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Information Article

Comparative Biomechanical Analysis of Dollyo-Chagi Head Strike Kinematics Across Variable Combat Distances in Taekwondo Athletes

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ABSTRACT

Research Objectives:

1. Identify selected biomechanical variables of the front roundhouse kick across long and short inter-combatant distances in Taekwondo.
2. Compare selected biomechanical variables, motor response time, and strike intensity (impact force) of the front roundhouse kick between long and short distances between the athlete and opponent in Taekwondo.

Methodology:

The researcher adopted a comparative repeated-measures design suited to the nature of the research problem. The study population comprised senior athletes of the Iraqi National Taekwondo Team across first, second, and third tiers (N = 24). The research sample consisted of (n = 15) athletes selected purposively, representing 62.5% of the total target population.

Conclusions:

1. Inter-combatant distance plays a pivotal role in modulating biomechanical variables, motor response latency, and impact intensity.
2. For offensive maneuvers, executing the front roundhouse kick from short range is preferable via momentum transfer rather than proximal-to-distal kinetic chaining (whip-like energy transfer). This execution—characterized by tighter foot and approach angles, a shorter curvilinear trajectory, and elevated angular velocity—yields high strike speed with minimized motor response time to secure three technical points.

Recommendations:

1. Athletes should systematically train strike executions across all operational distances, tailoring mechanics to specific tactical goals (minimizing motor response latency versus maximizing terminal impact force).
2. Optimal conditioning protocols for the front roundhouse kick should allocate greater training volume to dynamic boundary conditions—such as explosive ground reaction propulsion, preparatory chambering phases, engagement ranges, and reactive motor response times—while reducing time spent on aerial static kicking phases (the hallmark of traditional Eastern martial arts instructional paradigms).

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Introduction and Importance of the Research:

Taekwondo, of Korean origin, is an individual competitive sport and the only Olympic martial art. It was officially introduced in the 2000 Sydney Olympic Games (Falco et al., 2009, p. 242). This sport relies on attack, defense, and counter-attack, and the competitor who scores the most points in a match or wins by knockout is the winner.Since Taekwondo is a contact sport, the distance between the two competitors constantly changes according to the competition conditions. In both attack and counter-attack situations, the athlete must execute the kick with the fastest motor response and sufficient impact force to score points from varying distances from the opponent.

The importance of this research lies in the kinematic analysis of some biomechanical variables of the front roundhouse kick (Dolio Chaki) at different distances from the opponent (long and short). This analysis aims to achieve optimal technical performance based on the athlete's proximity to the opponent, leading to positive results that will help players improve their performance in the front roundhouse kick, thus contributing to the development of Taekwondo in Iraq. Research Problem:

In Taekwondo competitions, each athlete determines the distance for executing kicks based on their leg length, which is considered their fighting distance. However, athletes must adapt during matches and perform the front roundhouse kick from shorter or longer distances than the stated distance. This will affect the technique and speed of the kick (Estevan, 2011, p. 2851).

Based on the researcher's experience as a former Taekwondo player with extensive experience in participating in and following local and Asian championships in martial arts in general, and Taekwondo in particular, the researcher observed that the distance between the player and their opponent significantly influences the biomechanical variables, reaction time, and impact force of the forward roundhouse kick to the head.

Research Objectives:

1- To identify some biomechanical variables of the forward roundhouse kick at long and short distances between the player and their opponent in Taekwondo.

2- To compare some biomechanical variables, reaction time, and impact force of the forward roundhouse kick at long and short distances between the player and their opponent in Taekwondo.

Research Hypothesis:

There are statistically significant differences between the biomechanical variables, reaction time, and impact force of the forward roundhouse kick at long and short distances between the player and their opponent in Taekwondo.

1-4 Research Scope:

1- Human Scope: Players of the Iraqi National Team in the advanced category of Taekwondo. 2- Spatial Scope: The indoor hall of the Baghdad Sports Center

3- Temporal Scope: April 17, 2025 to July 25, 2025

2- Research Methodology and Field Procedures

Research Methodology: The researcher used the comparative method with repeated measurements, as it is suitable for the nature of the problem.

