Journal of Advanced Sport Technology 6(1):39-50.

Received: April, 15, 2022 Accepted: July, 03, 2022

Original Research

Comparing the Dynamic Model of Torque and Angular Velocity in Four Methods of Performing the Judan Mai-Mawashi-Geri Technique by Elite Male Karatekas

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ABSTRACT

The aim of this study was to compare the dynamic model of torque and angular velocity in four methods of performing the Judan Mai-Mawashi-Geri technique by elite male karatekas. Eighteen elite male kumite practitioners participated in this study with mean and standard deviation age of 24.1±3.5 years, height of 176.2±4.6 cm, and weight of 73.7±6.5 kg. They had 2.5±1.98 years of experience in the national karate team and 2.8±1 years of experience in Iran's Karate Super League. Six markers were attached to the anatomical points of the hitting foot. Three Hero3 cameras at a speed of 240 frames per second were used for collecting data about four methods of performing the Judan Mai-Mawashi-Geri technique. SkillSpector (version: 1.3.2) was used to obtain the joint coordinates (XY) and MATLAB was used to build the model. The one-way analysis of variance and the Bonferroni post-hoc test ($p \leq 0.05$) were used for statistical analysis after ensuring the normality of data distribution. The results showed a significant difference in the maximum torque and maximum angular velocity of the pelvic, knee, and ankle joints in the four methods of performing the Judan Mai-Mawashi-Geri technique. According to the results of the study, while emphasizing the sequential order of torque of the proximal to distal limb joints, we recommend the third method of performing the Judan Mai-Mawashi-Geri technique for an optimal and powerful implementation of this skill since the angular velocity of the knee joint is directly related to the peak velocity of the foot.

Keywords: Karate, Dynamic Model, Judan Mai-Mawashi-Geri, Torque, Angular Velocity.

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INTRODUCTION

Considered one of the most famous martial arts, karate means fighting with the use of hand and foot techniques and without any weapons for the purpose of self-defense [1, 2]. Mai-Geri, Mawashi-Geri, Ora Mawashi-Geri, Oshiro-Geri, and Yoko-Geri are the main foot techniques of karatekas. The Judan Mai-Mawashi-Geri technique (a rotational kick to the opponent's head with the front foot) is a combination of the two basic techniques of karate, i.e. Mai-Geri (kick from the front) and Mawashi-Geri (rotational kick) [3]. It is one of the most commonly used foot kicks in karate [4] especially in karate fighting competitions [5]. Studying eight World Championships including Spain (1992), Cyprus (2004), Finland (2006), Japan (2008), Serbia (2010), France (2012), Germany (2014), and Austria (2016), Toro et al. (2018) showed that Judan Mai-Mawashi-Geri was the highest scoring technique among the foot techniques [6]. In addition, the optimized implementation of the Judan Mai-Mawashi-Geri technique is of special importance for kumite competitors in kumite competitions since one hundredth and one thousandth of a second play a significant role in obtaining medals [7,8].

To obtain an optimal model, modeling the technique is necessary. Therefore, we can have a better understanding with the help of modeling four different ways of performing the Judan Mai-Mawashi-Geri technique which is a relatively complex movement. The aim of modeling athletic movements is to extract and infer the secondary quantities that are used for movement analysis [9]. Dynamics is a branch of mechanics that investigates all types of movement including athletic movements [10]. One of the aspects studied is the kinetic analysis of motion which means the study of forces and torques that are exerted on the body by external objects [11] as well as the internal forces and torques that are produced in the joints by muscles in order to create movement or resistance against movement [12]. The force applied by the muscles in the four different methods of performing the Judan Mai-Mawashi-Geri technique is evaluated by calculating the torque produced in the joints and a dynamic model is constructed [13]. The understanding of the details of motion and the relationships between the effective variables will be incomplete without applying the equations of motion. Modeling is a process by which we can study a difficult problem in an understandable and simple way. One of the advantages of this method is the possibility of changing each variable as desired. In this regard, some researchers have used models to analyze the basic movements [9]. For example, Spägele et al. (1999) showed a model for the lower limb in the vertical jump and managed to estimate the torque produced by the effective muscles [14]. Some researchers have used multi-link models in their research for the practical analysis of soccer shots [15]. Cynarski et al. (2014) studied the improvement of movements of basic karate techniques using motion recording and the concept of mathematical modeling for a research project. They concluded that by evaluating the values of kinetic parameters and their information, karatekas will be able to perform techniques with more control [16]. The kinetic parameters of this technique, which include the study of joint movements and the sequence and timing of movements, are studied by modeling [4].

