Original Article

doi: 10.16926/par.2025.13.14

Target Kinematic Effect in Kyokushin Karate Front Kicks: An Analysis of Velocity, Acceleration, and Muscle Activation Patterns

Dariusz Mosler ABCDE, **Tomasz Góra** ADE, **Jacek Kaczmarski** AB,
Monika Błaszczyszyn DE, **Marcin Chociaj** D, **Zbigniew Borysiuk** DE

[1] Instutute of Physical Culture Science, Jan Dlugosz University in Częstochowa, Poland
[2] Faculty of Physical Education and Physiotherapy, Opole University of Technology, Poland

Authors' Contribution: A – Study Design, B – Data Collection, C – Statistical Analysis, D – Manuscript Preparation, E – Funds Collection

Abstract: Background: Karate training involves extensive practice without physical targets. While target kinematic effect has been identified in taekwon-do, this phenomenon remains unexplored in Kyokushin karate. This study aimed to verify the extent of target kinematic effects in Kyokushin practitioners' front kicks through examination of acceleration, angular, and electromyographical data. Material and Methods: Nineteen male Kyokushin practitioners (mean age 27.05 years) participated. Movement data was collected using wireless sEMG system (3000 Hz) and MyoMotion inertial sensors IMU (ang. inertial measurement unit) (200 Hz). Participants performed front kicks under six conditions: before warm-up, after warm-up, and after shadow sparring, each with and without a target shield. Seven muscles were monitored via sEMG, while four inertial sensors tracked movement of the pelvis, thigh, shank, and foot. Results: Significant velocity differences emerged after shadow sparring (16.91 m/s target vs. 14.39 m/s non-target, $p = 0.045$). Foot segment acceleration nearly doubled with target presence (57.83 m/s^2 to 99.27 m/s^2). Angular measurements showed consistent adaptations across body segments when striking the target. EMG analysis revealed limited differences, with only the rectus femoris showing significant changes in the initial phase. Conclusion: The study confirmed target kinematic effect in Kyokushin practitioners, manifesting through substantial changes in acceleration and joint angles, particularly in distal segments. Limited EMG differences suggest consistent muscle activation patterns despite technique modifications. These findings indicate air-striking practice may not fully replicate the biomechanical demands of striking physical targets.

Keywords: Martial Arts, Biomechanical Phenomena, Electromyography, Athletic Performance

Corresponding author: Dariusz Mosler, email: dariusz.mosler@gmail.com

Recevied: 9.01.2025; Accepted: 15.01.2025; Published online: 16.01.2025

Citation: Mosler D, Góra T, Kaczmarski J, Błaszczyszyn M, Chociaj M, Borysiuk Z. Target Kinematic Effect in Kyokushin Karate Front Kicks: An Analysis of Velocity, Acceleration, and Muscle Activation Patterns. Phys Act Rev 2025; 13(1): 156-166. doi: 10.16926/par.2025.13.14

INTRODUCTION

Karate is an martial art originated from Okinawa, Japan. There are numerous branches, which evolved over last century. Upon those branches, there are two major one. One is traditional karate, that is expressed today but styles, which compete under World Karate Federation, and the other is Kyokushin karate founded by master Oyama and styles derived from it by his direct students [1]. Kyokushin style focus on physical capabilities of practitioners, especially their endurance [2], pain resistance [3] and overall direct approach to opponents [4]. It differs from traditional approach that are more prone to dodges or sophisticated techniques. Competition regime also makes impact on the style of fighting. In traditional Kyokushin there, hand strikes to a head was forbidden, only with foot[5]. Participants have headgear, but they did not have gloves. To end a fight immediately, one participant need to have constructive hit to a head of opponent. To achieve it, karateka usually use a combination of techniques, firstly trying to lower a guard of opponent. The best way to do this is to strike torso with front kick [6]. This linear kick with push-like movement is fast, suitable for striking middle part of the body.

As this technique is one of the most popular one its properties will be explored from perspective of practice. Karate practitioners spends considerable time doing kicks into an air [7]. Especially in a massive practice. Practicing in pairs or sparrings is later method. In traditional training, time spend on no target practicing is in high proportion to overall practice time. Previous studies with similar martial art – taekwon-do pointed out that phenomenon of target kinematic effect should be considered while assessing proportion of different training modalities [8]. However, target kinematic effect, which could be explained as phenomenon of different kinematic expressions of strike depending on target type, were not investigated outside of taekwon-do spatial-temporal data. In that conception, moment of maximum velocity of a strike, which occurs just before on at the moment of contact with target, could be seen as performance benchmark [9]. In non-target kicks to air, it is a moment at the end of technique execution, before limb is starting to go back to initial position.