Research Sample and Population: The research population is the Iraqi National Taekwondo Team for advanced players (first, second, and third ranks), totaling (24) players. The research sample consists of (15) players, selected purposively. Thus, the percentage of the research sample is 62.5% of the original population.

Journal of Sports Sciences
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Sample homogeneity:

Table (1) Homology of the research sample in terms of age and anthropometric measurements

Statistical indicators Variables	Units of measurement	arithmetic mean	standard deviation	The mediator	Torsion coefficient	Flattening
Chronological age	year	21,400	2.028	21.00	0.256	0.816-
Training age	year	10.533	2.065	10.00	0.731	0.231-
Mass (apparent (weight	kilogram	74,400	3.641	74.00	0.376	0.795-
height	centimeter	184,200	3.609	185.00	0.649-	0.335
man's height	centimeter	91,600	2.947	91.00	0.898	0.754

Table (1) shows the arithmetic mean, standard deviation and median for the variables (age, training age, mass, height, leg length) that are related to the research. The table shows that the values of the skewness and flattening coefficient are between (±1), and thus the research sample is homogeneous in the mentioned variables.

Equipment and Tools Used:

1- Two (2) Samsung Galaxy Note 9 mobile phone video cameras (Korean made) with a speed of 120 frames per second.

2- One (1) tripod camera stand and a specially designed 4-meter vertical camera stand for shooting from above.

3- A Mega Strike device for measuring the strength and response time of motor movements.

4- One (1) fixed ground punching bag.

5- Kinovea 0.9.5 motion analysis software.

Pilot Experiment:

The researcher conducted the pilot experiment on Wednesday, April 16, 2025, with a sample of three (3) players from the Iraqi national team at 3:00 PM in the Baghdad Sports Center.

Field Experiment (Main Experiment):

The main experiment was conducted on the research sample on Thursday, April 17, 2025, at 3:00 PM in the indoor hall of the Baghdad Sports Center by the researcher and the assisting team.

1- Players: The experiment was conducted on 15 players, and the right leg was used to perform the forward roundhouse kick.

2- Cameras: **a- Side Camera**: It was mounted on a tripod at a height of 110 cm, 4 meters away from the player's position and perpendicular to it.

b- Vertical Camera: It was mounted from above using a specially designed stand, 2 meters away from the player's position and 4 meters away, perpendicular to the player's position.

3- Phosphorescent Markers: Phosphorescent markers were placed on the players' joints, including the shoulders, elbows, hands, knees, and ankles.

4- Mega Strike Machine: The machine was mounted on a water-based floor punching bag and positioned at a height of 140 cm, measured from the bottom of the machine, with the center of the active area of the machine at a height of 175 cm, at all distances.

5- Distances between the Player and the Machine: Based on the researcher's experience, two distances were determined between the player and the machine, using leg length plus foot length, as follows:

Long Distance: Leg length + Foot length.

Short Distance: One-third of the leg length + Foot length.

Journal of Sports Sciences
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(Falco, Molina-García, Alvarez, Castillo, & Estevan, 2013, p. 4)

6- Execution of the Kick: The players were asked to perform the forward header (Dailo Chake) with the correct movement and according to each player's technique. After warming up and practicing some kicks, each player was given three attempts to perform the forward header at both distances (long and short). The device readings of reaction time and stroke intensity were recorded. Then, the best attempt for each player at each distance was selected based on reaction time, i.e., the kick with the shortest reaction time was chosen. See Figure (1).

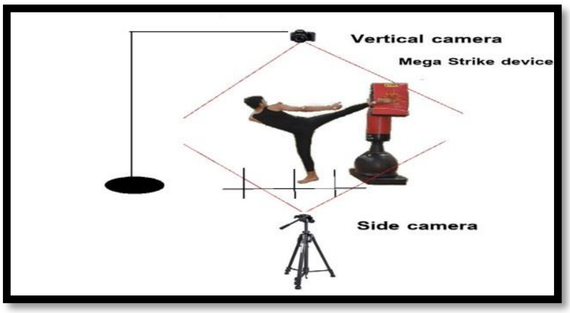

Figure (1) Illustrates the experimental field

Biomechanical intervention:

