from the treadmill and start with the first kick assigned. The kicks were assigned to each participant in a random order. While performing a set of 10 kicks, the participant would kick and come back in the fighting position, wait for the "go" from the investigator and then launch the next kick. After every 10 kicks, the participant would fill out the NASA TLX form and also the Pain Scale Assessment survey. This also provided the cooling period for the participant to restore their heart rate back to where it was.

Variables

The table below mentions the Independent and Dependent variables. The pain scale survey was used to summarize the common areas of pain and its intensity of different kicks.

Table 1. Dependent and Independent Variables

Independent Variables	Dependent Variables	Units
1) KICK TYPE a) Front Kick b) Side Kick c) Spin Kick d) Roundhouse Kick	Average Force per kick	Pounds (lbs.)
	Energy Consumption each set of 10 Kicks	Kilo Calories (kcal.)
	Average Force per energy consumed	Pounds/Calories (lbs. /cal.)
	Average Heart Rate for each set of 10 Kicks	Beats/min.
	Average Kick Time per kick	Seconds (sec.)
	Mental Demand	Scale of 1 to 21
	Physical Demand	Scale of 1 to 21
	Temporal Demand	Scale of 1 to 21
	Performance	Scale of 1 to 21
	Effort	Scale of 1 to 21
	Frustration	Scale of 1 to 21

The mental demand, physical demand, temporal demand, performance, effort and frustration were obtained from the NASA TLX scale and their definition is as follows:

1) Mental Demand – Measures the mental effort that goes into the task such as thinking, remembering, decision making, etc.
2) Physical Demand – Measures the physical effort applied in the task such as any physical activity.
3) Temporal Demand – Measures the time pressure on the participant.
4) Performance – Measures how successful the participant feels upon completion of the task.
5) Effort – Measures how hard the participant had to work in order to complete the task.
6) Frustration – Measures how aggravated the of the participant while doing the task.

Data collection

The table below shows the method incorporated for collecting each of the dependent variables mentioned above:

Table 2. Data collection method for each dependent variable

#	Dependent Variable	Data Collection Method
1	Average Force per kick	The force of every kick from a set of 10 kicks for a particular type of kick was measured with the help of SHIMPO FGV Force sensor. The average of these forces was then calculated for a participant for a particular type of kick.
2	Energy Consumption each set of 10 Kicks	With the help of OMNI Sense Analysis software, the data of a particular participant was split into 4 intervals for the 4 different types of kicks. The software then gave the direct calories consumed for each interval for a participant.
3	Average Force per energy consumed	The average force data obtained was divided by the calories consumed for a particular type of kick for a participant.

Table 2. Continued…

4	Average Heart Rate for each set of 10 Kicks	Similar to the calculation of the energy consumption, the software also directly gave the information of the average heart rate for a participant for each type of kick.
5	Average Kick Time per kick	The kicking time for each kick was calculated from the time of initiation of the kick to the time of striking the pad (sum of reaction and execution time). The time for 10 kicks was then averaged to give the average time of performing a particular kick for a participant.
6	Mental Demand	These were measured from the NASA TLX Scale that each participant would mark after performing a set of a particular type of kick. (APPENDIX C)
7	Physical Demand	
8	Temporal Demand	
9	Performance	
10	Effort	
11	Frustration	

Results

The data for Force, Energy, Force/Energy and Average Heart Rate was not normal and hence log transformation was done to make it normal. Since the goal of the study was to compare the kicks and establish an order for a given variable rather than finding the absolute difference, converting the results back was not essential. Two-Way ANOVA without interaction was conducted to determine whether the kicks were different from each other for a specific response variable and Tukey Pairwise Comparison was conducted to identify the significant pairs. A mixed effect model was used with Kick Type being the fixed effect and participant being the random effect since every participant was different from each other with respect to age, weight, gender, etc. The following was the equation where 'i' represents the kick and 'j' the participant: $y_{ij} = \mu_i + \bar{p} + \varepsilon_{ij}$ where 'μ_i' is the mean of the i^{th} kick type, '$\bar{p}$' is the participant mean and 'ε_{ij}' is the random effect (n=16).

The table 3 below provides the p-value of overall fixed effect and pairwise comparison for each dependent variable. A '*' symbol indicates that the p-value was significant.