Moreover, state of the art biomechanical analysis of includes not only spatial-temporal data like displacement of markers in time by systems like Qualisys [10] or Vicon [11] or inetrial measurement units (IMUs) [12], but also surface electromyography (sEMG) [13]. Modern systems are powerful enough to incorporate both types of data, which gives full insight into how muscle activity changes over time with corresponding body positions in space.

The aim of this study is to verify to what extent target kinematic effects occurs in a front kick delivered by Kyokushin practitioners, expressed by examination of acceleration, angular and electromyographical data. We hypothesized that there will be some significant differences between target and no-target circumstance of a kicks.

MATERIAL AND METHODS

Participants

The study examined anthropometric characteristics and training advancement of 19 kyokushin karate athletes (all male). The participants' age ranged from 18 to 55 years (M = 27.05 years, SD = 10.38), with the distribution skewed towards younger ages as shown by the median of 22 years. Physical characteristics analysis revealed mean body mass of 80.13 kg (SD = 12.90) and mean height of 1.81 m (SD = 0.05), resulting in a mean BMI of 24.49 (SD = 3.39). The cohort included practitioners from 6th kyu to 3rd dan, with 2nd kyu (31.6% of participants) and 6th kyu (26.3%) being the most common ranks. The anthropometric measurements included maximum body mass of 114 kg and maximum height of 1.96 m, while BMI values ranged from 20.23 to 35.19.

Surface Electromyography (sEMG) and kinematic measurement

The study utilized a wireless surface electromyography (sEMG) system manufactured by Noraxon, Scottsdale, USA, model DTS (Direct Transmission System), operating at a sampling frequency of 3000 Hz. This system records the bioelectrical activity of muscles. The EMG signal was transmitted wirelessly to a computer for processing and analysis using the myoResearch 3.16 software.

The recorded signals underwent band-pass filtering with cut-off frequencies set between 80 and 250 Hz. Subsequently, the data was smoothed using the RMS (Root Mean Square) algorithm with a 100 ms time window. Pre-gelled, self-adhesive surface electrodes (Ag/AgCl, manufactured by Sorimex) were placed along the longitudinal axis of the muscle, between the motor point and tendon attachments, in line with the SENIAM guidelines [14].

Before electrode placement, the skin was carefully prepared by removing hair, disinfecting, and drying the area. The sensors were affixed to the body using double-sided adhesive tape, and the setup, including electrodes, was secured with straps provided by Noraxon. In total, seven sensors were positioned for each analyzed muscle. Seven muscles of the right lower limb were evaluated: rectus femoris, biceps femoris, vastus lateralis obliquus, lateral gastrocnemius, medial gastrocnemius, soleus, and tibialis anterior.

To measure joint angles and the movement, a wireless inertial sensor system by Noraxon, model MyoMotion, was employed. The system consists of five IMU sensors operating at a sampling frequency of 200 Hz. Signal processing and analysis were conducted using the myoResearch 3.16 software. Four inertial sensors were attached to the participant's body using straps provided by Noraxon. On the pelvis at the sacral bone, on the middle of tight, middle of shank and dorsal part of foot. Sensors are presented on figure 1.

Protocol

The front kick, or *Mae Geri*, in karate involves complex biomechanical coordination, relying on precise interactions between the lower limb segments and the core to generate force and maintain balance. The movement begins with hip flexion and knee extension, facilitated primarily by the rectus femoris and iliopsoas muscles, while the gastrocnemius stabilizes the ankle in plantarflexion for impact. Effective execution requires a rapid transfer of angular momentum from the hip joint to the foot, optimizing the kinetic chain to maximize strike velocity. Simultaneously, the contralateral leg and core muscles, including the obliques and erector spinae, provide stabilization, ensuring dynamic balance and minimizing energy dissipation. This coordinated action not only increases kick precision and power but also minimizes injury risk through controlled deceleration during the retraction phase.