One of the effective factors in choosing this subject was its novelty and its implementation method in the field of sports biomechanics. Although models have been used worldwide to analyze sports movements in recent years, this has not been common in karate techniques and even other martial arts. The dynamic model of torque and angular velocity of the joints is presented in four methods of performing the Judan Mai-Mawashi-Geri technique in the attack position and the fixed position of the opponent for the first time in the world. Thus, the present study can fill this gap to some extent.

Considering the diversity of training and practice styles in teaching karate skills, there is not a single model for the instructors to teach. The aim of this study was to compare the dynamic model of torque and angular velocity in four methods of performing the Judan Mai-Mawashi-Geri technique by elite male karatekas by assuming the viability of achieving an optimal model, by considering the potential ability of modeling to predict the best performing patterns, and by the kinetic and kinematic analysis of the technique.

MATERIALS AND METHODS

The statistical population of this descriptive-comparative study consisted of 250 karatekas with an experience of participating in the Iranian National Karate Team and the National Karate Super League in the kumite section from 2017 to 2020. There were 21 kumite practitioners from the statistical population three of whom were removed using the Outlier command in SPSS software. The remaining 18 kumite practitioners with mean and standard deviation age of 24.1±3.5 years, 2.5±1.98 years of presence in the national karate team, 2.8±1 years of presence in the Karate Super League, height of 176.2±4.6 cm, and weight of 73.7±6.5 kg participated in this study purposefully and voluntarily. In order to observe the ethical principles in the tests, the present research proposal was reviewed and accepted by the Research Institute of Motor Sciences (ethics ID: IR-KHU.KRC.A-1000-A) and all stages of the research were performed in the laboratory of Sahand University of Technology.

Data Collection

Set-up system: The cameras were set by the relevant operator. Then, a place with the length, width, and height of 2, 2, and 3 meters, respectively, was calibrated. In this space, the karatekas were supposed to perform the Mai-Mawashi-Geri technique using four methods. Three Hero3 cameras (made in the US) were used to capture the karatekas' performance with a shooting speed of 240 frames per second. The cameras were set on a tripod at a distance of 2 meters from the calibrated space. One camera was put in front of the subject and the two others were placed on the left and right sides of him with a 90-degree angle to the front camera. The ADIOS software was used to synchronize the videos. Moreover, using a rod, an electronic taekwondo hogu was installed as the target and adjusted to the height of the subjects. All the frames related to the movement of the foot were processed and analyzed until the moment of hitting the target in the four methods of performing the Judan Mai-Mawashi-Geri technique.

Preparing the subjects: Before starting the test, the research process was explained to the subjects. All the karatekas filled in the satisfaction forms as well as personal and medical information forms including age, height, weight, record of presence in the national karate team of Iran or record of presence in the Karate Super League, the dominant foot (the leg they most often used to earn points), and the record of injuries (including bone fractures, ligament injuries, tendon injuries, muscle injuries, and any chronic pain) during the past year. The locations of 6 markers on the outer part of the iliac crest, large trochanter, outer epicondyle of the knee, outer ankle, heel, and the little toe of the striking foot were determined by the examiner. In addition, the calibrated space was marked with painter's tape (Figure 1).

Figure 1. Marker placement

Data collection steps: After 10 minutes of warm-up and stretching movements, the subjects were asked to perform the four methods of the Judan Mai-Mawashi-Geri technique in the calibrated space three times with the dominant foot in the attack position and the fixed position of the opponent. The best performance was approved by expert trainers and the research supervisor. The four methods of performing the Judan Mai-Mawashi-Geri technique were carried out in three phases (guard or preparation, the principle of movement or flight, the moment of hitting the target or the end of the movement) as follows:

The first method of performance: Guard, 90-degree thigh flexion (knee lift), knee opening, the moment of hitting the target, back to guard

The second method of performance: Guard, 45-degree rotation of thigh, knee opening, the moment of hitting the target, back to guard

The third method of performance: Guard, 90-degree rotation of thigh, knee opening, the moment of hitting the target, back to guard

