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	Title of research article Biomechanical Analysis of Kinematic Determinants in the Execution of the Mawashi Geri Technique: A Case Study of Senior Karate Clubs in Algeria
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Keywords	Mawashi geri; Biomechanics; Kinematic variables; Performance analysis; Sports training.
Abstract The Mawashi geri (roundhouse kick) is one of the most decisive techniques in karate-do, requiring precise coordination of lower limb kinematics, speed, and accuracy to achieve maximum efficiency in both training and competition. This study aims to analyze selected biomechanical and kinematic variables that determine the quality of Mawashi geri execution among senior karate athletes in Algeria. Using a descriptive-analytical approach, the researchers employed Cloussier and Kinovea software to conduct a frame-by-frame kinematic analysis of the movement phases. The study sample consisted of two elite-level athletes affiliated with senior karate clubs in Algiers and Laghouat. The analysis revealed the importance of variables such as angular velocity of the hip and knee joints, linear velocity of the striking limb, and the timing of segmental coordination in ensuring effective technique execution. Errors in coordination and timing were identified as key performance limitations. The findings underscore the potential of biomechanical diagnostics for detecting motor errors, improving technical training, and enhancing execution speed. This research highlights the pedagogical and	

practical value of kinematic analysis in refining karate techniques. By linking biomechanical insights with coaching strategies, the study contributes to the scientific foundation of sports training in martial arts.

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1. Introduction

Since sport has existed, athletes have wanted to improve their performance and that of others, encouraged by competition. It didn't take long to realise that some methods were more effective than others. Sport then met science, and this marked the beginning of a long journey together. Indeed, scientific study now seems to have taken a prominent place in sports training and sets the goal of achieving high performance. From improving equipment to the physical and mental preparation of players, nothing is left to chance.

Sports performance is the subject of scientific ingenuity in sports psychology, exercise physiology and biomechanical analysis of movement, all of which are essential for breaking world records. Karate Do, like all sports, has evolved, drawing on different fields of science and incorporating them into training methods with the aim of perfecting performance. This sport is defined as a discipline of great richness. Funkoshi Gichin (1869-1957), considered the father of modern Karate Do, said that "Karate Do is a martial art with infinite dimensions, considered a school of life, a philosophy in its regular practice, it transforms the practitioner physically and internally, making them strong through the confidence gained during training. Karate training, which requires a toll of suffering and tears, develops the qualities of humility and courtesy" (Funkoshi Gichin, 1979). Admittedly, improving the performance of karate athletes is a task of great importance, but with biomechanics having become an essential tool for achieving the goals of the quest for high performance. It enables the study of all the conditions that can lead to better modelling of the different parts of the human body, and kinematics is one of the most widely used tools in the study of physical and sporting activities. As a result, the value of kinematic analysis in the field of physical and sporting activities lies in the detailed description of movement in terms of trajectories, speeds and accelerations. Colin Gavaganand Mark Sayers (2017) demonstrated in their study that "several fundamental movement patterns were common to roundhouse kick techniques in Muay Thai, Karate and Taekwondo. Effective roundhouse kick performance was characterised by rapid pelvic axial rotation, hip abduction, hip flexion and knee extension speeds, combined with rapid movements of the COM towards the target."

All these details make martial arts a unique discipline that requires meticulous analysis in the observation of rapid movements. Indeed, Burke DT, al-Adawi S, Burke DP, et al. (2017) All these details make martial arts a unique discipline that requires meticulous analysis in the observation of rapid movements. Indeed, Burke DT, al-Adawi S, Burke DP, et al. (2017) state in their study that "a difference in momentum generated by martial arts kicks indicates

that the coordinated movement of the pelvis and lower limbs is an essential element in the development of linear momentum by the martial arts practitioner." This analysis can be comprehensive, in which case the individual is reduced to their centre of gravity and the focus is on the movements performed by the different body segments. Over the last decade, the trend towards sports and exercise biomechanics has continued to expand and develop. (Bartlett, Carl J. Payton and Roger M., 2007, p. 17).

It is surprising to note that despite the fact that karate is one of the most widely practised martial arts on the planet and also in Algeria, it will only be officially admitted to the Olympic Games in 2020 in Tokyo. As a result, research in kinematic science has begun a field of study based on the precise description of movement and its refinement, which is limited and sometimes rare, which has sparked our interest in conducting research in Karate do while using a biomechanical approach to enrich this field with in-depth research. It would therefore be interesting to highlight, on the one hand, the description of the mechanical parameters in karate practitioners and, on the other hand, to analyse this movement based on kinematic science in order to help coaches and senseis correct the movement of the 'Mawashi geri', which is considered the most widely used and mastered technique by Algerian athletes.

