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Three-dimensional dynamic analysis of support leg performance in the Kazami Mawashi Giri Karate kick

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Abstract

Three−dimensional dynamic analysis of martial arts skills, especially the kazami mawashi giri Karate Kick, is important for understanding performance and preventing injuries. However, little research has focused on the movement of the supporting leg and the effect of player weight on it. Objectives: The study aimed to investigate the three−dimensional movement of the supporting leg joint during the performance of the karate players' kick in light and heavy weights, with the identification of dynamic differences related to weight. Research Methodology: The researchers selected elite karate players (12 lightweight and 12 heavyweight players) who performed the maximum kazami mawashi giri kick towards the target. A three−dimensional motion capture system consisting of 10 cameras (240 Hz) and a ground−mounted force platform was used. Results: The results showed that heavyweight players leaned significantly more ankle during the first stage (preparatory), while lightweight players showed a wider range of ankle tilt during the second stage (hitting the target).

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1- Definition of research

1-1 Introduction and importance of the research:

(Kazami Mawashi Geri) Three-dimensional dynamic analysis of martial arts skills, especially the semicircular front kick, is important for understanding performance and preventing injuries. However, little research has focused on supporting leg movement and the effect of player weight on it. The supporting leg plays an effective role in achieving balance, transferring strength, and stabilizing the body during kicks, as the angles of the joints affect the distribution of body weight on them and thus the performance of the skill in particular. (Alsaeed, 2018) (Shenein, et al. 2019)

The importance of research: The importance of research in filling the gap of the lack of research related to the analysis of the movement of the supporting leg and the effect of body weight on it, especially in individual combat sports, including karate, which depends on dynamic balance and explosive power. Previous studies have shown that heavyweight players suffer from increased load on the joints of the supporting leg during performance, which may lead to injury to the ankle, knee, or thigh joint. On the other hand, lightweight players have greater flexibility in joint movement, enhancing their performance in kick-taking. (Abd Alkareem), at el,. 2023)(Alsaeed, 2017)

In addition, this study provides clear and practical insights for coaches and players to design special training programs for each category, which may improve performance or reduce injuries, and this is what the study indicated (Cynarski, et al., 2018) (pal, et al., 2020).

Therefore, this study contributes to increasing the scientific understanding of the mechanical factors associated with the performance of the kick of the Kzami Livestock Kerry. With a focus on the position of the supporting leg for players of different weights. It will also provide a basis for the development of science-based training strategies. This enhances athletic performance and reduces the risk of injuries in karate. (Witte, et al., 2007).

1-2 Research issue: Karate players use the Kazami mawashi giri kick largely due to it is an effective offensive skill, but there is still a lack of thorough understanding of the dynamic factors that affect its effectiveness. Especially about the role of the supporting leg during different weight distribution areas. Previous studies have focused on the striking leg in terms of motion mechanics. The leg contribution to balance and stability, as well as the transfer of force during kick performance, was often neglected. Furthermore, the relationship between biomechanics of the lower limbs and successful scoring points. They are not fully clarified. This issue reduces the ability of coaches and players to develop training programs tailored to individual players' skills, such as a weight clause. Therefore, this study focused on identifying and measuring the weight difference and its effect on support leg joints through a three-dimensional analysis of joint mechanics during kicks between light and heavy-weight karate players, and understanding how these biomechanical differences relate to performance outcomes and effective scoring. This study aims to enhance the comprehensive understanding of the movement of the supporting leg joints and the prevention of injuries during performance for karate players.

1-3 Research Objectives:

1-Three-dimensional kinetic analysis (3D) of the supporting leg joints (hip, knee, and ankle) during the execution of a kick as a livestock by karate players.

2- Comparison of the angles of the leg joint, angular speeds, and range of motion between karate players, light weight (55-60-67 kg) and heavyweight (75-84+84 kg), through the stages of the kick (first stage: knee bending and second stage: hitting the target).
3- Identify biomechanical differences related to weight division that may affect balance and stability during kick performance.
4- Provide vital mechanical insights through which special training strategies can be implemented, each according to their weight, aimed at improving the effectiveness of the kick and reducing the risk of injury in karate practitioners.