The fourth method of performance: Guard, 120-degree thigh flexion, knee opening, the moment of hitting the target, back to guard (Figure 2)

The first phase of the second method of performance | The first phase of the first method of performance

The first phase of the fourth method of performance | The first phase of the third method of performance

Knee opening and hitting the target in the four methods of performing the Judan Mai-Mawashi-Geri technique

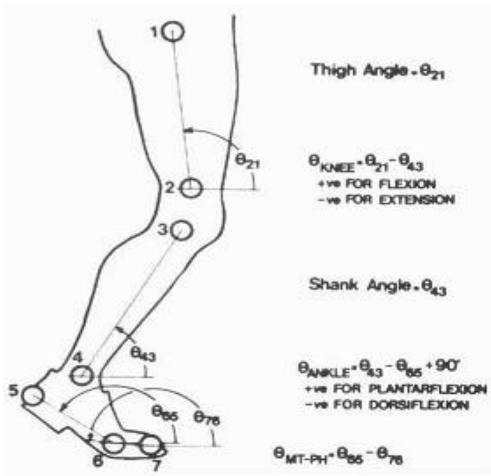
Figure 2. The four methods of performing the Judan Mai-Mawashi-Geri technique

The data processing stage: To evaluate the accuracy of the data at the time of data collection, the prior knowledge of the researcher and the research proposal were used [9,15]. To reduce the noise of the data, the smooth low-pass filter command of the MATLAB software was applied. For comparison, the collected data were normalized on the basis of time.

The Judan Mai-Mawashi-Geri technique was performed using four methods to build a dynamic model in four steps: 1. Calculating the coordinates of the joints (XY); 2. Calculating the angle, movement, angular velocity, and acceleration of the joints; 3. Calculating the anthropometric characteristics, the center of mass, and the moment of inertia of the joints; 4. Model construction and joint torque.

1- Calculating the coordinates of the joints: The joint coordinates of the pelvis, knee, ankle, heel, and little toe (XY) from the moment of raising the heel from the ground to the moment of hitting the target were obtained using the SkillSpector software (version: 1.3.2). When used appropriately, the accuracy of such software has been demonstrated to reach 0.3 mm. The interrater reliability was moderate to high with intraclass correlation coefficients (ICC) ranging from 0.71 to 0.99 [17-22]. Then, the obtained coordinates were transferred to the Excel software. Using the xlsread command, the Excel data file was loaded in the MATLAB software. Afterwards, the coordinates of the pelvic, knee, ankle, heel, and the little toe (XY) joints were defined in MATLAB software.

2. Using formula 1, the absolute angles with the horizon line and the relative angles of joint rotation were calculated through the difference of the absolute angles of the two limbs around it.



$$\theta_{ij} = \arctan\left(\frac{Y_j - Y_i}{X_j - X_i}\right)$$

$$\theta_{21} = \arctan\left(\frac{Y_1 - Y_2}{X_1 - X_2}\right)$$

$$\theta_k = \theta_{21} - \theta_{43}$$

$$\theta_a = \theta_{43} - \theta_{65} + 90^0$$

Formula 1

Moreover, the variables of movement, angular velocity, and acceleration of the joints were calculated and inserted into the model by using the following formula [23].

$$\omega_i = \frac{\theta_{i+1} - \theta_{i-1}}{2\Delta t}$$

$$\alpha_i = \frac{\theta_{i+1} - 2\theta_i + \theta_{i-1}}{\Delta t^2}$$

Formula 2

The theorem of parallel axes was used to calculate the moment of inertia around different parts of the limb (center of mass, proximal end, and distal end) and each of the links. They were inserted into the model using formula 3 presented by Winter (2002) [24].

$$I = I_{cm} + M\left(d^2\right)$$

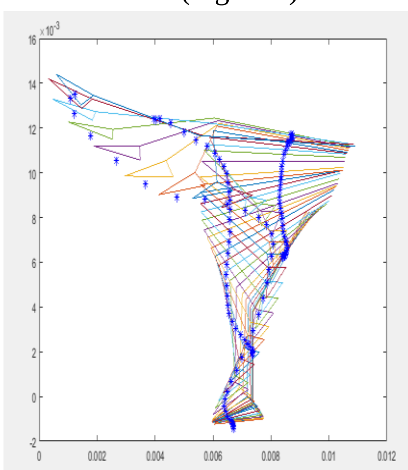
Formula 3

3. Calculating the anthropometric properties, the center of mass, and the moment of inertia of the joints: The height and weight of the subjects were calculated. Subsequently, the link lengths which are required in presenting and developing the dynamic model for calculating the kinetics of motion were calculated for each subject and inserted into the model (Table 1).