According to TM. Daniel and R. L. Petre (2014): "We refer to combat disciplines as any combat sport that involves motor and mental actions necessary for attacking, defending, dodging, blocking, etc.". The kinematic analysis of sporting movements consists of describing the movements of the body and its segments that occur at given moments, at specific points in space. These research characteristics on kinematic analysis in the world of martial arts, specifically in Karate do, led us to pose the following question:

- What are the basic mechanical variables that must be identified for the performance of the 'Mawashi geri' technique in karate?

This main question gives rise to the following sub-questions:

- What are the mechanical variables involved in the execution of the 'Mawashi geri' technique in our sample?
- What are the mechanical variables involved in each stage of the execution of the 'Mawashi geri' technique between the two people in our sample?

The principle of a kinematic analysis of martial arts consists of filming an individual practising karate during the execution of a technique, from the starting position to the return to the same starting position (the end of the execution).

This leads us to assume that there are basic mechanical variables that influence the execution of the 'Mawashi Geri' technique in karate. This leads us to assume that there are basic mechanical variables

that influence the execution of the "Mawashi Geri" technique in karate. Furthermore, we estimate the existence of mechanical variables that would intervene in the execution of the 'Mawashi geri' technique in our sample. Finally, in each phase of the execution of the 'Mawashi geri' technique between the two individuals in our sample, there may be mechanical variables that can be called upon.

The objective of this study is to first analyse the execution of the "Mawashi Geri", then we outline other objectives, which are as follows:

- Evaluate the kinematic variables of the technique in question.

- Determine the kinematic variables (linear movement C.D.M, and angles relating to the joints, and especially the analysis of the centre of gravity during the execution of the movement.
- Identify the mechanical variables specific to each stage of execution.

2. Procedural definition of the concepts mentioned in the research Kinematic analysis:

This is the mechanical analysis of the sporting movement and consists of describing the movements of the body and its segments that occur at given moments, at specific locations in space. (Bartlett, Carl J. Payton and Roger M., 2007, p. 16).

Qualitative analysis: The main characteristic of qualitative analysis is, naturally, the provision of information that has been identified as relevant to the sport or exercise activity under study. The information required may involve variables such as linear and angular displacements, speeds, accelerations, forces, torques, energies and powers. (Bartlett, Carl J. Payton and Roger M., 2007, p. 19).

Mawashi geri technique:

Mawashi geri is a horizontal circular whipping kick. The attacker lifts the knee to the side of the body. The knee moves in a semicircular direction towards the target. The foot comes off the ground and returns. After the foot returns, the knee also moves back to its original starting point. Finally, the kicking foot returns to the floor. The purpose of mawashi geri is to deliver a side attack. An attack coming from the side can be more difficult to see and defend against. It is also performed by stepping to the side as the opponent attacks, rotating the hips in a circular motion of the leg, so that the toes, the ball of the foot or the top of the foot whip inward perpendicular to the opponent's body (Funakoshi, Gichin, 1979, p. 25).

3. Practical part

3.1 Methods and tools of investigation

The protocol specific to this study falls within the framework of descriptive research with movement analysis. This protocol includes a case study.

All research involves methodological choices related not only to the object of study, but also and above all to the nature of the research itself. To carry out this work, we used biomechanical measurements presented in cinematography, which we believe to be the most appropriate methodological support for achieving our objectives.

3.2 Study population and sample

3.2.1 Study population

The population of this study consists of young karatekas (boys) aged 18-26 in clubs in Laghouat who are members of the Algerian Karate Federation .

3.2.2 Sample characteristics

The issue raised allowed us to make a specific choice of two young karatekas aged 18-26 (boys). From Laghouat team and an athlete from Algeria national team. Here are their characteristics:

Sample type	Category	Passage and grade	Weight(kg)	Length(m)	Achievement
Sample (1)	Senior	Black Belt	72	1.75	Champion of Algeria 2015
Sample (2)	Senior	Black Belt	69	1.86	2nd place in the university games

3.3 Variable identifiers

-Independent variable: mechanical variables

-Dependent variable: the 'Mawashi geri' technique in Karate do.

-Intermediate variable: Senior Karateka black belt (22-26 years old), males.