The forward position of the support at the start of the movement: This is the angle of the imaginary line parallel to the inner edge of the support foot with the angle of the imaginary line at the start of the movement. (Stefán et al., 2011, 3)

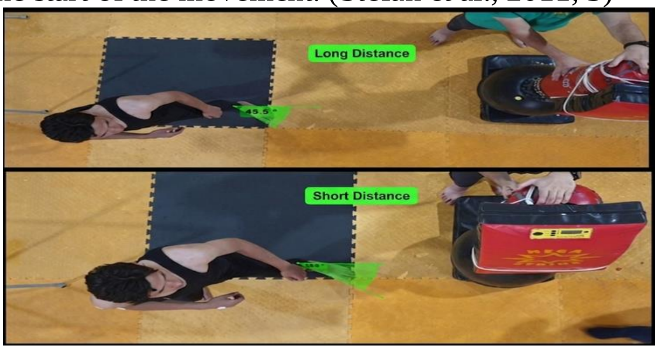

Figure (2) illustrates the angle of foot movement

Angle of attack (thigh): This angle can be determined by the imaginary line connecting the hip joint to the knee joint and the imaginary horizontal line at the moment of raising the knee in front of the body and the beginning of extending the knee joint. (Amin, 75, 2014)

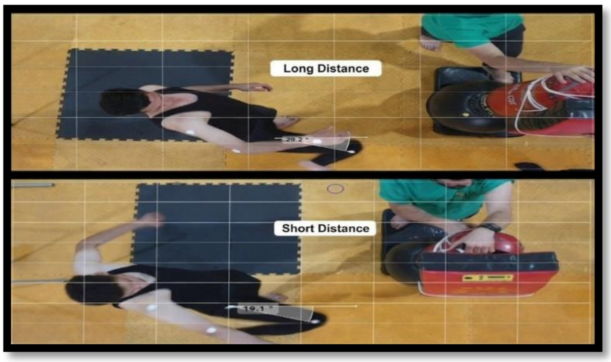

Figure (3) illustrates the angle of attack

Journal of Sports Sciences
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Journal Homepage: https://pessj.uodiyala.edu.iq

Vertical axial displacement of the hip: This is the linear movement along the longitudinal axis of a part of the body or the entire body, and it is measured as a vertical movement such as the difference in height of the player's center of mass from the beginning of the movement until the moment of impact with the apparatus. (Knudson, 2007, p. 167)

Figure (4) Vertical axis displacement of the hip

The angular velocity of hip rotation: It is the rotational movement of the joint, and the angular velocity of hip rotation is measured by dividing the radial angle (the line connecting the hip to the knee (thigh) of the striking leg from the beginning of the movement to the moment the knee rises in front of the body before extension) by its time through the following relationship: (Amin, 76, 2014)

Angular velocity = Radial angle (sector) / Time (seconds)

(Mardan and Abdul Rahman, 64, 2011)

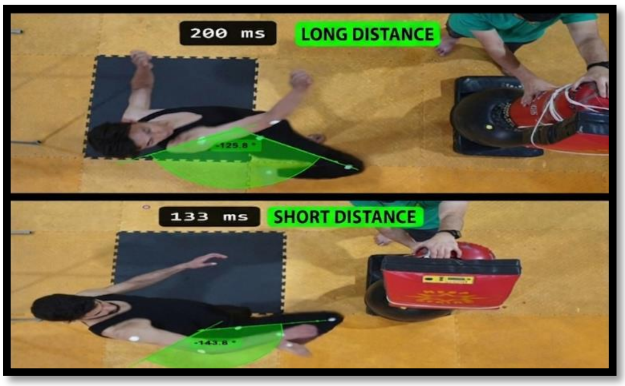

Figure (5) Angular velocity of hip rotation

Hip torque: This is the amount of rotational force that changes the angular state of an object (breaking its rest or changing its angular velocity). Hip torque can be measured from the start of the kicking leg's movement until the moment it strikes the device, according to the following formula: (Hill, 2014, 550) See Figure (6)

Torque = Moment of Inertia × Angular Acceleration (N·m)

- The radius is measured from the hip joint to the center of mass of the part, and was measured using a camera.

