KINEMATICS CHARACTERISATION OF DEFLECTION TECHNIQUE IN SENI SILAT CEKAK USING MOTION CAPTURE ANALYSIS

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ABSTRACT

This study investigates the effectiveness and kinematics of Kaedah A, a deflection technique in Seni Silat Cekak Malaysia (SSCM). As the scientific research on Malay Martial Arts (Silat) is limited, this study aims to analyze the execution time of Kaedah A and presents its kinematic profile. Twenty experienced SSCM practitioners performed Kaedah A, which was captured using a motion capture system (Microsoft Kinect via Cekak Visual 3D v1.0) at 30 frames per second. The captured hand positional data was analyzed to determine the hand's trajectory, velocity, and execution time. Results indicated that Kaedah A can be executed in less than 0.1 seconds, demonstrating its potential for rapid self-defense. The maximum average hand velocity was 5.02 m/s. Statistical analysis of kinematic variables, including velocity components, execution time and elbow joint angle, revealed normal distributions. The findings of this study contribute to a deeper understanding of SSCM techniques and its potential applications in self-defense.

Keywords: *Motion capture, Microsoft Kinect, Cekak Visual, Kinematics.*

1.0 INTRODUCTION

A punch delivers rapid force to an opponent, typically reaching its target within 0.1 seconds [1]. Given the estimated minimum human reaction time of 0.18 seconds, effectively defending against an unexpected punch appears to be a significant challenge. Current research on defensive techniques is limited. Even more, previous studies have even suggested that the techniques are inadequate for self-defense [2]. This investigation is among pioneering effort to understand the biomechanics of *Kaedah A*, one of defensive technique in Seni Silat Cekak Malaysia [3].

Seni Silat Cekak Malaysia (SSCM) is a Traditional Malay Martial Art focused on self-defense, emphasizing defensive techniques. It trains practitioners to effectively counter any attack. SSCM employs four primary deflection techniques (Kaedah A, Kaedah B, Kaedah C, and Kaedah D) as the foundation of its defensive strategies. These techniques can neutralize attacks depending on the location of the point of attack. While SSCM

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effectiveness is acknowledged by the practitioners, a scientific understanding of its mechanics of movement remains limited. This is a common challenge not only for SSCM but also for other combat sports like Taekwondo, where the quantification and performance analysis of techniques, such as striking velocity and impact force, are relatively unexplored [4]-[5]. This study aims to bridge that gap by characterizing the kinematics of *Kaedah A* using motion capture analysis.

Motion capture technology allows researchers to record the three-dimensional movement of the human body using specialized cameras and sensors [6]. Marker-based or markerless system meticulously tracks the body's position and orientation throughout the execution of a technique. This data is then analyzed to reveal the precise movement patterns, velocities, and joint angles involved. In the context of *Kaedah A*, motion capture can provide valuable insights into the speed and efficiency of the deflection that contribute to its effectiveness. By employing motion capture, this quantifies the movement, allowing for a more objective and detailed understanding of how *Kaedah A* works.

Most assessments in the field of martial art biomechanics studied some characteristics such as the speed [7]– [10], execution time [11], [12] and impact force [11], [13]-[15]. The reported characterisation as well contributes another area (structure of movement) [16]. Classification of technique execution into phases could assist the practitioner to enhance their understanding on how to execute the technique properly, thus improving their physical skill [16]– [20]. In terms of martial arts style involved in the study, common techniques selected are Taekwondo [20]-[28], Judo [29]-[31], Karate [11], [32]-[34] and Boxing [8], [9], [35], [36]. In this aspect, should be indicated that biomechanics research related to Silat (Malay Martial Art) biomechanics is still in its early stages and very few in research publications.

The purpose of this study was, therefore, to i) analyse the effectiveness of *Kaedah A* based on the total time of execution and ii) to present the kinematic of the *Kaedah A* performed by 20 experienced SSCM practitioner by quantifying the technique using 3D motion capture technology. The trajectory mapping and kinematics data as well will be used to classify the movement into phases (structure of movement). This reported work is novel as no study on any Malay Martial Art (Silat) movement classification has been reported. The finding was expected to provide better interpretation towards SSCM's philosophy on emphasizing proper technique execution instead of physical advantage (muscular strength) to dominate a confrontation.

2.0 METHODOLOGY

To characterize the kinematics of *Kaedah A*, this work employed a motion capture analysis approach.