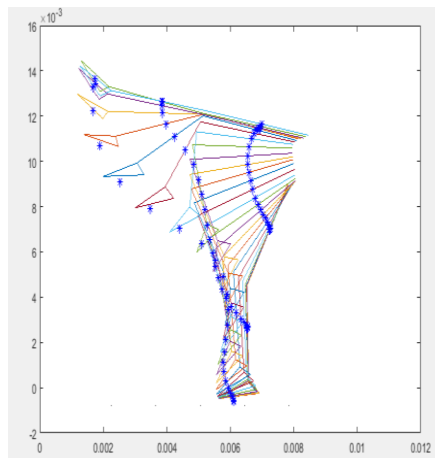
Table 1. Calculating the anthropometric properties of the subjects for the model

Height * 0.245=thigh length
Height * 0.246=leg length
Height * 0.152=leg length
Thigh length * (1-0.433)=center of mass of the thigh
Leg length * (1-0.433)=center of mass of the leg
Leg length * (1-0.5)=center of mass of the foot
Weight * 0.245=thigh weight
Weight * 0.246=leg weight
Weight * 0.152=foot weight
Moment of inertia of the thigh=(thigh length * 0.323)^2 * thigh weight
Moment of inertia of the leg=(leg length * 0.303)^2 * leg weight
Moment of inertia of the leg=(leg length * 0.475)^2 * leg weight

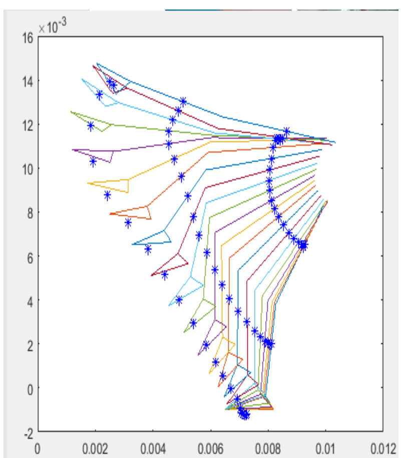
4. Building a model and calculating the torque of the joints: Following the calculation of the coordinates of the joints (XY), the movement, velocity, and acceleration of the angles of the joints, anthropometric properties, the center of mass, and the moment of inertia of the joints, a dynamic model was constructed using MATLAB software (Figure 3).



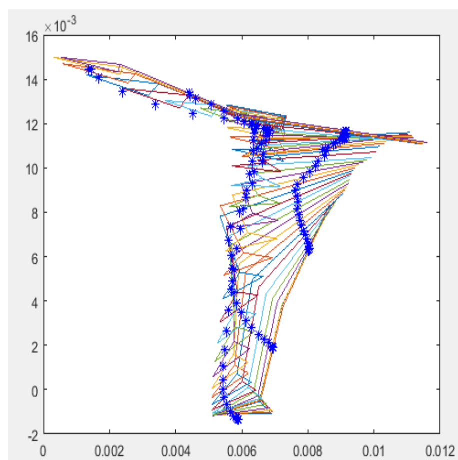
The second method



The first method



The fourth method



The third method

Figure 3. A model of the four most common methods of performing the Judan Mai-Mawashi-Geri technique

Furthermore, the joint torque (pelvis, knee, and ankle) was calculated using the inverse dynamic method. The calculations were started from the farthest limb from the upper part of the body (center) using formula 4 governing the motion (Newton-Euler) for each limb [9, 25].

$$\sum F_x = m a_x \quad \Rightarrow \quad R_{xp} - R_{xd} = m\overline{a_x}$$

$$\sum F_y = m a_y \quad \Rightarrow \quad R_{yp} - R_{yd} - mg = m\overline{a_y}$$

$$\sum M_G = \bar{I}\alpha \quad \Rightarrow$$

$$R_{yp} d_2 \cos\theta - R_{xp} d_2 \sin\theta + M_p - M_d + R_{yd} d_1 \cos\theta - R_{xd} d_1 \sin\theta = \bar{I}\alpha$$

Formula 4

For the statistical analysis of the data, the mean and standard deviation were used. After ensuring the normal distribution of data using Shapiro-Wilk tests, the Leven test was used for homogeneity of data variance, one-way analysis of variance test was employed to check the significant difference in the results, and the Bonferroni post-hoc test at the level of $p \leq 0.05$ was used with SPSS software (version: 22) in case of a significant difference.