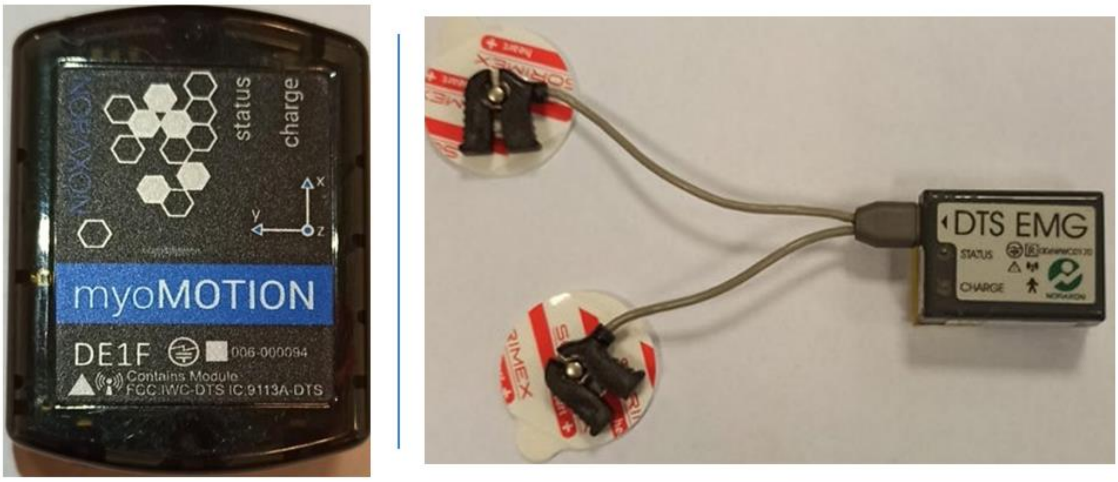

Figure 1. Sensors for electromyography (left) and acceleration data measurement used in this study.

Each participant was instructed to perform three consecutive kicks under three different conditions: before the warm-up, after the warm-up, and after "shadow sparring." In each condition, the participant executed three kicks into the air and three kicks targeting a pad. The target area for the kicks was the *chudan*, the middle section of the body above the waist and up to the neck.

When kicking the pad, participants struck a target held by the researcher. The action was initiated by the movement of the pad, allowing the reaction time to be measured. The results from the three kicks in each condition were averaged, providing a single score per participant: P1 and T1 (before the warm-up), P2 and T2 (after the warm-up), and P3 and T3 (after shadow sparring). Graphical representation of study schema is presented on figure 2.

Statistical analysis

In this study, a Jupyter Notebook was utilized to process and analyze kinematic and electromyographic (EMG) data collected during experimental sessions. The analytical workflow leveraged Python and a suite of libraries to ensure efficient data handling and computation. Pandas was used for data loading, cleaning, and manipulation, facilitating the organization and selection of relevant columns, such as accelerometer and EMG signals. Mathematical operations, including the computation of velocity and resultant accelerations, were performed using NumPy. Visualization of results was conducted using Matplotlib and Seaborn, enabling detailed exploration of trends and extracted features.

The preprocessing phase involved addressing missing values and ensuring consistency within the dataset. Accelerometer data, recorded in milli-g (mG), was converted into standard SI units of acceleration (m/s^2) by multiplying each value by the gravitational constant. Subsequently, velocity was computed from the acceleration data through numerical integration. Using the trapezoidal integration method (numpy.trapz), velocity values were calculated for each time interval, assuming a known time step derived from the sampling rate. This approach provided a continuous velocity profile for each body segment based on the accelerometer data. Peaks in velocity were identified using a peak detection algorithm, marking moments of significant dynamic activity during the analyzed movements.

At the identified peaks, corresponding accelerometer and EMG data were extracted for further analysis. Resultant accelerations were computed to quantify the overall magnitude of dynamic activity for each body segment. These resultant values were derived using the Euclidean norm, combining the X, Y, and Z components of acceleration for each segment (e.g., pelvis, thigh, shank, foot). This provided a single scalar measure representing the total acceleration experienced by a segment at any given moment.

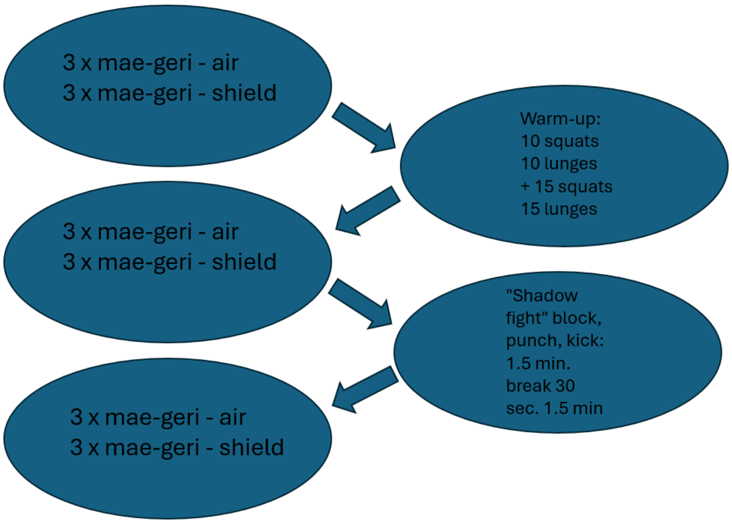

Figure 2. Representation of study protocol.

The workflow also included data selection and organization steps. Subsets of data corresponding to the identified peaks were compiled into tabular formats for detailed examination. These included raw accelerometer and EMG data, computed velocities, and resultant accelerations. To facilitate subsequent analysis and reporting, the processed data was exported into an Excel file using the Pandas library with the openpyxl engine. Statistical analysis involves standard computation of mean, standard deviation and finding minimum and maximum values. As most columns presents non-normal distribution, to find differences between independent variables by target type, U-Mann Whitney test was used.