2.1 Subjects

Twenty males (height: 168.35 ± 5.90, weight: 77.35 ± 21.70) were recruited from Kelas Latihan Cekak Universiti Teknologi MARA. The subjects had been practicing SSCM, completed the syllabus and prepared for physical test to obtain the primary certificate of Seni Silat Cekak Malaysia (Ujian Sijil Rendah Silat Cekak). For each participant, the anthropometric data were collected, and the subjects were required to wear tight-fitting body garments to ascertain a better body shape recognition by the Microsoft Kinect sensor. Informed consent was obtained and descriptive instruction about the procedures has been given to the subjects prior to their participation. This study was approved by the UiTM Research Ethics Committee.

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2.2 Equipment

In this work, Cekak Visual 3D v1.0 (CV3D) was utilized to provide the positional data. CV3D was developed for the use of Seni Silat Cekak Malaysia (SSCM) practitioners (ref) and is able to operate at a speed of 30fps. It is operated using the integration of Matlab GUI and Microsoft Kinect. CV3D is a portable system which offers a simpler and faster set up yet can track up to twenty body landmarks. The system is user-friendly as the installation process is easier and does not involve placement of markers on the subject's body. Thus, it is expected to give better data acquisition since it does not limit the practitioner's movement.

2.3 Data Collection

The measuring system (CV3D) was calibrated before each assessment and procedures. Calibration is essential because it relates the output of a measuring instrument with the true value and provides the allowable deviation from a true perspective model [37] - [39]. The task was to characterise Kaedah A. The subjects were allotted 5-minutes stretching and warm up session for them to prepare themselves and become comfortable with the task. The execution was accomplished by all subjects start from a static upright standing position and facing the sensor at a distance of > 2.5m. From this position, subjects were instructed to perform their maximum effort of Kaedah A with imaginary incoming force (punch) at the middle of their thorax area. To obtain optimum results and simulate real condition, the subjects were instructed to execute Kaedah A immediately (as fast as they could) when the command was given by the instructor. This technique was executed with the left hand as a reaction toward an imaginary incoming force from a right-handed opponent. They were asked to perform a thrice repetition [16] of Kaedah A to observe repeatability and each movement was then captured by Cekak Visual 3D v1.0.

2.4 Data Analysis

Analyses of data were conducted on kinematic parameters within the range of onset of motion and point of impact. The trajectory mapping method was performed in order to identify time of execution (ToE) and motion representation [39]. Based on the trajectory mapping, the initial point, t_i is identified when the left hand starts moving; and the impact point is at the intersection position, tip of the hand with the punch concentration point (overlapping of the coordinate data). The punch concentration point was obtained using Equation (1) below:

$$X_c = \left(\frac{X_{LS} - X_{RS}}{2}\right) + X_{LS} \tag{1}$$

For each trial, the time elapsed between these two points is defined as the time of execution of Kaedah A (ToE) as indicated in equation (2). This information is crucial as it is one of the important aspects that gives the competitor the advantage.

$$\Delta t = t_{ip} - t_i \tag{2}$$

Kinematic data such as positional changes, velocities, acceleration and angle of projection, were calculated based on data collected from CV3D. MATLAB function was used to develop a function capable of analysing the motion data captured by the system. Data processing was conducted on motion data within the range of onset of the motion and point after impact. Point after impact was defined as the moment after contact until the subject's hand stops the execution. The average velocity data from the execution indicated that either y axis or x axis component dominates due to the trajectory of the technique executed. The most effective way to consider all axes into account is to calculate the Root Mean Square of all three axes.

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Another kinematic variable considered in this work is the joint angle measurement during the execution. The elbow angle for each frame was measured since it is a critical joint movement in *Kaedah A* execution. The determination was made to identify whether the rate of movement reaches and goes beyond the limited and abnormal values which could lead to injury to the practitioner which applied the defensive technique *(Kaedah A)*. Line segments of the lower arm and upper arm were obtained using the coordinate data of shoulder, elbow and wrist from the motion capture procedure.

2.5 Statistical Analysis

For the recorded parameters the means values and standard deviations (SD) were calculated using standard statistical procedure. The Shapiro-Wilks tests were used to test the normality distribution. All the statistical calculations were carried out with the use of MS Excel.