3.4 Research areas

Spatial domain

The tests were carried out at the Dada Younes Laghouat sports hall.

Temporal domain

The tests for our study were carried out from 7 January 2018 to 15 August 2018. We have summarised them in the table below:

Table 2: Overview of the characteristics of the time frame

Date	Event
10/01/2018	Pre-test of preliminary sample
18/01/2018	Post-test
28/02/2018	Sample test no. 02
30/04/2018	Sample test no. 01
03/05/2018	Kinetic analysis of gestures

3.5 Investigation tools

3.5.1 Kinematic movement analysis tests

The objective of the test is to extract and calculate the variables of movement. The test is based on a complex principle of kinematic analysis of the 'Mawashi geri' technique using specialised computer programs that measure the extracted motor variables as follows: the angles of the knee and trunk joints, the determination of C.G. (centre

of gravity) of the body during the execution of the technique using two methods, the Kinovea program and the Clousser table.

These variables were determined by:

- Descriptive performance of the technique (Hberstzer, Roland, 2003, p. 184) .
- Movement analysis of the technique

3.5.2 Photography procedures

After checking the validity of the research equipment and appropriate lighting, the researcher placed camera 01 in a lateral position and camera 02 in a position relative to the targets to determine the horizontal and vertical distances. The method of testing: the sample is ready at the specified marks and at the signal, the sample performs the technique.

The kinetic analysis was performed by a Nikon CoolPix P510 camera at a rate of 60 frames per second with appropriate equipment and lighting according to the following programmes:

-AFTEREFFECT: is a video editing programme adopted to track the points representing the body's joints.

-Kinovea programme: The kinematic analysis programme was used to measure angles and dimensions, as well as to track the centre of gravity and extract data. Determine the C.DM of the technique indicated for each phase of the technique's execution.

3.6-Scientific basis for the test used:

Table 3: Presentation of test reliability and validity values

Test	Reliability (r)	Validity
Biomechanical analysis	0.89	0.94

The main objective of this study was to determine the validity and reliability of the Kinovea software for obtaining angular and distance data at different perspectives of 90°, 75°, 60° and 45°.

The results obtained indicate that the Kinovea software is a valid and reliable tool capable of accurately measuring distances up to 5 m from the object and within an angular range of 90° to 45°. However, for optimal results, an angle of 90° is recommended.

Test procedure:

- a. Imaging procedures: after checking the validity of the research equipment and appropriate lighting, the researchers placed camera 01 in a lateral position and camera 02 in an initial position to determine the horizontal and vertical distances.
- b. Laboratory processing: The laboratory is used to place marks on the body's joints to facilitate subsequent analysis.

Static methods used:

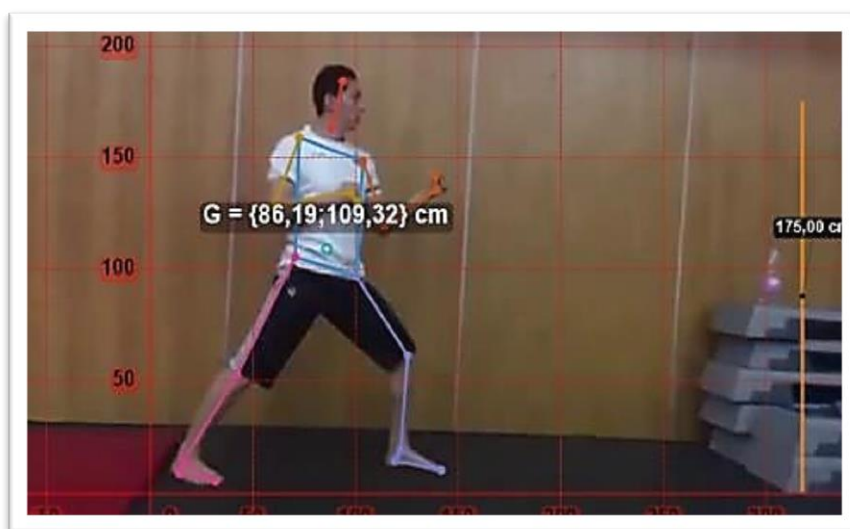
- Arithmetic mean
- Standard deviation
- Person's correlation coefficient

4. Analysis and discussion of results

4.1. Results of first hypothesis.

Table 4: Presentation of biomechanical variables specific to the first sample, initial phase