Ethics

The Ethics Committee for Scientific Research at the Opole University of Technology has reviewed and approved the research project titled "The Movement Pattern of the Mae-Geri Kick at Various Stages of Training in Kyokushin Karate" on 15 March 2023 with number 4/2023.

RESULTS

The mean front kick velocities of karatekas in the no-target circumstances were 15.36 m/s for P1 (N=20), 15.88 m/s for P2 (N=18), and 14.39 m/s for P3 (N=22). The minimum and maximum recorded velocities were 5.12 m/s to 25.67 m/s for P1, 6.03 m/s to 24.81 m/s for P2, and 4.78 m/s to 26.02 m/s for P3. A U Mann-Whitney test showed no statistically significant differences between P1 and P2 (U = 794.0, p = 0.545) or between P2 and P3 (U = 859.0, p = 0.142). These results indicate consistent performance across the three no-target circumstances in terms of front kick velocity.

The mean front kick velocities of karatekas in the shield target circumstances were 15.92 m/s for T1 (N=19), 16.04 m/s for T2 (N=21), and 16.91 m/s for T3 (N=20). The minimum and maximum recorded velocities ranged from 5.31 m/s to 24.98 m/s for T1, 6.21 m/s to 24.67 m/s for T2, and 5.44 m/s to 26.89 m/s for T3. U Mann-Whitney tests revealed no statistically significant differences between T1 and T2 (U = 951.0, p = 0.885) or between T2 and T3 (U = 790.0, p = 0.556). These results suggest consistent front kick velocities across the shield target circumstances.

A comparison of the no-target and shield target circumstances showed that the mean front kick velocities were 15.36 m/s for P1 (N=20) compared to 15.92 m/s for T1 (N=19), 15.88 m/s for P2 (N=18) compared to 16.04 m/s for T2 (N=21), and 14.39 m/s for P3 (N=22) compared to 16.91 m/s for T3 (N=20). The minimum and maximum velocities were similar across the no-target and shield target circumstances, but a U Mann-Whitney test found no significant differences between P1 and T1 (U = 1024.0, p = 0.720) or P2 and T2 (U = 766.0, p = 0.902). However, a significant difference was observed between P3 and T3 (U = 580.0, p = 0.045) (figure 3).

For the pelvis, the acceleration saw notable growth, particularly in T1, where it rose from 9.83 m/s^2 to 14.38 m/s^2, and in T3, which jumped from 10.71 m/s^2 to 15.89 m/s^2. While T2 also showed an increase, it was not statistically significant. The thigh recorded significant boosts across all comparisons, with the largest change between P1 (33.85 m/s^2) and T1 (45.42 m/s^2). Similar trends were evident in P2 to T2 and P3 to T3, each demonstrating meaningful growth. The shank followed suit, with its most substantial rise in T3, where the mean acceleration increased from 34.89 m/s^2 to 43.12 m/s^2. All phase comparisons for the shank showed significant changes. The foot experienced the most dramatic increases. In T1, the mean acceleration almost doubled, rising from 57.83 m/s^2 to 99.27 m/s^2, while T3 saw another sharp jump from 66.98 m/s^2 to 103.36 m/s^2 (table 1).

For the pelvis, significant changes appeared only in roll angles, with a drop from -1.45° in P2 to -12.11° in T2. Pitch and course angles showed no significant differences, with p-values remaining well above the threshold. The thigh displayed notable shifts in course angles. The most pronounced changes occurred in P2 to T2, where the mean angle increased from -72.11° to -40.86°. Smaller yet significant adjustments were observed in P1 to T1 and P3 to T3, with course angles shifting closer to neutral in both cases. Pitch and roll angles, however, remained stable throughout. For the shank, pitch angles stood out as the primary area of change. From P1 to T1, the angle shifted from -36.47° to -19.32°, while in P2 to T2, it moved from -36.43° to -18.51°. Roll and course angles showed no substantial variation across conditions.

The foot exhibited the most consistent and widespread differences. Pitch angles significantly increased across all comparisons, with the largest adjustment occurring in P3 to T3, where the mean shifted from -52.65° to -31.55°. Roll angles also saw meaningful declines in most phases, particularly in P2 to T2, though no significant change was detected in P3 to T3. Course angles varied less, showing a notable decrease only in P2 to T2 (table 2).