3.0 RESULTS & DISCUSSION

Figure 1 & 2 shows the trajectory mapping for the repetition of hand movements in sagittal plane and in three dimensional (average). The data values were obtained from the CV3D for *Kaedah A's* left-hand execution. In order to reduce the nuisance factor, the movements were repeated three times by each practitioner. Since the variances of the repeated data were not significant, the average value of each data was then calculated to observe the trajectory pattern for the execution of Kaedah A. A three-dimensional (3D) trajectory of Kaedah A execution was also obtained using Matlab to get a better insight into multi-planar movement of the motion.

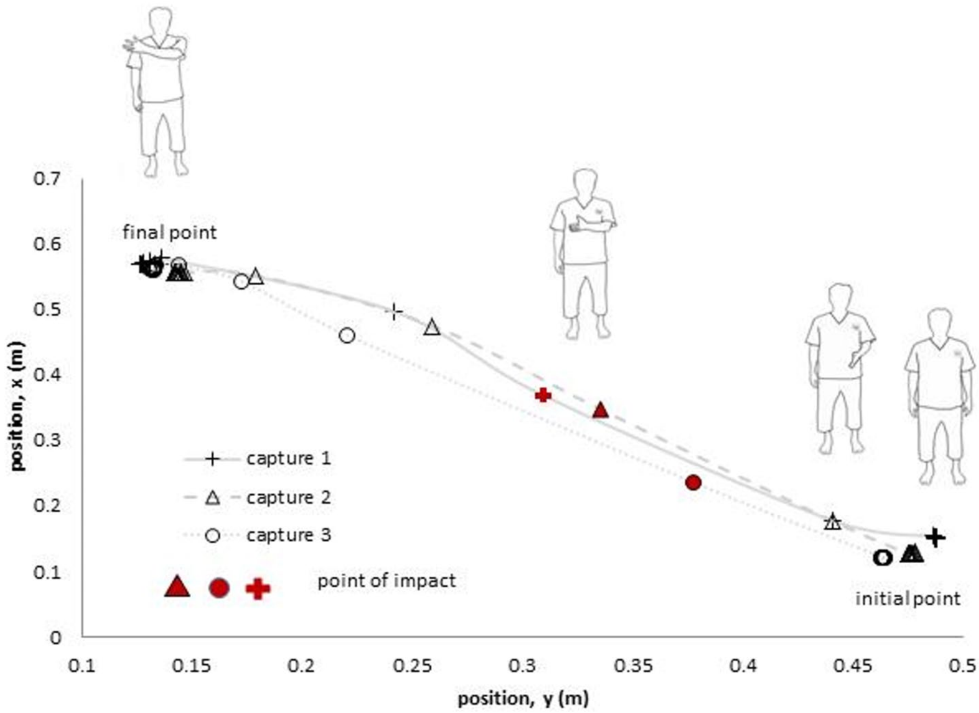

Figure 1: Subject hand trajectory mapping in the sagittal plane

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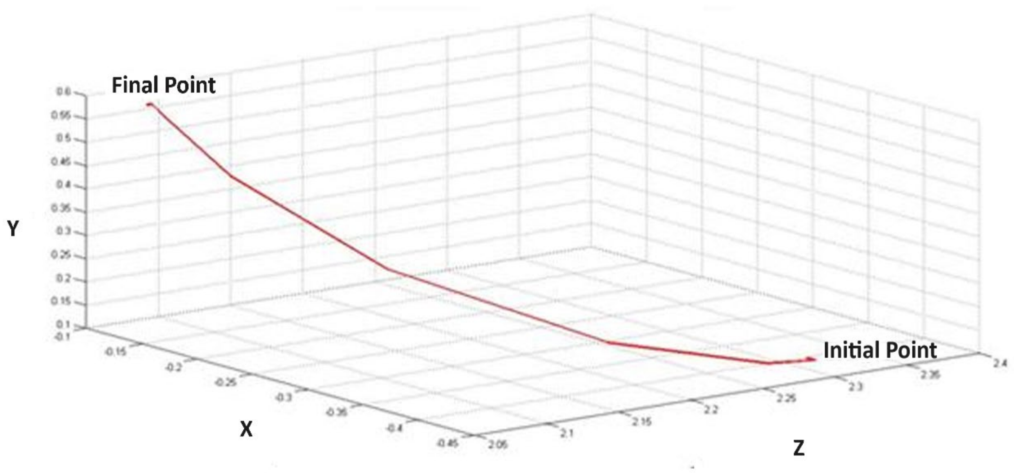