Table 3. Statistical Analysis Results (One-Way ANOVA, Tukey's Test, ls means)

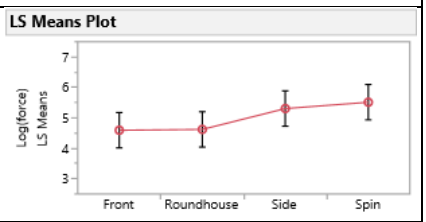
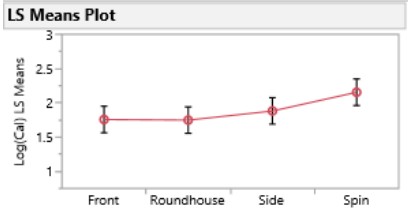
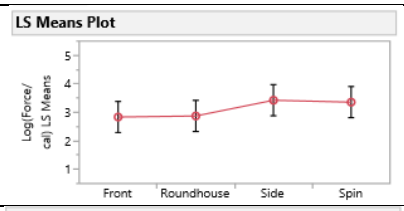
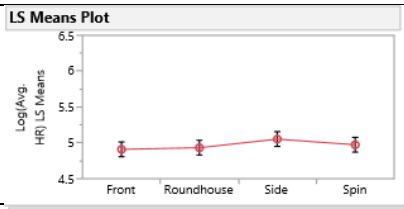
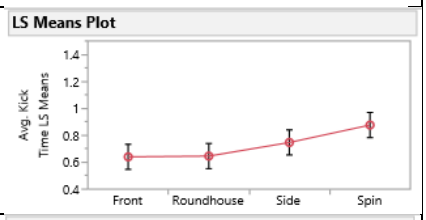
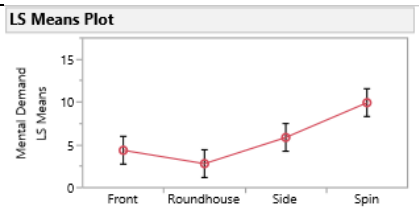
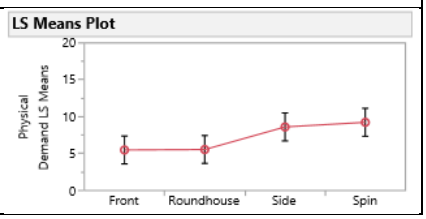
#	Dependent Variable	P-value	Pairwise Tukey Comparison		Lease Square Means
			Pair	P-value	
1	Average Force per kick	0.0004*	Spin – Front	0.0029*	
			Spin – Roundhouse	0.0040*	
			Side – Front	0.0290*	
			Side – Roundhouse	0.0382*	
			Spin – Side	0.8351	
			Roundhouse – Front	0.9995	
2	Energy Consumption on each set of 10 Kicks	0.0020*	Spin – Roundhouse	0.0038*	
			Spin – Front	0.0047*	
			Spin – Side	0.0828	
			Side – Roundhouse	0.6355	
			Side – Front	0.6819	
			Front – Roundhouse	0.9998	
3	Average Force per energy consumed	0.0357*	Side – Front	0.1014	
			Side – Roundhouse	0.1363	
			Spin – Front	0.1726	
			Spin – Roundhouse	0.2245	
			Side – Spin	0.9934	
			Roundhouse – Front	0.9989	
4	Average Heart Rate for each set of 10 Kicks	0.0857	Side – Front	0.0796	
			Side – Roundhouse	0.1809	
			Side – Spin	0.5334	
			Spin – Front	0.6859	
			Spin – Roundhouse	0.8936	
			Roundhouse – Front	0.9779	
5	Average Kick Time per kick	<0.0001*	Spin – Front	<0.0001*	
			Spin – Roundhouse	<0.0001*	
			Spin – Side	0.0357*	
			Side – Front	0.1129	
			Side – Roundhouse	0.1438	
			Roundhouse – Front	0.9994	
6	Mental Demand	<0.0001*	Spin – Roundhouse	<0.0001*	
			Side – Front	<0.0001*	
			Spin – Side	0.0004*	
			Side – Roundhouse	0.0092*	
			Front – Roundhouse	0.3374	
			Side – Front	0.3733	
7	Physical Demand	0.0001*	Spin – Front	0.0016*	
			Spin – Roundhouse	0.0020*	
			Side – Front	0.0107*	
			Side – Roundhouse	0.0128*	
			Spin – Side	0.9135	
			Roundhouse – Front	0.9999	