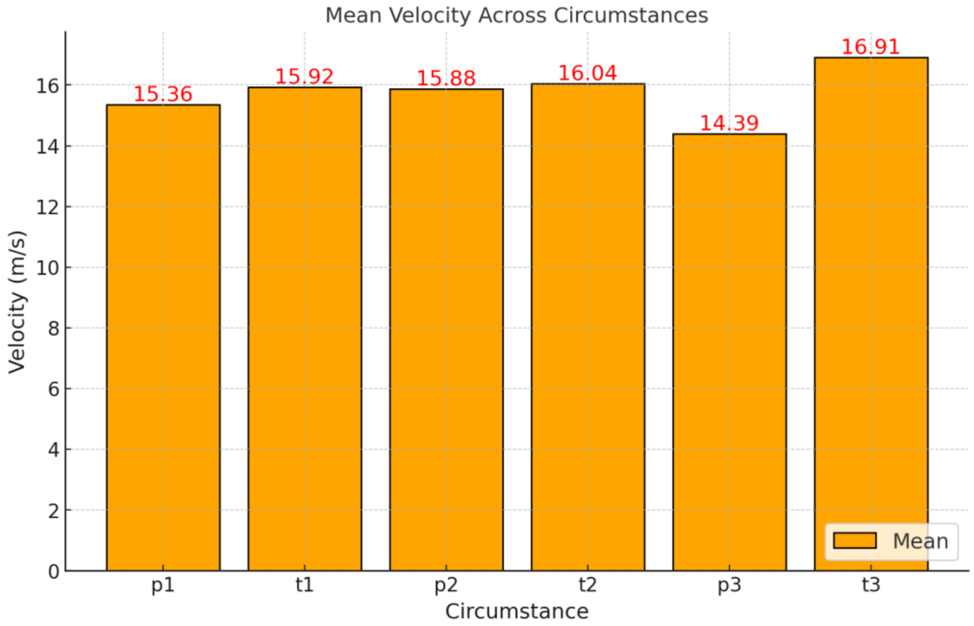

Figure 3. Mean peak velocity data revealed by Kyokushin athletes for each circumstance (p- air, t – shield).

Table 1. Results of participants resultant acceleration values across different measurement circumstances by a body segments.

Segment	Comparison	U Statistic	p-value	Mean P	Mean T
Pelvis	**P1 to T1**	**738.0**	**0.01**	**9.83**	**14.38**
	P2 to T2	623.0	0.127	9.88	15.63
	P3 to T3	**527.0**	**0.012**	**10.71**	**15.89**
Thigh	**P1 to T1**	**478.0**	**0.0**	**33.85**	**45.42**
	P2 to T2	**429.0**	**0.001**	**35.16**	**44.03**
	P3 to T3	**400.0**	**0.0**	**37.17**	**51.69**
Shank	**P1 to T1**	**622.0**	**0.001**	**31.28**	**40.35**
	P2 to T2	**449.0**	**0.001**	**33.36**	**45.76**
	P3 to T3	**411.0**	**0.0**	**33.66**	**42.92**
Foot	**P1 to T1**	**467.0**	**0.0**	**57.83**	**99.27**
	P2 to T2	684.0	0.354	65.54	79.67
	P3 to T3	**474.0**	**0.002**	**66.98**	**103.36**

Bolded – statistical significance at p<0.05.

Table 2. Comparison of angular velocities at the moment of maximal velocity divided by a body segment.