- Mass is calculated as the percentage of body mass for each part: Thigh mass 10.3%, Leg mass 4.3%, Foot mass 1.5% (Abdul Rahman & Issa, 122, 2022).

Moment of inertia = Thigh moment of inertia + Leg moment of inertia + Foot moment of inertia.

- Angular acceleration = Angular velocity^2 – Angular velocity^1 / Time (sq/s^2).

- Torque = (Max × r^2) × (Angular velocity^2 – Angular velocity^1 / Time).

Journal of Sports Sciences
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Journal Homepage: https://pessj.uodiyala.edu.iq

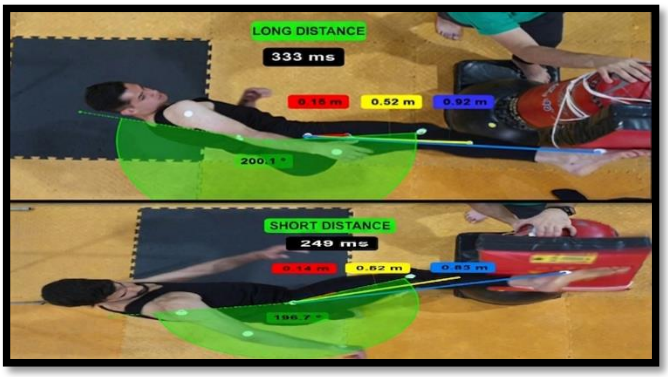

Figure (6) Illustrates the torque of the femur

Angular momentum of the striking man: It is the quantity of angular motion that the body obtains and is extracted through the following equation: (Amin, 77, 2014) See Figure (7)

Angular Momentum = Moment of Inertia × Angular Velocity (Al-Khalidi and Al-Amiri, 2010, 102).

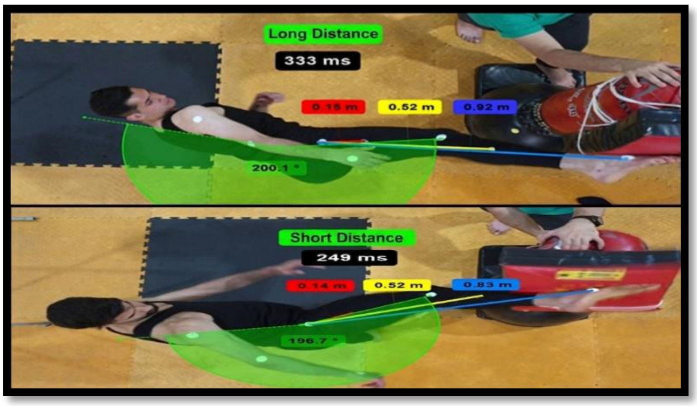

Figure (7) Angular Momentum

Response speed and impact intensity: The kinetic response time and impact force are extracted through the (Mega Strike) device, where the response speed time is recorded in seconds and the impact force is unitless.

Figure (8) Mega Strike device

How the Device Works:

The player stands in front of the device in a ready position to perform the movement to be measured. The (Reaction) button is pressed once to measure both force and timing. The device emits an audible signal. Then, the (Reset) button is pressed, and a dashed line (----) appears on the display screen. The device then emits a long beep (random duration between 4-8 seconds). Upon hearing the beep, the player strikes the device at

Journal of Sports Sciences: Volume 18, Issue 69, September 2026

Journal of Sports Sciences
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Journal Homepage: https://pessj.uodiyala.edu.iq

the active area (star and text) with maximum force and speed. The device can be struck with the fist, elbow, foot, or knee.

Statistical Methods:

The researcher used the statistical package (IBM SPSS Statistics 25).

3- Presentation of the results of the Paired Samples T-Test between the biomechanical variables of the forward roundhouse kick over long and short distances.

Table (2) shows the arithmetic means, standard deviations, and significance of differences between the biomechanical variables of the front circular kick in long and short distances.