Table 3. Continued…

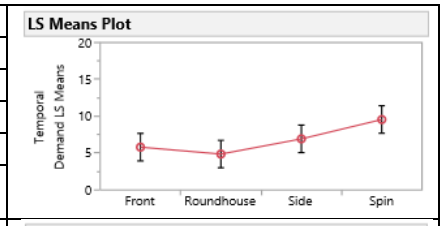
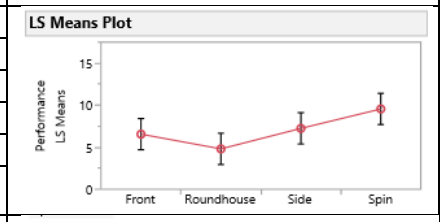
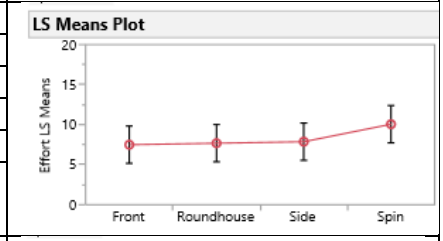
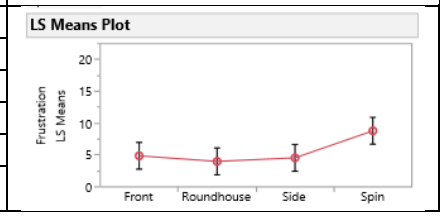
8	Temporal Demand	<0.0001*	Spin – Roundhouse	<0.0001*	
			Spin – Front	0.0012*	
			Spin – Side	0.0342*	
			Side – Roundhouse	0.1336	
			Side – Front	0.6235	
			Front – Roundhouse	0.7452	
9	Performanc e	0.0007*	Spin – Roundhouse	0.0003*	
			Spin – Front	0.0341*	
			Spin – Roundhouse	0.1141	
			Spin – Side	0.1449	
			Front – Roundhouse	0.3626	
			Side – Front	0.9158	
10	Effort	0.1837	Spin – Front	0.2167	
			Spin – Roundhouse	0.2773	
			Spin – Side	0.3476	
			Side – Front	0.9916	
			Roundhouse – Front	0.9989	
			Side – Roundhouse	0.9989	
11	Frustration	0.0001*	Spin – Roundhouse	0.0002*	
			Spin – Side	0.0011*	
			Spin – Front	0.0028*	
			Front – Roundhouse	0.8388	
			Side – Roundhouse	0.95	
			Front – Side	0.9907	

Table 4. Summary of Statistical Analysis

#	Dependent Variable	Overall Sig. Diff	Pairwise Sig. Diff	Least Square Means Rankings			
				Best			Worst
1	Force	Yes	Yes	Spin	Side	Round	Front
2	Force/Energy	Yes	No	Side	Spin	Round	Front
3	Calories	Yes	Yes	Round	Front	Side	Spin
4	Avg. HR	No	No	Front	Round	Spin	Side
5	Kick Time	Yes	Yes	Front	Round	Side	Spin
6	Mental Dmd.	Yes	Yes	Round	Front	Side	Spin
7	Physical Dmd.	Yes	Yes	Front	Round	Side	Spin
8	Temporal Dmd.	Yes	Yes	Round	Front	Side	Spin
9	Performance	Yes	Yes	Round	Front	Side	Spin
10	Effort	No	No	Front	Round	Side	Spin
11	Frustration	Yes	Yes	Round	Side	Front	Spin

Table 4 summarizes the entire statistical analysis conducted. Kicks with the same color indicate no significant difference among them and having the similar output value for a particular response variable. The kicks have been classified from best to worst for a dependent variable according to the least square mean values obtained from statistical analysis. Graph from figure 8 represents the overall average kilo calories consumed by all the participants for each type of kick.

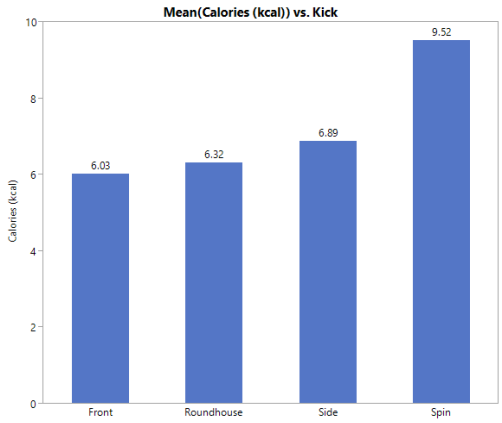


Figure 8. Mean Kcal consumption of Participants for each Kick

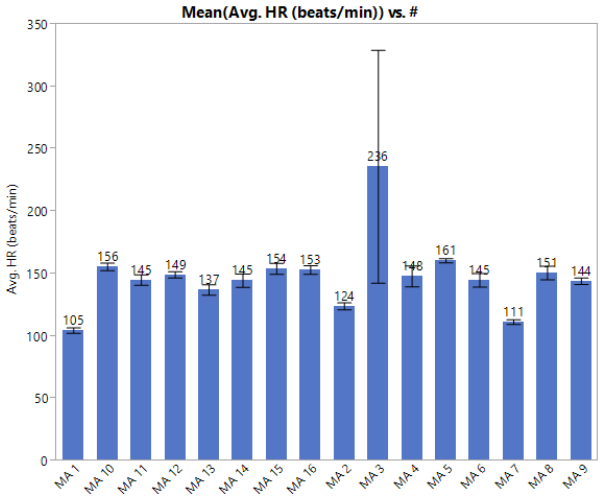


Figure 9. Mean of Avg. HR for each participant over 4 kicks

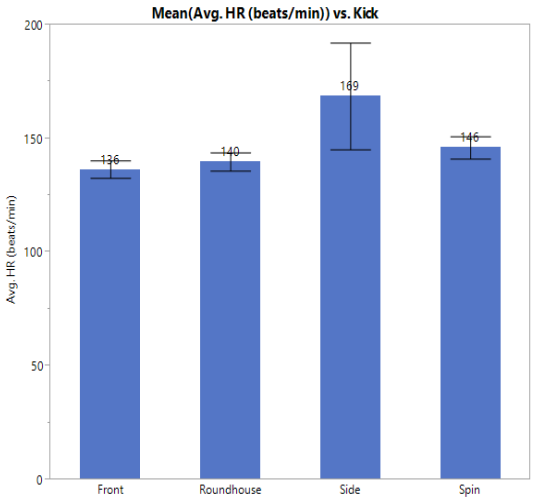


Figure 10. Mean of Avg. HR for each kick over 16 participants

The graph in figure 9 shows how much was the heart rate of each of the participant averaged over all the four types of kicks while the graph in figure 10 tells about the average heart rate all the 16 participants had for each type of kick.