RESULTS

The mean, standard deviation, maximum and minimum of the maximum torque of the lower limb joints in the four methods of performing the Judan Mai-Mawashi-Geri technique and the results of the Bonferroni post-hoc test are presented in Table 2. There is a significant difference between the maximum torque of the pelvic, knee, and ankle joints in the four methods of performing the Judan Mai-Mawashi-Geri technique. The most and least torque functions of the muscles in the joints of the lower limb are observed in the implementation of the third and fourth methods, respectively.

Table 2. Mean±SD, maximum and minimum of the maximum torque (N.m) of the lower limb joints in the four methods of performing the Judan Mai-Mawashi-Geri technique, and the results of one-way analysis of variance (F,p1) and the Bonferroni post-hoc tests (p2)

Maximum joint torque (N.m)	The method of performing the technique	Mean and standard deviation	Maximum	Minimum	F	P1	Comparing the four methods of performing the technique	P2
Pelvis	First	312.43±336.47	364.36	258	15.046	0.000	First-second	0.001
							First-third	0.020
	Second	350.69±15.79	375.21	330.11			First-fourth	0.001
	Third	300.67±38.66	358.71	239.76			Second-third	0.000
	Fourth	352.33±16.19	385.23	331.12			Second-fourth	0.037
							Third-fourth	0.000
Knee	First	154.04±9.40	167.61	140	5.496	0.002	First-second	0.04
							First-third	0.039
	Second	145.50±9.07	169.61	135.78			First-fourth	0.001
	Third	146.61±10.42	162.53	130.81			Second-third	0.036
	Fourth	141.65±8.51	159.98	127.12			Second-fourth	0.042
							Third-fourth	0.004
Ankle	First	25.88±2.81	33.51	22.81	4.659	0.005	First-second	0.042
							First-third	0.02
	Second	23.70±2.31	27.98	20.19			First-fourth	0.004
	Third	24.10±2.74	31.12	20.62			Second-third	0.03
							Second-fourth	0.011
	Fourth	22.91±1.87	26.71	19.12			Third-fourth	0.042

The mean, standard deviation, and the maximum and minimum of the maximum angular velocity (dg/s) in the lower limb joints in the four methods of performing the Judan Mai-Mawashi-Geri technique as well as the results of the Bonferroni post-hoc test are presented in Table 3. As observed, the results showed a significant difference between the maximum velocity angles of the pelvic, knee, and ankle joints in the four methods of performing the Judan Mai-Mawashi-Geri technique. The most and least angular velocity functions in the joints of the lower limb are observed in the third and fourth methods of performing the technique, respectively.

Table 3. Mean±SD, and maximum and minimum of the maximum angular velocity (dg/s) in the lower limb joints in four methods of performing the Judan Mai-Mawashi-Geri technique and the results of one-way analysis of variance (F,p1) and the Bonferroni post-hoc tests (p2)

Maximum angular velocity of joints (dg/s)	The method of performing the technique	Mean and standard deviation	Maximum	Minimum	F	P1	Comparing the four methods of performing the technique	P2
Pelvis	First	584.43±82.01	666.45	504.16	160.12	0.000	First-second	0.001
							First-third	0.031
	Second	617.81±98.65	671.81	563.78			First-fourth	0.001
	Third	661.19±67.27	728.67	593.85			Second-third	0.01
	Fourth	543.91±75.36	619.27	468.55			Second-fourth	0.000
							Third-fourth	0.000
Knee	First	1674.67±102.96	1776.12	1572.12	459.46	0.000	First-second	0.000
							First-third	0.041
	Second	1762.61±133.16	1862.88	1662.14			First-fourth	0.000
	Third	1877.56±143.58	1977.77	1771.41			Second-third	0.000
	Fourth	1550.24±135.44	1685.63	1450.31			Second-fourth	0.000
							Third-fourth	0.000
Ankle	First	683/43±98.21	781.81	585.59	187.27	0.000	First-second	0.000
							First-third	0.000
	Second	719/80±100.11	826.12	620.12			First-fourth	0.01
	Third	770.47±110.34	880.14	660.83			Second-third	0.000
							Second-fourth	0.031
	Fourth	632.88±105.63	737.16	527.10			Third-fourth	0.000