Figure 2: Hand trajectory during *Kaedah A* execution in three dimensional

3.1 Total Time of Execution of *Kaedah A*

The trajectory mapping graph provides the information on the initial and intersection points for ToE calculation. The initial point is identified when the hand starts moving; identified at t_i= 0.033s and the impact point is at the intersection position of the hand with the punch concentration point. The average value for Kaedah A time of execution (ToE) was found to be 0.096s (less than 0.1s). The ToE obtained from the study indicates that Kaedah A met the main criteria for a technique to be established as an effective reaction towards a punch (the execution time must be less than 0.1s). In comparison with the total time to react for a normal human (0.18s), Kaedah A has eliminated 0.05s which would have consisted of the time allocated for thinking of the best reaction and reduced the time to start moving due to the constant training. Based on the calculated average ToE (0.096s), the point of impact point for each average trajectory (three captures) was identified.

Initial point (t_i) was identified at the beginning of the hand movement, while the final point (t_f) was identified when the hand stop moving. Both points were identified by observing the graph trajectory mapping. Whereas the impact point (tip) was identified 0.096s after the initial point.

3.2 Kinematics Description

The trajectory data was then differentiated with respect to time to obtain the velocity profile of the hand motion. Figure 3 illustrates the positional first and second derivatives against time graphs of the hand movement upon the execution of Kaedah A. Figure 3 demonstrates how the hand velocities change during the execution of Kaedah A. It can be observed that velocity starts from 0 m/s, which denotes the stance posture (in which hands are stationary and practitioner are in preparatory phase). The graph also shows that the execution produced a bell-shaped velocity profile, speed up at the initial phase and achieved the average maximum velocity, V_{max} ave of is 5.02 m/s.

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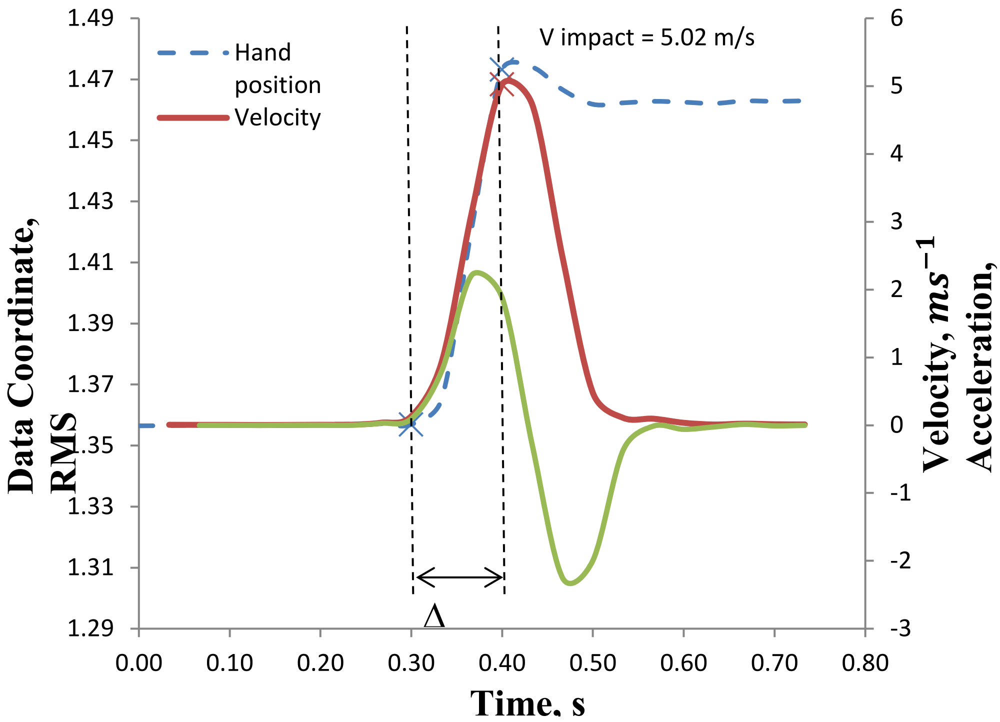

Figure 3: Hand position data, velocity and acceleration for *Kaedah A* execution

While the acceleration-time graph for *Kaedah A* can be described as two events. Positive acceleration indicates acceleration in the direction of elbow flexion, while negative acceleration indicates acceleration in the direction of elbow extension.