Discussion

The factors that contribute to the performance in Martial Arts are mobility, power, speed and coordination factors (Katic, Blazevic, & Zagorac, 2010). The methods of measuring force, time and other dependent variables in this study is much different than the methods that have been used in other. However, even though the absolute values cannot be compared due to this difference, it is always instructive to compare the rankings or the order of the kicks obtained in this study for different variables with those obtained in other studies if they exist.

1) Kicking Force

The forces of the 4 kicks were significantly different from each other with Spin Kick and Side Kick having the highest force followed by the pair of Front and Roundhouse kick. Even though a kick with a larger force is better, it doesn't qualify as the best kick. Not all martial art forms allow hard hitting and instead focus on techniques. For instance, sport karate involves controlled sparring and knock out or drawing blood are not amongst its rules (Gibson & Wallace, 2004). International competitions of the Shotokan karate state that the fighters must control their kick at the point of impact to avoid injuring the opponent, which makes it essential for the attacker to brake the kick at the point of impact (Pozo, Bastien, & Dierick, 2011). The forms of Martial Arts that even allow knockout have very confined regions where the attacker is allowed to hit in order to win with a knockout. For example, in Taekwondo, a fighter could be able to win by a knockout is by kicking the opponents head or chest and nowhere else. This could be possible only by the elite athletes and participants with lesser experience rely heavily on points. Thus, even though front kick and roundhouse kick had a lesser force in comparison to spin and side kick, they had a considerable force to put the opponent at unease or cause minor injuries and at the same time stick to the rules of the bout. Around 80% of the

participants didn't prefer the front kick as their best kick yet they were kicking with a force approximately equal to the roundhouse kick. As compared to the Roundhouse kick which is a 'push' kick, a front kick is a 'snap' kick and its visible force and impression is lesser to that of a Roundhouse (Djurdevic, 2011). However, the impact of the front kick due to the snap could prove detrimental and of a greater intensity than that of a roundhouse kick if mastered.

Also the results of force were contrary to what Sung and Pieter had obtained in their respective studies on Korean National Taekwondo team and US Olympic Taekwondo team in which roundhouse had larger force than spin and side kick (Sung, Lee, & Joo, 1987) (Pieter & Pieter, 1995). The reason behind this was the difference in the type of targets on which the kicks were performed. The current study had a target that simulated the strength and hardness of the mid-section of the human body. A human body is a flexible structure, which deforms on impact unlike a heavy bag which more like a brick wall (Djurdevic, 2011). Due to this hardness there was a pull-back effect by the participants at the time of striking as a precautionary measure to prevent them from kicking with all the force they were capable of. The force of a strike is influenced by the technique, size and kind of the striking body part (Pedizch, Mastalerz, & Urbanik, 2006). As per this, the Roundhouse kick is hit with the instep of the foot, which has softer tissue as compared with the heel or the edge of the foot; areas used to perform the spin and side kick respectively.

2) Calories Consumption

From various literature, the average kcals consumption has been between 5 and 14.5 Kcals/min for various Martial Arts activities such as bouts, form practice etc. (Glass, Reeg, & Bierma, 2002). The average calorie consumption for each set of each kick in our study fell between this range since each set of 10 kicks lasted between 45 sec to 60 sec. Even the

kilocalorie consumption of every participant averaged over the 4 different sets of kicks fell in this range. Front, Roundhouse and Side Kick had a similar consumption of calories and were lower than the consumption of the spin kick for a set of 10 kicks. Front, Roundhouse and Sidekicks are performed directly from the defensive stance and do not require movement of legs. However, Spin requires a turn of 360 degree, which includes executing a kick while turning. This excessive movement results in higher calories consumption and could make the participant tired soon if used frequently as compared to the other kicks.

2) Force/Energy Consumed

The overall p-value by one-way ANOVA while comparing the lbs/kcal of the 4 kicks was 0.0325* which was significant but very close to 0.05 and Tukey's method revealed no pairs having a significant difference. Even though the overall force/energy consumed was different for the 4 kicks, no pairs were found having a significant difference. However, the p-values for pair wise comparison between Spin, Side and Front, Roundhouse was 0.99 which indicated that the two kicks in each of the pairs above were very similar to each other in terms of lbs/kcal consumed. Moreover, considering the least square means of each of kick, Side Kick and Spin kick had a similar natural log value of force/energy consumed which was 3.423 and 3.358 respectively while the pair of Roundhouse and Front kick had 2.87 and 2.83 respectively. Thus, Roundhouse and Front kick were more efficient than spin and side kick.