DISCUSSION

The aim of this study was to compare the dynamic model of torque and angular velocity in the four methods of performing the Judan Mai-Mawashi-Geri technique by elite male karateka in the attacking position and the fixed position of the opponent. The trend of changes in the torque of the lower limb joints was relatively the same in the four methods of performing the Judan Mai-Mawashi-Geri technique except in the first phase of the technique. For this reason, in this study, the four methods of performing the Judan Mai-Mawashi-Geri technique are generally discussed. The ability of the muscles to produce more muscular torque while performing the four methods of the Judan Mai-Mawashi-Geri technique causes the joints to move faster and ultimately leads to more powerful strikes.

In the present study, the torque of the joints in the four methods of performing the Judan Mai-Mawashi-Geri technique has been calculated and presented using the inverse dynamic method as well as the dynamic model. After reviewing the proposals of previous researches, we were unable to find similar studies on martial arts to compare our results with theirs. However, we found some studies which investigated torque performance in soccer using a dynamic model [9, 26-30]. In the aforesaid researches, the authors obtained different torques for the lower limb joints in soccer shots. However, in most of them, the amount of generated torque around the pelvic joint was twice as much as that of the knee joint [9, 26, 27, 31]. In the present study, the ratio of torque in the pelvic joint was approximately twice as much as that of the knee joint in the four methods of performing the Judan Mai-Mawashi-Geri technique. In this regard, it is consistent with the mentioned studies.

In this study, the ankle joint torque was between 22 and 25 Nm in the four methods of performing the Judan Mai-Mawashi-Geri technique. This is in line with the results of previous studies conducted by some researchers who studied the ankle joint torque and reported a number between 12 and 35 Nm [9, 28].

In performing athletic skills, it is assumed that motion is transferred from the proximal limb to the distal limb. This sequence leads to an increased velocity in the distal limb and ultimately increases the strike velocity [32, 33]. Pimontz et al. (2013) stated that each distal limb begins to move when the proximal limb has reached its maximum angular velocity [34]. In addition, Hudson (1986) argued that rotation in the limbs is based on acceleration and velocity in them which are also based on the sequence and simultaneity in the movement of the limbs [35]. Tommy (1989) claimed that movement in one limb depends on the movement in the adjacent limb [15] and that individuals use proximal to distal sequences to achieve maximum angular velocity.

Since there is a direct relationship between the torque and velocity of the angles of the joints, the sequence of the proximal to distal limbs can be inferred. According to the results, the generated torque in the pelvic joint reaches its maximum value in the first phase of the four methods of performing the Judan Mai-Mawashi-Geri technique which causes an increase in the angular velocity of the pelvis. Increasing the angular velocity of the pelvis creates a force (torque) in the knee joint (as a distal joint to the pelvic joint) which is called motion-dependent torque. This torque, along with the generated torque by the knee opening muscles, reaches its maximum value and causes a large angular velocity in the knee joint. This angular velocity is the most effective component for increasing the speed of the technique [34].

Furthermore, this process continues in the ankle joint where the torque caused by the rapid movement of the knee joint gives rise to more plantarflexion of the ankle. The maximum torque of the ankle joint as a distal limb in the foot technique maximizes the angular velocity of the plantarflexion of the ankle at the moment of hitting the target.

Quinzi et al. (2013) studied the angular velocity of the Mai-Mawashi-Geri technique in elite and beginner karatekas. Based on their results, angular velocity in the knee and thigh of elite karatekas was higher than that of the beginners. The angular velocities of elite karatekas were reported to be 608±62 °C in the pelvis, 1734±108 °C in the knee, and 708±30 °C in the ankle, whereas the angular velocities of the beginner karatekas were 6375±60 °C in the pelvis, 1633±102 °C in the knee, and 693±115 °C in the ankle [36].

Davit and Heinrichs (2012) stated that the shooting speed was directly related to the angular velocity of the pelvis. They introduced the increase of angular velocity of the pelvis as the most important factor in increasing the shooting speed [37]. In contrast, Levanon and Dapna (1998) and Barfield (1995) found out that the angular velocity in the opening knee joint was the most effective factor in increasing the speed of the foot before hitting the target [38, 39].