Comparison	Variable	U Statistic	p-value	Mean P	Mean T	Segment
P1 to T1	Pelvis pitch,deg	992.0	0.545	6.14	10.31	Pelvis
P1 to T1	Pelvis roll,deg	1299.0	0.079	-1.55	-4.18	Pelvis
P1 to T1	Pelvis course,deg	957.0	0.381	-75.82	-85.44	Pelvis
P2 to T2	Pelvis pitch,deg	711.0	0.508	8.45	13.53	Pelvis
P2 to T2	**Pelvis roll,deg**	**1021.0**	**0.018**	**-1.45**	**-12.11**	**Pelvis**
P2 to T2	Pelvis course,deg	772.0	0.949	-73.5	-81.16	Pelvis
P3 to T3	Pelvis pitch,deg	741.0	0.656	8.18	12.61	Pelvis
P3 to T3	Pelvis roll,deg	833.0	0.663	-2.56	-3.92	Pelvis
P3 to T3	Pelvis course,deg	655.0	0.2	-77.1	-86.76	Pelvis
P1 to T1	Thigh pitch RT,deg	1189.0	0.364	13.09	14.25	Thigh
P1 to T1	Thigh roll RT,deg	1056.0	0.911	-14.1	-27.01	Thigh
P1 to T1	**Thigh course RT,deg**	**784.0**	**0.027**	**-75.1**	**-48.2**	**Thigh**
P2 to T2	Thigh pitch RT,deg	836.0	0.579	8.42	11.03	Thigh
P2 to T2	Thigh roll RT,deg	770.0	0.934	-11.77	-27.62	Thigh
P2 to T2	Thigh course RT,deg	579.0	0.05	-72.11	-40.86	Thigh
P3 to T3	Thigh pitch RT,deg	725.0	0.548	6.6	12.58	Thigh
P3 to T3	Thigh roll RT,deg	743.0	0.67	-13.88	-24.17	Thigh
P3 to T3	Thigh course RT,deg	585.0	0.05	-72.73	-53.41	Thigh
P1 to T1	**Shank pitch RT,deg**	**778.0**	**0.024**	**-36.47**	**-19.32**	**Shank**
P1 to T1	Shank roll RT,deg	1144.0	0.576	-11.32	-17.35	Shank
P1 to T1	Shank course RT,deg	1078.0	0.96	-64.03	-74.17	Shank
P2 to T2	**Shank pitch RT,deg**	**559.0**	**0.031**	**-36.43**	**-18.51**	**Shank**
P2 to T2	Shank roll RT,deg	878.0	0.334	-10.16	-20.82	Shank
P2 to T2	Shank course RT,deg	865.0	0.402	-60.37	-72.59	Shank
P3 to T3	Shank pitch RT,deg	693.0	0.362	-40.43	-24.22	Shank
P3 to T3	Shank roll RT,deg	774.0	0.9	-6.71	-13.14	Shank
P3 to T3	Shank course RT,deg	800.0	0.907	-54.32	-63.72	Shank
P1 to T1	**Foot pitch RT,deg**	**687.0**	**0.003**	**-48.61**	**-28.55**	**Foot**
P1 to T1	Foot roll RT,deg	790.0	0.03	-23.91	-15.67	Foot
P1 to T1	Foot course RT,deg	1192.0	0.352	-48.44	-65.05	Foot
P2 to T2	**Foot pitch RT,deg**	**493.0**	**0.005**	**-49.96**	**-29.15**	**Foot**
P2 to T2	**Foot roll RT,deg**	**503.0**	**0.007**	**-25.4**	**-20.23**	**Foot**
P2 to T2	**Foot course RT,deg**	**1009.0**	**0.024**	**-37.56**	**-67.58**	**Foot**
P3 to T3	**Foot pitch RT,deg**	**489.0**	**0.004**	**-52.65**	**-31.55**	**Foot**
P3 to T3	Foot roll RT,deg	633.0	0.135	-18.7	-12.63	Foot
P3 to T3	Foot course RT,deg	860.0	0.485	-51.81	-66.54	Foot

Bolded – statistical significance at $p<0.05$.

The Biceps Femoris showed no significant differences in EM/S activity across comparisons. While mean activity levels fluctuated, such as an increase from -0.76 μV in P1 to 19.02 μV in T1, and a decrease from -5.50 μV in P3 to -62.45 μV in T3, none of these changes reached statistical significance. The Rectus Femoris stood out with a significant increase in activity from -97.17 μV in P1 to 4.98 μV in T1 ($p=0.043$). However, other comparisons, such as P2 to T2 and P3 to T3, showed changes without statistical relevance. For the Vastus Lateralis, EM/S activity showed no significant changes across conditions, despite slight decreases such as from 42.17 μV in P1 to -13.58 μV in T1 and from 30.45 μV in P3 to -2.98 μV in T3.

Table 3. Comparison of electromyography activity of measured muscles at the moment of maximal velocity divided by a body segment.

Comparision	Muscle	U Statistic	p-value	Mean P	Mean T
P1 to T1	BICEPS FEM. RT,uV	897.0	0.18	-0.76	19.02
P3 to T3	BICEPS FEM. RT,uV	882.0	0.362	-5.5	-62.45
P2 to T2	BICEPS FEM. RT,uV	681.0	0.339	-39.24	16.44
P3 to T3	LAT. GASTRO RT,uV	832.0	0.67	13.71	52.88
P1 to T1	LAT. GASTRO RT,uV	1088.0	0.899	26.86	11.62
P2 to T2	LAT. GASTRO RT,uV	948.0	0.098	229.84	-9.56
P1 to T1	MED. GASTRO RT,uV	970.0	0.438	-17.38	-0.05
P3 to T3	MED. GASTRO RT,uV	836.0	0.641	-39.38	-51.43
P2 to T2	MED. GASTRO RT,uV	707.0	0.483	-26.83	19.89
P1 to T1	**RECTUS FEM. RT,uV**	**809.0**	**0.043**	**-97.17**	**4.98**
P3 to T3	RECTUS FEM. RT,uV	861.0	0.479	-7.67	2.36
P2 to T2	RECTUS FEM. RT,uV	729.0	0.627	-37.09	-3.85
P2 to T2	SOLEUS RT,uV	819.0	0.698	-10.16	-34.5
P3 to T3	SOLEUS RT,uV	811.0	0.823	-55.92	-75.61
P1 to T1	SOLEUS RT,uV	1047.0	0.856	-24.73	72.59
P1 to T1	TIB.ANT. RT,uV	1015.0	0.668	16.75	42.71
P3 to T3	TIB.ANT. RT,uV	826.0	0.712	-7.74	-38.74
P2 to T2	TIB.ANT. RT,uV	683.0	0.349	-15.86	-46.0
P3 to T3	VLO RT,uV	763.0	0.816	17.37	17.45
P1 to T1	VLO RT,uV	1185.0	0.381	42.17	-13.58
P2 to T2	VLO RT,uV	912.0	0.194	0.91	-47.54

Bolded – statistical significance at $p<0.05$.