3) Average Heart Rate

The One-way ANOVA p-value was 0.8 which was very high and signified that there was no significant difference in the average heart rate between sets of different kicks. Figure 9 shows the average heart rate for each participant for the entire trial and figure 10 shows the

average heart rate for each type of kick. Considering %HRmax has been established in Taekwondo for different types of exercises for e.g. forms have 80% of HRmax, kicking and technical combinations with 90% HRmax and simulated dynamic sessions between 88.3-92.2% HRmax for experienced practitioner (Bridge, Jones, Hitchen, & Sanchez, 2007). The drill executed by the participants in this study was slightly simpler to the activities listed above and thus accounting that into consideration, the average heart rate obtained was acceptable. Thus, overall in terms of heart rate, all the kicks were at the same level and the difference between them was not statistically significant.

4) Kicking time

Several literatures out there state that velocity is the primary factor in measuring performance in Karate athletes (Katic, Blazevic, & Zagorac, 2010) & (Ravier, Digue, Grappe, & Rouillon, 2006). The spin kick had the slowest time per kick with a least square mean of 0.87 seconds for each kick followed by Side (0.74 sec), Roundhouse (0.64 sec) and Front Kick (0.64 sec). This result was similar to the results obtained by Pieter and Sung in their respective study with Roundhouse kick being faster (Pieter & Pieter, 1995) (Sung, Lee, & Joo, 1987). Even though statistical analysis resulted that there wasn't a significant difference between Side, Roundhouse and Front Kick, it can be estimated from least square mean values that front and roundhouse kicks were similar to each other in speed and faster than side kick. The front kick is a straight kick not requiring any turning movements, which makes it faster to execute. Roundhouse and Sidekick both require turning the body sideways but roundhouse is executed quickly due to the concept of Moment of Inertia and Torque. While performing the round house kick, the body is turned while one swings the leg. This increases the distribution of mass around the axis of rotation resulting into a higher moment of inertia and the swinging leg provides a

longer lever arm for generating the additional torque. This is not the case in Side Kick because while turning, the leg is in a bend position and the attacker is lifting his knees up which does not generate the additional torque or moment of inertia as observed in Roundhouse kick. Hence, the roundhouse kick turns out to be faster than side kick. The fact that spin kick involves a complete turn makes it the slowest kick.

5) Psychological demand

Mental toughness which relates to Psychological demand differs among levels of expertise in a specific martial arts form (Chen & Cheesman, 2013). In this study, all the participants had martial arts as their hobby and none of them were a full time athlete thus classifying all of them at the same level. This uniformity made the results more reliable. The psychological demand was measured in terms of Mental Demand, Physical Demand, Temporal Demand, Performance, Effort and Frustration.

Table 5. Participant preference ranking for each kick

Kick Type	**# of participants for a rank**				**Total**
	Rank 1	**Rank 2**	**Rank 3**	**Rank 4**	
Front	3	7	3	3	16
Side	1	6	8	1	16
Spin	1	0	3	12	16
Roundhouse	11	2	2	1	16

i) Mental Demand

Spin Kick had the highest Mental demand followed by Side, Front and Round. The Mental demand signified the mental effort that went into while performing the task such as

thinking, remembering, decision making etc. During the pre-trial survey line 11, the participants had to rank the 4 kicks from 1 to 4 in order of their preference for each of the kicks with 1 indicating most perfect and 4 indicating least perfect. The distribution of participants has been shown in the table above. From 16 participants, 12 participants gave a ranking of 4 for spin kick while 3 gave a ranking of 3. This indicated that the participants didn't prefer the spin kick from the beginning which must have resulted in an increase in the mental demand. Also, either rank 1 or 2 was marked by 7 participants for the Side Kick, 10 participants for Front Kick and 14 participants for the Roundhouse Kick. This order of preference was reflected on the outcome of the mental demand. Roundhouse kick is the most used kicks in Taekwondo competitions and athletes tend to focus a lot of time on it (Pieter & Pieter, 1995). Since 14 out of 16 participants were from Taekwondo style, this was the reason why the mental demand of the Roundhouse kick was lesser than that of the front kick. A proper focus and practice of the front kick will definitely lower the mental demand.

ii) Physical Demand

Physical demand measured the perception of the participants with regards to the physical effort they thought was being applied for the task. Front Kick had the least Physical Demand followed by Roundhouse, Side and Spin Kick. From the statistical analysis, the pairs of Front, Roundhouse and Side, Spin were not significantly different from each other. Per the way the kicks are executed, Front Kick requires the least amount of movement followed by Roundhouse, Side and Spin Kick. This reason must have resulted into the obtained difference in Physical Demand.