Statistical descriptive (mean and standard deviation, minimum and maximum) of specific kinematic variables which is the maximum velocity (V_x, V_y, V_z), Total Time of Execution (TToE), angle of projection and joint angle (Elbow) were presented in Table 1. The preliminary analysis (Shapiro Wilk) showed a normal distribution of all the considered variables. All data are normally distributed (retain the null hypothesis) since the p-value > 0.05. Velocity $V_{x\ max}$ is the velocity at which the hand approaches the imaginary target laterally while velocity V_y max is the velocity at which the practitioner lifted his hand in upwards direction.

Table 1: Selected kinematic parameter (Mean ± SD) from ready position up to moment of impact

Variable	Mean ±SD	Min to max
Total time of Execution (s)	0.096 ± 0.022	0.044 - 0.148
V_x max (m/s)	2.940 ± 0.671	1.993 - 5.158
V_y max (m/s)	4.610 ± 0.549	3.875 - 5.989
V_z max (m/s)	1.011 ± 0.534	3.004 - 3.846
Angle of projection, θ_{exe} (°)	31.86 ± 2.94	23.73 - 39.62
Elbow Angle, θ min (°)	19.54 ± 1.36	12.12 - 28.12
Elbow Angle, θ max (°)	78.72 ± 4.16	61.16 - 107.05
Elbow Angle, ROM (°)	59.19 ± 4.16	91.19 - 40.45

To ensure that the Kaedah A execution is safe to be executed and does not cause strain towards the elbow of the practitioner, the elbow angle, θ was calculated. The calculated elbow angle and its derivation (angular velocity, angular acceleration) are presented in Figure 4.

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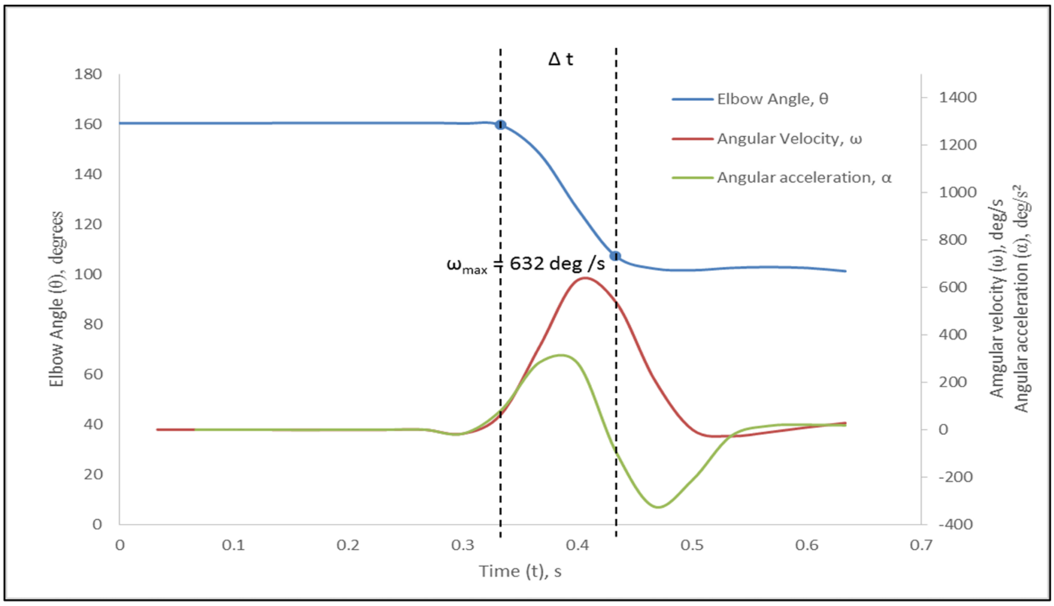

Figure 4: Angular displacement, velocity and acceleration of elbow extension/flexion movement in *Kaedah A* execution

The determination was made to identify whether the rate of movement reaches and goes beyond the limit of abnormal values which could lead to injury to the practitioner which apply the defensive technique *(Kaedah A)*. According to the angular displacement, velocity and acceleration profile plotted in Figure 4, the kinematic sequence of the segmental movements in the execution of *Kaedah A* begin with the forearm pronation, followed then by the forearm rotation and elbow flexion which begin at t > 0.03s. The execution ends with elbow extension and forearm in supine position. The maximum elbow angle and minimum elbow angle during the flex gave the maximum ROM of 60° which is within normal functional range (30° to 130°).