1-4 Research Hypotheses:

1- There are significant differences in the movement of the three-dimensional choke joints (hip, knee, and ankle) between light and heavyweight karate players during the performance of the kick of Kazami Zuki.
2- Lightweight players show greater knee flexion angles and angular velocities in the supporting leg during the knee bending stage (first stage) compared to heavyweight players.
3- Heavyweight players show more ankle inclination in the supporting leg during the knee flexion stage (first stage) compared to lightweight players, reflecting a strategy to enhance joint stability.
4. During the target hit phase (second stage), lightweight players show a wider range of ankle tilt and hip rotation in the supporting leg compared to heavyweight players, indicating greater movement and dynamic balance control.

1.5 Research fields:

Human field: Karate club players in Basra
Timeline: 25/01/2025 to 10/04/2025
Spatial field: Sports hall in the Faculty of Physical Education and Sports Sciences.

3- Research Methodology and Field Procedures:

3-1 Research Methodology: The experimental method was chosen to suit the nature of this study and to measure the variables practically within the laboratory.
The study determined to conduct specific tests on the leg supporting the front semicircular kick (Kazami Mawashi Kiri) with three-dimensional imaging of the research sample of karate players according to special criteria, and they were divided into two groups of light and heavy weight to perform the required kick in two stages:
The first stage (knee flexion): from the standby position to the maximum bend of the knee.
The second stage (hitting the target) is from the maximum bend to the contact with the target.
3.2 Research Sample: 24 players (12 lightweight and 12 heavyweight) were deliberately selected from the national teams.
3.3 Selection Criteria:
1- More than five years of competitive experience (participation in tournaments)
2- The leading leg is the right leg (striking leg)
3- There have been no injuries to the lower extremities in the past six months.

3.4 Devices used:

A three-dimensional motion capture system using 10 cameras with a shooting speed (240 Hz) to smooth the speed of kick performance, distributed according to the need of researchers to photograph all angles of movement with 54 reflective marks placed on all joints of the body to form a skeleton of the player's body.
2- Force Platform: 2 simultaneous force platforms (1200 Hz) were used to collect movement data.

3- Target: Medium-sized racket with a height of 1.2 meters
4. Visual 3D mechanical modeling software was used (figures 1 and 2)

Figure 1: Front view of the skill steps on the force plates

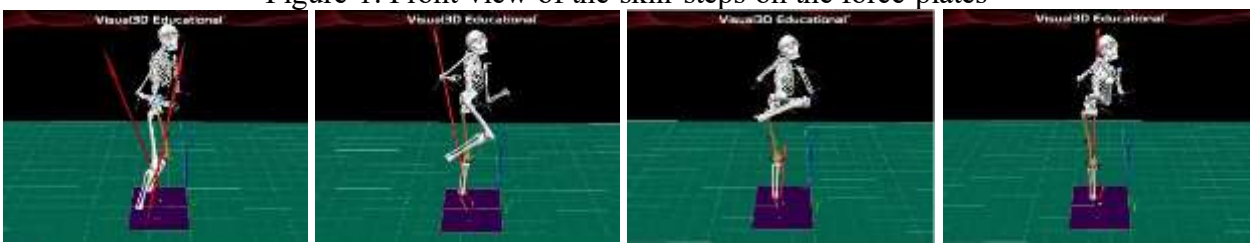
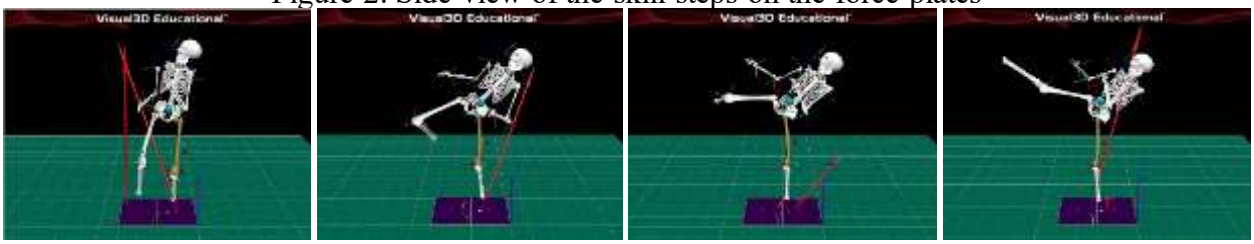