Conclusion

According to the results of the research, the angular velocity of the knee joint with the peak velocity of the foot is effective in the optimal and successful implementation of the Judan Mai-Mawashi-Geri technique. Regarding the direct relationship between these two variables in the third method of performing the mentioned skill, it can be said that the third method is the preferred one among the four methods. Finally, it should be noted that the existence of a sequential order of torque in the joints of the proximal to distal limbs is an influential factor in the coordinated and powerful implementation of the Judan Mai-Mawashi-Geri technique.

Authors' Contributions: Conceptualization, SHR and HS.; methodology, SHR, HS, AGR, SN. and A; formal analysis, SHR, and HS.; investigation, SHR and HS; resources, SHR; data curation, SHR, AGR; writing—original draft preparation, SHR. and HS; writing—review and editing, HS; supervision, HS.; project administration, SHR. All authors have read and agreed to the published version of the manuscript.

Funding: This research received no external funding. This study was extracted from the Ph.D. dissertation of the first author at the Department of Sports Biomechanics, Central Tehran Branch, Islamic Azad University, Tehran, Iran.

Institutional Review Board Statement: The study protocol was approved by the Department of Physical Education and Sport Science, Central Tehran Branch, Islamic Azad University (Tehran, Iran).

Informed Consent Statement: Informed consent was obtained from all subjects involved in the study.

Data Availability Statement: The data will be available upon request.

Acknowledgments

We would like to thank the participants as well as those who contributed to the implementation of this study.

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مقایسه‌ی مدل دینامیکی گشتاور و سرعت زاویه‌ای در چهار شیوه‌ی اجرای تکنیک مای ماواشی‌گری جودان کاراته‌کای نخبه‌ی مرد

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چکیده

هدف از انجام مطالعه حاضر، مقایسه‌ی مدل دینامیکی گشتاور و سرعت زاویه‌ای در چهار شیوه‌ی اجرای تکنیک مای‌ماواشی‌گری جودان کاراته‌کای نخبه‌ی مرد بود. ۱۸ کومیته‌رو با میانگین و انحراف معیار سنی ۳/۵±۲۴/۱ سال، با سابقه‌ی حضور ۱/۹۸±۲/۵ سال در اردوی تیم ملی کاراته و با سابقه‌ی۱±۲/۸ سال حضور سوپرلیگ کاراته، قد ۴/۶±۱۷۶/۲ سانتی‌متر و وزن ۶/۵±۷۳/۷ کیلوگرم به صورت هدفمند و داوطلبانه در این پژوهش شرکت کردند. شش مارکر به نقاط آناتومیکی پای ضربه زننده متصل و از چهار شیوه‌ی اجرای تکنیک مای ماواشی‌گری جودان با سه دوربین Hero3 با سرعت تصویر برداری ۲۴۰ فریم بر ثانیه فیلم‌برداری شد. با استفاده از نرم افزار Skillspector.1.3.2 مختصات مفصل‌ها (XY) بدست آمد و با استفاده از نرم افزار مت‌لب، مدل دینامیکی ساخته شد. پس از اطمینان از نرمال بودن توزیع داده‌ها، از آزمون تحلیل واریانس یک طرفه و آزمون تعقیبی بونفرونی در سطح ($p \leq ۰/۰۵$) برای تحلیل آماری استفاده شد. نتایج پژوهش اختلاف معنی‌داری در حداکثر گشتاور و حداکثر سرعت زاویه‌ای مفاصل لگن، زانو و مچ‌پا درچهار شیوه‌ی اجرای تکنیک مای ماواشی گری جودان را نشان داد. باتوجه به نتایج پژوهش، ضمن تاکید بر ترتیب توالی وار گشتاور مفاصل اندام پروگزیمال به دیستال، در اجرای بهینه هماهنگ و پر قدرت تکنیک مای ماواشی‌گری جودان، از آنجایی که سرعت زاویه‌ای مفصل زانو با سرعت اوج پا رابطه‌ی مستقیم دارد شیوه‌ی سومین اجرای مهارت تکنیک مای ماواشی‌گری جودان، نسبت به سه شیوه دیگر توصیه می شود.

واژ های کلیدی: کاراته، مدل دینامیکی، مای‌ماواشی‌گری جودان، گشتاور، سرعت زاویه‌ای