iii) Temporal Demand

The temporal demand was a measure of the time pressure that the participants felt while completing the task for example whether the task was relaxed or fast paced. The order of the kicks going from lowest to highest was Roundhouse, Front, Side and Spin Kick with Roundhouse, Front and Side kick not being significantly different from each other. Participants felt a higher temporal load for the spin kick and side kick because the kicks involved additional movements in comparison to front and roundhouse kicks. Apart from this as stated in table 5, 14 participants had 2nd or 3rd preference for the side kick while 12 participants had the least preference for the spin kick. This showed that since the participants were not good at these kicks in comparison to others, they felt the time pressure to keep their performance at par with the kicks they were good at. The performance variable below also reflects on this.

iv) Performance

Performance was a measure of evaluating how successful the participants felt about their task upon completion of a certain type of kick. The pair of Roundhouse and Front Kick had the best performance rating which was followed by Side and Spin Kick. The performance of the participants on Spin kick was by far considered as the worst. This was directly in conformation with the skill level of the participants marked for each type of kick and also the frustration level discussed further.

v) Effort

Effort indicated how hard the participants felt in completing the task and it was not significantly different for all the kicks. Since the participants had to perform the same number

of kicks of each type and their goal was to go as hard as possible in the least amount of time, this must have resulted in an equal effort for all the kicks.

vi) Frustration

As the term means, Frustration conveyed how aggravated the participant was while performing the task. It related to the performance ratings inversely. Since the performance of Spin kick was worst, the frustration involved with spin kick was highest. Another reason that contributed to the frustration of the participants was due to missing out on the targets. From the data, at least one spin kick from a set of 10 kicks would miss the target by every participant which must have added to the frustration. Roundhouse, Side and Front kick had a similar level of frustration.

6) Safety

According to a study done over a span of 5 years, Martial Arts is regarded as a safe sports as compared to other sporting activities such as football, wrestling, gymnastics, lacrosse, sledding, etc. because the amount of risk and the intensity of injuries is lower in the former (Birrer & Halbrook, 1988). However, leg injuries do happen because of the frequent use of kicks since they are more powerful than punches and yield more points. The most common areas of leg injuries are on the instep or the shin on coming in contact with the opponent's boney parts such as hips, elbow or forearm (Macan, Bundalo-Vrbanac, & Romic, 2006). Amongst the 4 kicks, the participants did express their concern about the roundhouse kick since the target was harder than what they were used to and also the roundhouse kick is struck with the instep which is softer than the other striking parts of the foot. The ones that failed to judge the hardness of the target well enough ended up controlling their kick considerably for the

remainder of the set. The data collected from the pain scale survey showed that mostly all kicks were safe overall since none of the participants had a higher rating for pain at any location. A majority of the areas marked were the portion of the foot that was striking the force sensor but that was within the no pain and moderate pain region. However, the roundhouse kick did receive a higher rating for the kicking foot where all 16 participants marked pain in their toes and instep which were between the moderate pain and extreme pain region. The reason behind this was that the instep being weaker than the heel, ball of the foot and the edge of the foot, which were the point of contact of the other kicks. This was also in lines with Macan's claim that the most common areas of leg injuries were the instep and the shin.

Limitations

The location of the study provided major constrains on the type of participants being recruited. Being in a college town gave the accessibility to only college going students who pursued martial arts as a hobby or as a means of exercise and were not professionals. Moreover, because the major on-campus club teaches Taekwondo, 14 out of 16 participants were from the Taekwondo background. This could influence the data to some extent because different forms sometimes have a different way of executing a particular kick. For example the Side Kick is performed with a more of snapping motion as compared to the Taekwondo Style of doing Side Kick (Pieter & Pieter, 1995). Another major limitation was the force and speed (time) measuring equipment. The cost factor prevented in collecting the exact value of force which could either be done by using a force sensor of a higher range that didn't require springs and could measure the absolute force. The time was measured manually using a stop watch from the recorded video whose accuracy could have been improved by using automated devices.

Conclusion

The eastern world has been well versed with Martial Arts for a long time now where as the western world has come across martial arts in the past 50 to 60 years. Forms and tournaments such as Ultimate Fighting Championship, Kick Boxing, Mixed Martial Arts have flourished in the past couple of decades. Considering the fast paced nature of fights and restricted nature of hard hitting, it is essential for an athlete to have the right selection of kick that will have the essential force, lesser time, lesser psychological demand, lesser energy consumption and most importantly safe. As discussed in the discussion section, the front kick and roundhouse kick were clear winners in almost all the categories except for the force generated. However, this is not significant since force obtained even for roundhouse and front kick, even though lesser than the spin and side kick, is enough to put the opponent at unease or injure them (Bir & Sandler, 2008). From the safety point of view, the Front kick proved better than the Roundhouse kick since the chances of the attacker being injured was least in the latter and also the participants displayed pain on their instep during the roundhouse kick. The front kick has a snapping nature has compared to the push nature of the other kicks to some extent. Even though the participants didn't have the front kick as their 1st preference and instead had the roundhouse kick at the top as mentioned in table 5, the overall results of both of them were similar. This clearly indicated that an equal emphasis and practice on the front kick as it is in the case of roundhouse kick would clearly make it better than the rest of the kicks. The fact that previous literatures never included the Front Kick during the comparison study clearly made it evident of the kick been neglected over the years. MMA fighters have also started incorporating this kick in their fights, which has resulted in knockouts due to its

disguised nature, and sudden impact. This was earlier considered as an 'unorthodox' kick in forms that practiced on heavy bags largely such as MMA and Kick Boxing (Djurdevic, 2011).