Echantillon 1 phase initial							
Position fondamentale							
Parts of the body	R. Mass	L. On the drawing	R.half diagonals	X	Y	The mass X*	The mass Y*
Head	5.25	5.25	46.4	9	11	47.30	57.81
C.V	36.50	36.50	38	9	8	328.53	292.03
Arm.R	1.87	1.87	51.3	7.25	9	13.57	16.84
Arm.L	1.87	1.87	51.3	10	8.75	18.72	16.38
Forearm .R	1.15	1.15	39	8.75	8.25	10.08	9.50
Forearm .L	1.15	1.15	39	11.10	8.25	12.78	9.50
Hand.R	0.50	0.50	18	9.5	8.75	4.78	4.41
Hand.L	0.50	0.50	18	11.5	8.75	5..79	4.41
Thigh.R	7.41	7.41	37.2	7.25	6.75	53.76	50.05
Thigh.L	7.41	7.41	37.2	9.75	5.5	72.30	40.78
Calf.R	3.09	3.09	37.1	5.75	3	17.80	9.28
Calf.L	3.09	3.09	37.1	10.75	3.10	0.63	9.59
Foot.R	1.08	1.08	44.9	5	1.25	5.4	1.35
Foot.L	1.08	1.08	44.9	11.10	1.75	11.98	1.89
Weight (body) Kg	72	72	/	114.95	92.1	602.84	523.87



The table above presents the different biomechanical variables used during the execution of the 'mawachi geri' technique proposed by sample no. 1. Among the variables, we cite: the R. half diagonals of the head = 46.4, C.V = 38, right and left arm = 51.3, right and left weapon = 39, right and left hand = 18, right and left thigh = 37.2, right and left calf = 37, and right and left foot = 44.9

Table 5: Representation of biomechanical variables specific to sample 2, initial phase.

Echantillon 2 phase initial							
Position fondamentale							
Parts of the body	S. Mass	M. On the drawing	R.half diagonals	X	Y	The mass X*	The mass Y*
Head	0.07	5.25	46.2	9.25	9	46.59	45.33
C.V	0.50	36.50	37	9.75	6.25	341.08	218.64
Arm.R	0.02	1.87	50.1	7.25	6.75	13	12.10
Arm.L	0.02	1.87	50.1	12.5	7.10	22.42	12.73
Forearm .R	0.01	1.15	37.5	9.75	6.25	10.76	6.9
Forearm .L	0.01	1.15	37.5	15	7.10	16.56	7.83
Hand.R	0.007	0.50	16	11	6.25	5.31	3.01
Hand.L	0.007	0.50	16	16	7.75	7.72	3.74
Thigh.R	0.10	7.41	36.8	7.25	4.5	51.52	31.98
Thigh.L	0.10	7.41	36.8	12.75	4.75	90.61	33.75
Calf.R	0.04	3.09	36.1	4	2.5	11.86	7.41

Calf.L	0.04	3.09	36.1	15	2.75	44.50	8.15
Foot.R	0.01	1.08	43.5	1.5	0.75	1.55	0.77
Foot.L	0.1	1.08	43.5	15.5	1.10	16.04	1.13
Weight (body) Kg	1	69	/	9.12	10	1336.58	1113.55



4.2. Discussion of the first hypothesis

According to the results in Tables 3 and 4, we can see that there are different variables involved in the execution of the 'mawachi geri' in Karate Do, and that the different variables involve different segments and parts of the body, such as arm speed and lower segment acceleration, as well as counter-gravity displacement during the execution of the Mawachi Geri technique. This confirms our first hypothesis, which is the existence of mechanical variables that come into play when performing the 'Mawachi geri' technique in karate. The existence of mechanical variables that arise during the execution of the 'Mawachi geri' technique in our sample

4.3. Analysis and results of the second hypothesis

Table 6: Representation of the results of samples (1) and (2) according to Clousser and Kinovea

The parts	Sample	C.G according to table Clousser	C.G according to the Kinovea programm
Initial phase(Raising of the foot)	01	8,086 9,439	(106.58 ;107.59 cm)
	02	16,138 19,370	(132.86 ;109.00 cm)
Preparation phase (Maximum part of the	01	11,712 7,061	(149.80 ;118.96 cm)

striking foot)	02	5,786 11,225	(149.75 ;105.57 cm)
Final phase	01	6,184 8,012	(86.19 ; 109.32 cm)
	02	7,159 8,520	(132.86 ;109.00 cm)

According to the table below, which shows the centre of gravity results for the two samples evaluated by Kinovea and Clousser, and which also demonstrates the centre of gravity value according to the different stages of performing the Mawashi Geri technique. In the initial phase, we observe that the centre of gravity of the first sample is (8.086-9.349) according to Clousser and (106.58-107.59) according to Kinovea, and for the second sample (16.138-19.370) according to Clousser and (132.86-109.00) according to Kinovea. As for the preparatory part, the centre of gravity of the first sample is (11.712-7.061) according to Clousser and (149.80-118; 96) according to Kinovea, and for the second sample, the results recorded are (5.786-11.225) according to Clousser and (149.75-105.57).