3.3 Kinematic Parameter Comparison

A comparison with previous investigations reveals discrepancies in the measured total time of execution and average maximum velocity [40]. While prior research reported a shorter execution time of 0.060 s and a higher average maximum velocity of 5.42 m/s, the current study reported values of 0.096 s and 5.02 m/s, respectively. Despite the use of identical motion sensors, these variances may be due to variations in data processing software used and numbers of respondents involved. This study expanded upon previous work by incorporating a detailed kinematic analysis of elbow angle during extension and flexion, providing a more comprehensive understanding of the technique's execution.

4.0 CONCLUSION

The purpose of this study was to understand the kinematic characteristics of *Kaedah A* to demonstrate the applicability of this technique. The result and consideration presented might be used in comparative studies and indicate a way forward for future research. It was concluded from the findings that:

i. The objectives in analysing the efficacy of Kaedah A based on the total execution time as well as in describing the kinematic characteristics of the hand movement upon its execution have been successfully achieved.

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ii. This work serves as an initiative in establishing data gathering and processing methods as a form of benchmarking to generate comparable results for future works.

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CONFLICT OF INTEREST

The author declares that there is no conflict of interest regarding the publication of this paper.

REFERENCES

[1] Emmermacher, P. (2005). Acceleration course of fist push of Gyaku-zuki. *International Symposium on Biomechanics in Sports*, 844–847.
[2] Wąsik, J. (2009). Chosen aspects of physics in martial arts. *Archive of Budo, 5*(4), 11–216.
[3] Mustapha, G., Wan Sulaiman, W. R. W. A. A. M., Mohd Yahya, N. H., & Mahmud, J. (2014). Kinematics and efficacy analysis of the Seni Silat Cekak Malaysia (Kaedah A). *Applied Mechanics and Materials, 680*, 267–270.
[4] Lenetsky, S., Uthoff, A., Coyne, J., & Cronin, J. (2022). A review of striking force in full-contact combat sport athletes: Methods of assessment. *Strength & Conditioning Journal, 44*(1), 71–83.
[5] Corcoran, D., Climstein, M., Whitting, J., & Del Vecchio, L. (2024). Impact force and velocities for kicking strikes in combat sports: A literature review. *Sports, 12*(3), 74. https://doi.org/10.3390/sports12030074
[6] Halim, A. H. A., *et al.* (2024). Training efficiency application for Buah Pertama Seni Silat Cekak Malaysia using motion capture approach. *2nd International Conference on Innovation and Technology in Sports, ICITS 2023*, Bukit Jalil, Malaysia.
[7] Wąsik, J. (2015). Kinematics of Taekwon-do front kick. *Archives of Budo Science of Martial Arts and Extreme Sports, 11*, 23–29.
[8] Kim, D., & Thiel, D. V. (2015). Hand speed measurement in boxing. *Procedia Engineering, 112*, 502–506.
[9] Cheraghi, M., Alinejad, H. A., Arshi, A. R., & Shirzad, E. (2014). Kinematics of straight right punch in boxing. *Annals of Applied Sport Science, 2*(2), 39–50.
[10] Estevan, I., Jandacka, D., & Falco, C. (2013). Effect of stance position on kick performance in taekwondo. *Journal of Sports Sciences, 31*(16), 1815.
[11] VencesBrito, A. M., *et al.* (2011). Kinematic and electromyographic analyses of a karate punch. *Journal of Electromyography and Kinesiology, 21*(6), 1023–1029.
[12] Falco, C., Molina-García, J., Álvarez, O., & Estevan, I. (2013). Effects of target distance on select biomechanical parameters in taekwondo roundhouse kick. *Sports Biomechanics, 12*(4), 381–388.
[13] Cheraghi, M., Alinejad, H. A., Arshi, A. R., & Shirzad, E. (2014). Kinematics of straight right punch in boxing. *Annals of Applied Sport Science, 2*(2), 39–50.
[14] Wąsik, J. (2007). Power breaking in taekwon-do - physical analysis. *Archives of Budo, 3*, 68–71.
[15] Falco, C., *et al.* (2009). Influence of the distance in a roundhouse kick's execution time and impact force in Taekwondo. *Journal of Biomechanics, 42*(3), 242–248.
[16] Wasik, J. (2011). Kinematics and kinetics of Taekwondo side kick. *Journal of Human Kinetics, 30*, 13–20.
[17] Wąsik, J., Ferreira da Silva Santos, J., & Franchini, E. (2013). Movement structure and kinetics of the traditional straight punch: Measurements in taekwon-do athletes. *Journal of Martial Arts Anthropology, 13*(1), 42–47.
[18] Pyke, F. (2013). *Coaching excellence*. Human Kinetics.
[19] Bartlett, R. (1997). *Introduction to sports biomechanics*.