Figure 2: Side view of the skill steps on the force plates



3.5 Field research procedures:

Warm-up: A stretching routine of uniform stability and movement for 15 minutes.
Reflective marking: Reflective markings were placed on the leg's joints to be tracked by cameras.
VICON Calibration: A static experience was recorded in a standing position according to the requirements of the three-dimensional imaging system.

3.6 Test Performance Method:

1- Each player (5) takes kicks at maximum speed and force on a fixed target (racket) at a distance of 1.5 meters.
2- Voice Command: (Attacked) in Japanese, and means the beginning of the attack.
3- Rest periods: The player is given 90 seconds to prepare for the second kick.
Data and calculation of XYZ joint angles were collected by Visual 3D from the moment the knee began to bend.
Calculated: 1- Maximum inclination of the ankle joint 2- Knee flexion and extension / angular velocity, 3- Hip rotation range in and out.

3.7 Statistical means:

The data was processed using the statistical program SPSS

4- Presentation and discussion of the results:

1- Heavyweight players showed maximum ankle inclination during the first stage (significance level 0.01), Table 1. Figure 1
2-Lightweight players showed greater ankle tilt during stage two (significance level 0.03) Table 1. Figure 1
3-Knee flexion angles and speeds are significantly higher in lightweight players during the first stage (significance level 0.001), Table 2. Figure 2
4-The inner and outer hip rotation field and speed were moderately greater in lightweight players during the second stage (significance level 0.05). Table 2. Figure 2
Angular displacement curves show greater ankle leaning in heavy weights during the first stage and greater inclination range in light weights during symmetrical angular velocities. The most important findings and discussed are: ankle tilt significantly in heavy weights during the first stage, with previous research indicating that heavier players tend to rely on increased joint stability to

control reaction forces (Lee et al., 2020) (Riyadh, at el,. 2023). This is also likely to enhance the inclination to medial-lateral support, compensating for the increased inertia associated with higher body mass. Conversely, lightweight players showed more scope than ankle tilt during the second stage, suggesting increased ankle mobility that may facilitate dynamic balance while hitting the target, consistent with their findings (Durgham, at el,. 2024) (Kim, at el,. 2018)(Al-Saeed, 2018; Al-Saeed & Pain, 2017) Table 1. Figure 1

On the other hand, the significantly knee flexion angles and angular velocities of lightweight players during the first stage indicate a strategy that emphasizes elastic energy storage and rapid joint stretching, reinforcing the theory of reducing the stretch period in kick biomechanics (Alsaeed, at el,. 2025) (Cheng, et al., 2019)(Alsaeed et al., 2024). Low knee flexion may reflect heavy weights as favoring joint stability over maximum elastic recoil, due to their increased mass and altered neuromuscular control. At the same time, hip rotation variations, while moderate, suggest lightweight players use greater rotational motion to enhance kick speed and accuracy, as noted from previous three-dimensional analyses (Smith & Jones, 2021)(Alsaeed, 2014; Yaseen & Alsaeed, 2022). Table 2. Figure 2

These confirm the results of this study by comparing them with previous studies that separately examined the mechanics of the lower limb joints in karate kicks. While the earlier work focused mainly on the strike leg (Lee et al., 2017), this study highlights the significant role of the support leg, particularly in the process of balancing and transferring strength to all different weight classes. The integration of three-dimensional motion with its phase analysis also provides more accurate matching between kick performance stages. Overall, each weight has its strategic approach to scoring points, and neither speed nor strength is superior. The lightweight players prefer speed to get points because they have these skills, and their body is ready to do it, but the heavyweight players cannot do it as others do; they prefer their way and what their body is designed to do in the best way.