T	Variables	Unity	The long one		Short		T test		Significance
			S	A	S	A	Calculated	sig	
1	foot angle	degree	50.01	3.90	28.28	3.61	15.82	0.000	moral
2	attack Angle of	degree	32.36	2.66	20.40	6.21	6.84	0.000	moral
3	axial Hip displacement	poison	20.25	1.36	15.01	1.93	8.56	0.000	moral
4	angular velocity	Sector/ Th	11.42	1.24	14.62	1.40	6.62-	0.000	moral
5	torque	Newton.m	206.20	6.17	147.33	8.15	22.28	0.000	moral
6	Angular momentum	kg.m² / s	18.10	1.38	21.30	1.58	5.89-	0.000	moral

- **The significance level is less than 0.05; the correlation is significant.**
- **Degrees of freedom = 30 – 2 = 28**

Foot Angle at Kick Start

Table (2) shows significant differences in the starting foot angle of the kick between long and short distances. The researcher attributes this to the fact that the smaller the starting foot angle, the shorter the reaction time and the less force involved. Since time is more important than force in Taekwondo rules, headgear sensors allow for scoring three points for a forward roundhouse kick to the head with a minimal force (1 bar = 10 N/cm²), a very low value.

Attacks in standing positions with a greater load on the front foot during the kick are executed faster than those with equal load on both feet. Therefore, it appears that standing positions at a 90-degree angle are not as suitable as standing positions at a 45-degree angle. Athletes in positions ranging from 0 to 45 degrees performed forward roundhouse kicks with less execution time compared to those in a 90-degree position. (Estevan et al., 2013, p. 217)

Angle of Attack

Table (2) also shows that there are significant differences between the angle of attack at long and short distances. The researcher attributes this to the fact that the smaller the angle of attack, the smaller the arch of the foot, resulting in a shorter reaction time but less impact force.

This is what Amin (2014) indicated: that a player performing a forward spin kick at a large angle of attack gains the appropriate acceleration in the striking leg, thus increasing the power of the kick at the expense of its time. (Amin, 2014, p. 107)

This was also mentioned by Górski. Orysiak: "A greater distance allows the athlete to accelerate the limb for a longer period to obtain greater impact force at the expense of its time" (Górski, Orysiak, 2019, p. 196).

Hip Vertical Axial Displacement

In Table (2), it is evident that there are significant differences between the hip vertical axial displacement in long and short distances. The researcher attributes this to

Journal of Sports Sciences
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Journal Homepage: https://pessj.uodiyala.edu.iq

the fact that the lower the hip vertical axial displacement on the longitudinal axis, the lower the motor response time. In short distances, the athlete is very close to the target, and the forward hip movement is minimal, but its vertical and rotational movement remains very important. Early initiation of the explosive hip movement is an important reason for reaching the target (head) in the shortest time. This is what Ervilha et al. (2018) indicated: "The large magnitude of explosive force in the preparation phase obtained by elite athletes can be explained by moving the hip earlier than lower-level athletes." Ervilha, Fernandes, Souza & Hamill, 2018, p. 11)

Hip Angular Velocity

Table (2) shows significant differences between angular velocity over long and short distances. The researcher attributes this to the athletes' ability to utilize the close distance to the target to increase the efficiency of knee and hip flexion and reduce the radius of rotation. This minimizes the pelvic rotation arc, thus reducing the negative impact of inertia, which hinders angular movement at the start of the kick. Furthermore, the athlete benefits from the appropriate explosive ground thrust when kicking from close range to increase knee angular velocity and execute the kick with the shortest possible reaction time.

Torque

Table (2) shows significant differences in torque between long and short distances. The researcher attributes this to the fact that short distances don't allow the athlete to use a large mass, i.e., the torso, in executing the kick. Therefore, the focus is on the explosive preparatory phase, during which the athlete gains torque in the hip. This is an important factor, but even more crucial is maintaining and transferring this force from one part of the kicking leg to another. This is achieved through angular acceleration, which depends on increasing angular velocity and decreasing moment of inertia. The correct timing of flexing the knee and hip joints simultaneously plays a significant role in increasing angular velocity and reducing moment of inertia. This facilitates the execution of the forward spin kick with a highly coordinated near-far sequence.