Hence, even though the front kick or the snap kick is not visually impressive and might look less powerful when seen, on mastering it could prove to a lethal weapon in the fighter's armor. As per saying "Old is Gold", this study will bring back the focus of different martial arts forms to the basics and make them revisit their combination techniques which they use in everyday practice. With the help of this study, they could also modify their training.

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CHAPTER IV
OVERALL CONCLUSION

With too much advancements or improvements, one generally forgets the basics and it is very essential to go back to the basics from time to time in order to remain on track since its said that ‘old is gold’. The conclusion of this study is on the same grounds. On comparing Front, Roundhouse, Spin and Side kick, the Front kick came out as the winner; the first kick that is taught to any martial art and eventually loses emphasis in the long run. Being a martial arts practitioner since the past 18 years, I myself have ended up neglecting the Front Kick and focused more on the newly techniques that were taught to me from time to time and were visually impressive. This study having proven the Front kick superior to the Roundhouse kick which is a kick that has been used a lot in competitions, etc. will help athletes and instructors to shift the focus on front kick and not neglect it. Very importantly, it will drop the injury rate in martial arts which occur due to leg injuries since athletes will be trained to have a proper selection of kick which have a lower risk of injury. This will eventually contribute towards a safer environment to work.

APPENDIX A

IRB APPROVAL

IOWA STATE UNIVERSITY
OF SCIENCE AND TECHNOLOGY

Institutional Review Board
Office for Responsible Research
Vice President for Research
1138 Pearson Hall
Ames, Iowa 50011-2207
515 294-4566
FAX 515 294-4267

Date: 4/27/2016

To: Anupam Singh
221 S. Oak Ave. #25
Ames, IA 50010

CC: Dr. Richard T Stone
3004 Black Engineering
Dr. Michael Dorneich
3018 Black Engineering Bldg

From: Office for Responsible Research

Title: Analysis of Force, Metabolic Burn and Safety for Various Common Kicks in Martial Arts

IRB ID: 16-137

Approval Date:	4/27/2016	**Date for Continuing Review:**	4/4/2018
Submission Type:	New	**Review Type:**	Full Committee

The project referenced above has received approval from the Institutional Review Board (IRB) at Iowa State University according to the dates shown above. Please refer to the IRB ID number shown above in all correspondence regarding this study.

To ensure compliance with federal regulations (45 CFR 46 & 21 CFR 56), please be sure to:

- **Use only the approved study materials** in your research, **including the recruitment materials and informed consent documents that have the IRB approval stamp**.
- **Retain signed informed consent documents for 3 years after the close of the study**, when documented consent is required.
- **Obtain IRB approval prior to implementing any changes** to the study by submitting a Modification Form for Non-Exempt Research or Amendment for Personnel Changes form, as necessary.
- **Immediately inform the IRB of** (1) **all serious and/or unexpected adverse experiences** involving risks to subjects or others; and (2) **any other unanticipated problems involving risks** to subjects or others.
- **Stop all research activity if IRB approval lapses**, unless continuation is necessary to prevent harm to research participants. Research activity can resume once IRB approval is reestablished.
- **Complete a new continuing review form** at least three to four weeks prior to the **date for continuing review** as noted above to provide sufficient time for the IRB to review and approve continuation of the study. We will send a courtesy reminder as this date approaches.

Please be aware that IRB approval means that you have met the requirements of federal regulations and ISU policies governing human subjects research. **Approval from other entities may also be needed.** For example, access to data from private records (e.g. student, medical, or employment records, etc.) that are protected by FERPA, HIPAA, or other confidentiality policies requires permission from the holders of those records. Similarly, for research conducted in institutions other than ISU (e.g., schools, other colleges or universities, medical facilities, companies, etc.), investigators must obtain permission from the institution(s) as required by their policies. **IRB approval in no way implies or guarantees that permission from these other entities will be granted.**

Upon completion of the project, please submit a Project Closure Form to the Office for Responsible Research, 1138 Pearson Hall, to officially close the project.

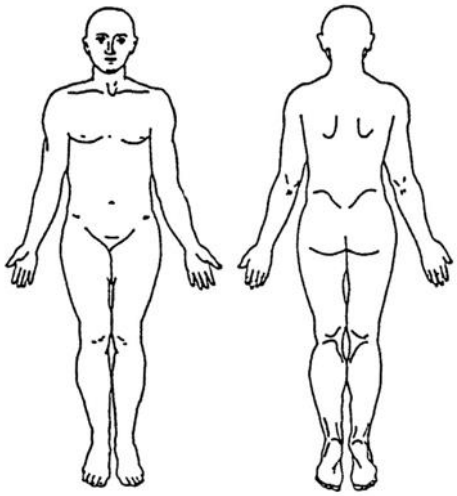
Please don't hesitate to contact us if you have questions or concerns at 515-294-4566 or IRB@iastate.edu.