This study was on a limited sample of karate players who were distinguished by kicking with the right leg, which may limit generalization to all karate practitioners who use the left leg as a leading leg, as well as the rest of the martial arts. Also, tests in a private laboratory or hall do not definitively represent what happens during the actual competition. On the other hand, muscular activity during kick performance is not addressed, which enhances understanding of performance in terms of neuromuscular coordination.

Table 1: Shows the average joint angles (SD±) of the supporting leg during the first stage (knee bending) and the second stage (hitting the target) with the performance of the front semicircular kick (Kazami Mawashi Kerry) for both light and heavy weight players.

Effect size between the two groups	Significance level P-value	Standard deviation of heavyweight	Average heavyweight	Standard deviation of lightweight	Medium light weight	Stage	Joints
1.48	<0.01	6.03	44.86	5.12	36.29	1	Maximum ankle tilt (°)
0.93	0.03	4.21	18.83	3.87	22.45	2	Ankle tilt range (°)

2.05	**<0.001**	**6.89**	**41.55**	**7.34**	**55.68**	**1**	**Knee bending angle (°)**
0.88	**0.04**	**3.65**	**11.47**	**4.11**	**15.12**	**2**	**Hip rotation range in and out (°)**

Figure 1

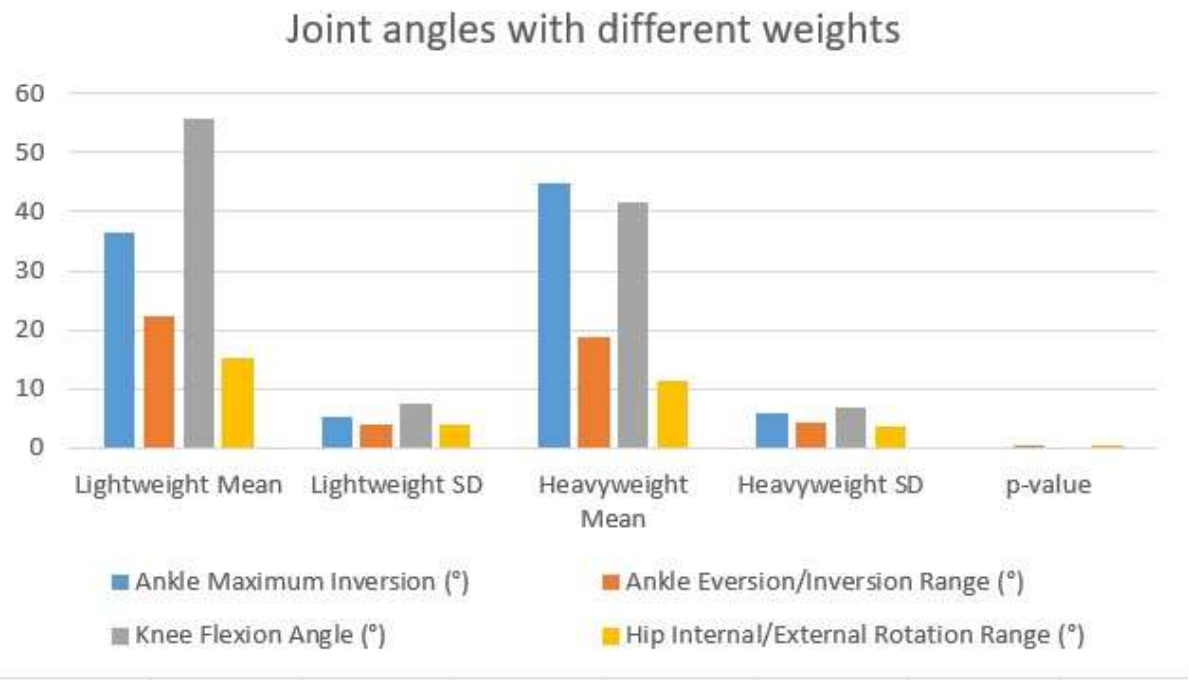
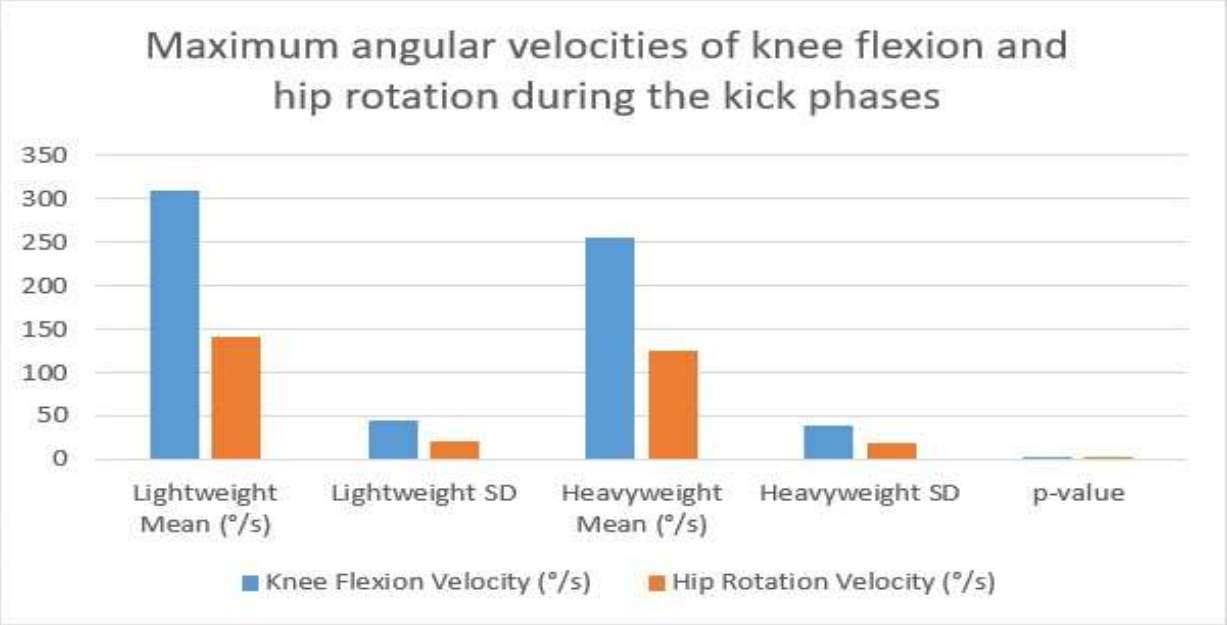