The Tibialis Anterior also demonstrated consistent increases in mean activity, rising from 16.75 μV in P1 to 42.71 μV in T1, but these shifts were not statistically significant. Finally, the Lateral Gastrocnemius showed only minor fluctuations in EM/S activity, with no significant differences. For instance, mean activity dropped slightly from 26.86 μV in P1 to 11.62 μV in T1 and increased marginally from 13.71 μV in P3 to 52.88 μV in T3. The Rectus Femoris was the only muscle with a statistically significant increase in activity, specifically between P1 and T1. All other muscles showed changes that were either small or not statistically significant(table 3).

DISCUSSION

The analysis of kinematic data, along with electromyography at the moment of maximum velocity turns out to be valuable approach. Surprisingly, target kinematic effect, which supposed to occur from the beginning, or as in the case of taekwon-do athletes, was revealed after warm up and shadow fighting drills (circumstance 3). Mentioned taekwon-do athletes studied by Wąsik et al. (2018), had been tested after short warm-up [15]. Moreover, exhibited maximal velocities were much lower than our karate athletes (no more than 11 m/s in mean value for taekwon-do athletes and with karatekas mean more than 15 m/s). However, in other research, authors reported maximal velocities more corresponding to those of taekwon-do athletes [16,17], To add more, in case of front kick, target kinematic effect was reversed, where kicking into an air resulted in higher velocities than those to shield, which is confirmed by systematic review [18]. In our findings, kicking into shield in last circumstance revealed statistically significant difference in favor of kicking into a shield. It was confirmed in a previous research, where karate athletes exhibited front kick velocities at mean over 17 m/s [19], and another indicating that kicks delivered by karatekas are faster than those delivered by taekwon-do athletes [20].

As this study were done with use of accelerometers, analysis of acceleration at a moment of maximum velocity was performed, indicating proximal to distal pattern of movement of martial art kicks, which is concurrent with previous research [21]. As we were unable to find a research with similar acceleration data in full picture, we could only confirmed that one research reported foot maximal acceleration at around 130 m/s2 [20], which match our data. Again, taekwon-do athlete exhibited much lower peak acceleration while kicking into a shield [22], but the difference was that shield was mounted to rigid column, not held by assistant as in our case.

The angular data revealed that, there is difference between mean angle of every segment for no target and shield circumstance. It was not show in every dimension, but at least one per segment showed different alignment. Other researchers took approach to asses angular velocity instead of linear in their works, so there are no works connecting approach to linear velocities and angular alignment of specific body segments. Analysis of results revealed higher roll of pelvic while kicking into a shield, suggesting that there was more body rotation. Tight angles were lower, suggesting adjustment to a target rather than abstract position while kicking into an air, but only during first set of kicks. Shank pitch were statistically different between first and second circumstance, while target effect diminished at third. The most significant results were showed on the foot segment, when differences were shown not only in more axes, but also across all circumstances. It may be to the fact that foot need to prepare for a contact with a target, and could be thrown more deliberately while kicking into an air. Those reasoning finds confirmation in previous research of front kick analysis, but with different approach to ankle measurements [23].

For the electromyographic analysis, there was only one significant difference between rectus femoris muscles activity in a first circumstance. Rest muscles shows different activity patterns, but it turns out that variability was not high enough, therefore we can assume that there was some similarity in activation patterns. Negative values of rectus femoris may indicate strong excentric work, which could be explained that this muscle act as a break to lock knee joint from overextension, as there was no target to stop on. Kicking into a shield requires generating force upon contact to push into a target, therefore there was concentric work of this muscle. We were unable to find similar research to compare results, but other researchers indicates occurrence of co-contraction of rectus femoris with biceps femoris [24], therefore, significant difference should be found also in the biceps femoris in our study. Researchers analyze an electromyographic signals as a whole during a movement. In every case, there is some degree of variability between tested athletes [25]. Maybe similarity between pattern of activation between different targets are more clear if we took more sophisticated approach to EMG analysis, but the content would be to extensive for one study. For the future inspection of target kinematic analysis, with techniques like Mean Absolute Value (MAV), Zero Crossings (ZC), Waveform Length (WL), Slope Sign Changes (SSC) [26].