The final part recorded a centre of gravity of (6.184-8.012) according to Clousser and (86.19-109.32) for the first sample, and for the second sample, the results recorded are (7.159-8.520) according to Clousser and (132.86-109.00) according to Kinovea.

4.4. Discussion of the second hypothesis

a. The preparatory period:

The results on the x-axis: the increase in sample 02 on this axis returns to the step it added before taking the 'zenkutsu dachi' position. There is a difference in the increase in the centre of gravity in our sample, which returns to the position of sample 01: 'zenkutsu dachi' position at the start, and sample 02: low 'zenkutsu dachi' position. As for the moment of elevation of the striking foot, both axes confirm that

the foot did not completely leave the ground, which explains the small change in our sample.

b. Initial period: Maximum height of the striking foot

The results in this period confirm the increase in sample 02:

The angle (B, C, D) of the trunk is greater than in sample 01, which means that the lower the angle of the trunk, the lower the centre of gravity in the 'Mawashi geri' technique. The results confirm that the value of the second sample is higher than sample number 1 in angle (A, C, A'), due to the greater height, which led to an increase in C.G.

c. The final period

The results in this phase show that during the return to the basic 'zenkutsu dachi' position, there is an increase in the centre of gravity on the x-axis, returning to the distance travelled since the start of the execution of the 'Mawashi geri' technique. However, the value of the centre of gravity on the y-axis is the same as in the preparatory period in our sample. Neass Tahchi and Abderrahmaine Tahchi (2015) mention that 'the kinematic variables for the

approach phase, the approach speed and the launch angle of the centre of gravity contribute to increasing the vertical distance to the centre of gravity by a percentage of (9.43%)’.

After these various observations, we note that the value of the centre of gravity changes from one part to another (initial, preparatory and final) during the execution of the Mawashi geri technique, which confirms our second hypothesis that there are mechanical variables that can be used in each phase of the execution of the ‘Mawashi geri’ technique between the two individuals in our sample.

Conclusion

Martial arts, activities with a triple religious, warrior and philosophical vocation, have long been practised on the Asian continent before spreading to the rest of the world. They have undergone profound changes throughout historical events. And the recent news is that this sport will be part of the 2020 Olympic Games, which will open a great door to this wonderful art.

Indeed, the demands of modern sport are constantly increasing, and technical sciences are developing technologies such as VAR and video checks every day to avoid refereeing injustices. In karate, researchers use kinematic analysis of the biomechanical variables involved in performing different techniques, where precision of movement is required in different segments of the body. In order to better analyse the performance of karate athletes and develop different technical qualities, Benchouhra Yacine et al (2014) stated that ‘biomechanics has become one of the most important sciences because it studies the phenomenon and analyses the different stages of movement’.

Findings

- **Kinematic Variables:** Angular displacement and angular velocity of the hip and knee were the primary determinants of Mawashi geri performance. Linear velocity of the foot during the striking phase was strongly correlated with execution efficiency.
- **Motor Coordination:** Effective sequencing of hip rotation, knee extension, and foot trajectory was critical for accuracy and impact force. Errors in joint synchronization resulted in decreased speed and power.
- **Software Utility:** The use of Clousser and Kinovea software allowed precise detection of motor errors across the preparatory, execution, and recovery phases. Such tools can provide coaches with actionable insights for refining athletes’ technical performance.
- **Practical Implications:** Biomechanical evaluation can serve as a corrective training method, contributing to the improvement of execution speed, accuracy, and technical stability. Systematic application of kinematic analysis may foster greater individualization of training in karate clubs.

Ethical Considerations

The study was conducted in accordance with ethical research standards in sports science. Informed consent was obtained from all participants. No invasive procedures were involved, and confidentiality of participants’ data was maintained.

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Conflict of Interest

The authors declare that they have no conflict of interest.

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