Table 2: Shows the maximum angular velocities of knee flexion and hip rotation during kick stages

Effect size between the two groups	**Significance level P-Value**	**Standard deviation of heavyweight**	**Average heavyweight**	**Standard deviation of lightweight**	**Medium light weight**	Stage	Joints
1.26	0.002	± 38.4	255.8	± 45.7	310.2	1	Knee flexion speed (°/s)
0.77	0.05	± 18.9	125.6	± 20.3	140.5	2	Hip rotation speed (°/s)

Figure 2



5. Recommendations:

1- The researcher recommends that other studies be conducted on the rest of the martial arts to find out how these factors affect the distribution of weight in various games.

2- The researcher recommends incorporating electromyography (EMG) and kinetic analyses that will deepen understanding of muscle-joint compatibility.

3- The researcher recommends conducting longitudinal studies that examine training interventions aimed at improving the mechanics of the supporting leg that the designing training programs based on scientific evidence.

Also in practice, coaches and players can customize training to emphasize ankle stability and knee flexion strategies according to weight category, which can improve kick performance and reduce the risk of injury. In theory, this study emphasizes the importance of the leg in kick biomechanics and advocates its inclusion in future biomechanical models and performance analyses.

These ideas illuminate the way for more individualized and effective training methodologies grounded in scientific evidence in biomechanics.

6. Conclusions:

The study showed that supporting leg in front kizami mawashi giri kicks varies significantly between light and heavyweight karate players. Lightweight players use greater knee flexion and ankle movement to increase elastic energy storage and dynamic balance, while heavy weights emphasize ankle tilt to enhance joint stability under higher mass conditions.

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Conflict of Interest

The author declares no conflict of interest.

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