APPENDIX B

PAIN SCALE SURVEY

Where is Your Pain?

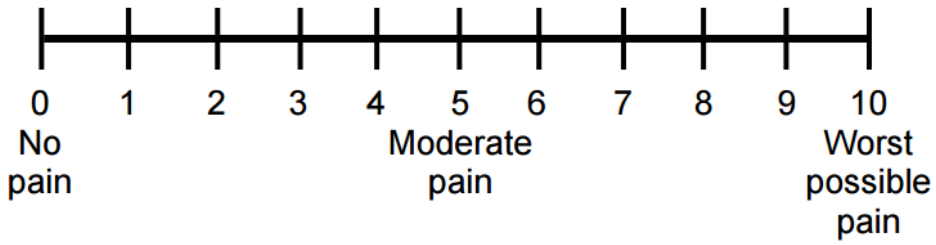
Please mark, on the drawings below, the areas where you feel pain. Write "E" if external or "I" if internal near the areas which you mark. Write "EI" if both external and internal.



Reprinted from *Pain*, Vol 1, Melzack R, The McGill Pain Questionnaire: major properties and scoring methods, 277-299, Copyright 1975, with permission from the ***International Association for the Study of Pain.***

Now for each of the areas listed about in which you are experiencing a pain, rate it according to the scale below

0–10 Numeric Pain Rating Scale



Reprinted from Pain: Clinical Manual, McCaffery M, et al, P. 16, Copyright 1999, with permission from Elsevier.

(Melzack, 1975) & (McCaffery & Pasero, 1999)

APPENDIX C

NASA TLX SCALE

NASA TLX SCALE

NASA-TLX Workload Scale Instruction

There are two ways to assess the effectiveness of decision support tools and their related tasks. One method is to gauge performance using accuracy scores and response time measures. The second method is to consider the perceived level of workload. Your performance will be measured using both methods throughout the experiment. In order to measure your subjective workload, you will be asked to fill out a NASA Task Load Index (NASA-TLX) at the end of all trials.

The section of the NASA-TLX that you will complete consists of six rating scales. Each scale represents an individual workload descriptor: mental demand, physical demand, temporal demand, performance, effort, and frustration. **Place an 'X' along each of the six scales indicating the place along the index that best describes your workload for the trial immediately preceding the administration of the rating scales.** Be sure to note the descriptions associated with each of the scales. Performance has "good" on the left and "poor" on the right, while the rest of the scales have "low" and high" as endpoints. Accompanying the ratings scales is a description of each of the measures. Read the descriptions in order to familiarize yourself with the meanings of the workload descriptors.

- **Mental Demand** – how much mental effort is required to perform the task (e.g., thinking, deciding, remembering)
- **Physical Demand** – how much physical effort is required to perform the task (e.g., pushing, pulling, reaching, stretching)
- **Temporal Demand** – how much time pressure you feel to complete the task (e.g., relaxed pace or fast and furious?)
- **Performance** – how successful you feel you are in completing the task
- **Effort** – how hard you work to complete the task
- **Frustration** – how aggravated or annoyed versus secure or content you feel about accomplishing the task.

Example:

Mental Demand

NOTE: When completing the NASA-TLX rating sheet, consider *only* the immediately preceding scenario. Specifically concentrate on the level of workload you experienced in completing the tasks involved.

NASA-TLX Workload Questionnaire

Instructions: Place an 'X' along each of the six scales indicating the place along the index that best describes your workload *only* for the trial immediately preceding the administration of the rating scales. For a description of the six rating scales, please review the description on the previous page.

Mental Demand

Physical Demand

Temporal Demand

Performance

Effort

Frustration

(Human Performance Research Group (NASA), 1986)

APPENDIX D

PRE-TRIAL SURVEY

PRE-TRIAL SURVEY

Analysis of Force, Metabolic Burn, and Safety for Various Kicks

1) Participant #: _____ (To be assigned by PI or CO-PI)

2) Age: ____ 3) Height: _____ 4) Weight: _____ 5) Sex: M / F

5) Experience: _____

6) Dominant Leg for :
i) Front Kick: LEFT / RIGHT
ii) Round House Kick: LEFT / RIGHT
iii) Side Kick: LEFT / RIGHT
iv) Spin Kick: LEFT / RIGHT

7) Length of Each Leg: Right: _____ Left: _____

8) Approximate Horizontal Reach: _____

9) Martial Arts Style: _____

10) Current Martial Arts Belt: _____

11) Rank the kicks according to your preference
(number them from 1 to 4 with 1 being the most perfect)
Front Kick: ___ Round House Kick: ___ Side Kick: ___ Spin Kick: ___