DOI 10.11113/jm.v48.575

[20] Szerdiova, L., Simsik, D., & Dolna, Z. (2010). Standing long jump and study of movement dynamics using human motion analysis. *8th IEEE International Symposium on Applied Machine Intelligence and Informatics*, 263–266.
[21] Pearson, J. N. (1997). *Kinematics and kinetics of Taekwon-Do turning kick*.
[22] Estevan, I., *et al.* (2011). Impact force and time analysis influenced by execution distance in a roundhouse kick to the head in Taekwondo. *Journal of Strength and Conditioning Research, 25*(10), 2851–2856.
[23] Koh, J. O., & Watkinson, E. J. (2002). Video analysis of blows to the head and face at the 1999 World Taekwondo championships. *Journal of Sport Medicine and Physical Fitness, 42*(3), 348.
[24] Wasik, J. (2006). Physical parameters of the rising kick in taekwon-do. *Archives of Budo, 2*, 28–30.
[25] Fife, G. P., O'Sullivan, D., Pieter, W., & Kaminski, T. W. (2013). Effects of taekwondo kicks on head accelerations and injury potential: A pilot study. *International Sport Journal, 14*(2), 53–66.
[26] Bercades, L., & Pieter, W. (2006). A biomechanical analysis of the modified Taekwondo axe kick. *Journal of Asian Martial Arts*.
[27] Moreira, P. V. S., *et al.* (2021). Are isokinetic leg torques and kick velocity reliable predictors of competitive level in taekwondo athletes? *PLoS One, 16*(6), e0235582. https://doi.org/10.1371/journal.pone.0235582
[28] Lin, Y. C., *et al.* (2023). Differences in kick-leg kinematics in various side-kick heights. *European Journal of Sport Science, 23*(11), 2170–2177. https://doi.org/10.1080/17461391.2023.2213189
[29] Imamura, R. T., Iteya, M., Hreljac, A., & Escamilla, R. F. (2007). A kinematic comparison of the judo throw Harai-goshi during competitive and non-competitive conditions. *Journal of Sports Science and Medicine, 6*, 15.
[30] Zaggelidis, G., & Lazaridis, S. (2012). Evaluation of vertical ground reaction forces in three different judo hip throwing techniques in novice and advanced Greek athletes. *Medicina Dello Sport, 65*(1), 29–36.
[31] Imamura, R., Hreljac, A., & Escamilla, R. (2006). A three-dimensional analysis of the center of mass for three different judo throwing techniques. *Journal of Sports Science and Medicine, 5*(SI), 122–131.
[32] Dworak, L. B., Oziewiecki, K., Mclczynski, J., & Education, P. (2005). *Characteristics of kinematics and kinetics of strokes in karate - biomechanical approach*.
[33] Quinzi, F., *et al.* (2013). Intra-limb coordination in karate kicking: Effect of impacting or not impacting a target. *Human Movement Science, 33*, 108–119.
[34] Gianino, C. (2010). Physics of Karate. Kinematics analysis of karate techniques by a digital movie camera. *Physics Education, 4*(1), 32–34.
[35] Sidthilaw, S. (1996). *Kinetic and kinematic analysis of Thai boxing roundhouse kicks*.
[36] Stojsih, S. (2010). *The biomechanics of amateur boxers* [Doctoral dissertation, Wayne State University].
[37] Gruen, A. (1997). Fundamentals of videogrammetry - A review. *Human Movement Science, 16*, 155–187.
[38] Bruton, A., Conway, J. H., & Holgate, S. T. (2000). Reliability: What is it and how is it measured? *Physiotherapy, 86*(2), 94–99.
[39] Jounghoon, B., David, H., & Hanseok, K. (2014). Rule-based trajectory segmentation for modeling hand motion trajectory. *Pattern Recognition, 47*, 1586–1601.
[40] Mustapha, G., Zakaria, M., Wan Sulaiman, W. R. W., & Mahmud, J. (2014). The mechanical aspects of martial arts: Total time of execution and kinematics of Kaedah A. *Proceedings of the International Colloquium on Sports Science, Exercise, Engineering and Technology 2014 (ICoSSEET 2014)*, 647.

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