Angular Momentum

Table (2) shows significant differences in angular momentum between long and short distances. The researcher attributes this to the fact that the players' technique for performing the short-distance kick relies on momentum transfer rather than energy transfer (the whip kick), using less mass. This allows them to perform the kick at high angular velocities of the leg joints in less time. "Moving a part of the body's mass, rather than the entire body, allows that mass to move faster. Therefore, achieving a shorter reaction time depends on moving the least possible amount of mass to accelerate the parts involved in the movement as quickly as possible."
(Vieten et al., 2007, p. 296)

Table (3) shows the arithmetic means, standard deviations, and significance of the differences between motor response time and impact force of the front circular kick at long and short distances.

T	Variables	Unit	The long one		Short		T test		Significance
			S	A	S	A	Calculated	sig	
1	Severity of the blow	-	100.466	5.59	74.466	12.03	7.58	0.000	moral
2	Motor response time	sec.	0.792	0.04	0.633	0.02	13.19	0.000	moral

Journal of Sports Sciences
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Strike Intensity

Table (3) shows significant differences in strike intensity between long and short distances, favoring the long distance. The researcher attributes this to the players' focus on producing a powerful and effective kick rather than a quick one in the shortest possible time—that is, transferring energy rather than momentum. This contrasts with the requirements of Taekwondo, where points are scored using sensors on head and body protectors. It's worth noting that the minimum pressure for scoring on head protectors is (1 bar), a very low value. Therefore, a long-distance kick could be used as a knockout punch in a counterattack where the opponent's defense is weak.

Similarly, the greater the distance from the target, the greater the angle of rotation of the pelvis. When the distance is long or the angle of attack is large, a longer path of attack is required, meaning the kick must be executed with a longer trajectory and arc than if the kick were executed with a smaller angle of attack. This results in greater speed and impact force (Liu et al., 2021, p. 35).

Regarding motor response time

Table (3) shows significant differences between motor response time at long and short distances, favoring the short distance. The researcher attributes this to the effect of distance; the closer the player is to the opponent, the shorter the motor response time for the kick. This was also noted by Diniz et al. (2018) when comparing karate and Muay Thai players: "Muay Thai players perform the forward roundhouse kick with a shorter response time than karate players because they kick from a short distance" (Diniz et al., 2018, p. 5). This is especially true in circular movements, where the closer the moving part is to the axis of rotation, the smaller the arc distance and consequently the time. This is further reinforced by the simultaneous flexion of the hip and knee to reduce moment of inertia and increase... Angular Velocity،This involves transferring angular momentum from the near end to the far end using a near-far sequence strategy.

4- Conclusions:

1- The distance between the player and the target plays a significant role in influencing biomechanical variables, reaction time, and strike intensity.

2- When attacking, it is preferable to use a short-range forward spin kick, employing momentum transfer rather than energy transfer using a near-far sequence (like a whip), with small foot angles and a shorter arc distance, and high angular velocity to achieve a fast kick and minimal reaction time, aiming for three points.

3- When counter-attacking, it is preferable to use a long-range forward spin kick, employing energy transfer rather than momentum transfer, with large foot angles and a longer arc distance, and high peripheral velocity to achieve a fast kick with high impact force (a knockout punch).

Recommendations:

1- Players should practice performing the kick from all distances, considering the characteristics of each distance and the objective: whether it is to achieve minimal reaction time or high impact force. 2. The optimal training program for the front roundhouse kick should allocate more time to the various aspects of the kick, such as the explosive ground thrust, the preparation phase, the distance of execution, and the reaction time, while spending less time on the aerial kick phase (which is the essence of the traditional training method in Eastern martial arts).

Journal of Sports Sciences
ISSN: 2074 - 6032 ISSN-e: 2710 - 5016
Journal Homepage: https://pessj.uodiyala.edu.iq

3. Conduct an experimental study to implement a training program based on biomechanical and ballistic exercises to develop the explosive power of the lower limbs and correlate it with the reaction time of the front roundhouse kick.

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