Overall findings from this study confirms existence of target kinematic effect in yet another martial artists group. Collected data allows to dive deeper into this phenomenon, but limitation of a content in a single paper forced us to focus on our main hypothesis and approach to analyze event only during peak velocity, as in original idea presented by Wąsik et al. in their works [8,27,28]. As always in biomechanics papers, number of participants could be higher, but it was in scope of standard number used in previously mentioned works. Also, number of strikes per circumstance could be higher for better insight, but at the same time, we wished to avoid learning effect. Another possible bias could be computation method for velocity. In a stereogrammetry methods with IR cameras tracking marker spatial-temporal positions, velocity computation is more accurate than calculating it from acceleration data.

CONCLUSION

The study revealed that Kyokushin karate practitioners demonstrate the target kinematic effect, with significantly higher velocities when kicking a shield (16.91 m/s) compared to kicking the air (14.39 m/s), though this difference only emerged after warm-up and shadow fighting exercises.

Analysis of acceleration data showed a clear proximal-to-distal pattern through the movement chain, with the foot segment exhibiting the most dramatic increases. When striking the target, foot acceleration nearly doubled from 57.83 m/s^2 to 99.27 m/s^2, demonstrating substantial adaptation in force generation with a physical target.

The research found notable differences in body segment alignments between target and non-target conditions. The foot segment showed the most consistent adaptations across all circumstances, highlighting how practitioners modify their technique when facing a physical target versus striking the air.

Muscle activation patterns, as measured by EMG, showed surprising consistency across conditions. Only the rectus femoris muscle displayed statistically significant changes between target and non-target conditions, suggesting that while external movement patterns adapt, the underlying muscular coordination remains largely stable.

These findings have important implications for martial arts training methodology, indicating that practice kicks to the air may not fully replicate the biomechanical demands of striking a physical target. This suggests that training programs should incorporate an appropriate balance of both target and non-target striking practice.

Funding Statement: This research received no external funding.

Aknowledgment: The authors would like to express their sincere gratitude to Champion Klub Karate Kyokushin from Opole for their active participation in the research project and their invaluable contribution to the study. Their engagement and support greatly facilitated the successful completion of this work.

Conflicts of Interest: The authors declare no conflict of interest.

REFERENCES

1. Mkacher W, Nasri R, Frih B, Hammami N, Tabka Z. Anthropometric and physical profiles of Tunisian kyokushinkai competitors. Sci Sports 2021; 36: 485–8. doi: 10.1016/j.scispo.2021.01.004
2. Navickaitė A, Thomas G. Strength and Conditioning Considerations for Kyokushin Karate Athletes. Strength Cond J 2023; 45: 272-282. doi: 10.1519/SSC.0000000000000721
3. Piepiora P, Witkowski K, Piepiora Z. Personality profiles of karate masters practising different kumite styles. Arch Budo 2018; 14: 247-257
4. Lozovyy A. Karate sports disciplines from the spotlight of the paradigm shift of Japanese combat systems: analytical study. J Kinesiol Exerc Sci 2023; 33: 30–7. doi: 10.5604/01.3001.0016.2851
5. Iide K, Imamura H, Yoshimura Y, Yamashita A, Miyahara K, Miyamoto N, et al. Physiological Responses of Simulated Karate Sparring Matches in Young Men and Boys. J Strength Cond Res 2008; 22(3): 839-844. doi: 10.1519/JSC.0b013e31816a5af6
6. Szczęsna A, Błaszczyszyn M, Pawlyta M. Optical motion capture dataset of selected techniques in beginner and advanced Kyokushin karate athletes. Sci Data 2021; 8. doi: 10.1038/s41597-021-00801-5
7. Rezaei M, Parnow A, Mohr M. Additional high intensity intermittent training improves aerobic and anaerobic performance in elite karate athletes. Sport Sci Health 2024; 20: 779–88. doi: 10.1007/s11332-023-01156-7
8. Wąsik J, Mosler D, Ortenburger D, Góra T, Cholewa J. Kinematic Effects of the Target on the Velocity of Taekwon-Do Roundhouse Kicks. J Hum Kinet 2021; 80: 61–9. doi: 10.2478/hukin-2021-0103
9. Wąsik J, Mosler D, Ortenburger D, Góra T. Stereophotogrammetry measurement of kinematic target effect as speed accuracy benchmark indicator for kicking performance in martial arts. Acta Bioeng Biomech 2022; 22(4): 117-125. doi: 10.37190/abb-01926-2021-06
10. Mudric M, Cuk I, Janicijevic D, Nedeljkovic A, García-Ramos A. Feasibility of a modern video-based technology for assessing the reaction time during specific karate kumite situations. Int J Perform Anal Sport 2020; 20: 620–30. doi: 10.1080/24748668.2020.1767355
11. Goethel MF, Vilas-Boas JP, Machado L, Ervilha UF, Moreira PVS, Bendilatti AR, et al. Performance, Perceptual and Reaction Skills and Neuromuscular Control Indicators of High-Level Karate Athletes in

the Execution of the Gyaku Tsuki Punch. Biomechanics (Switzerland) 2023; 3: 415–24. doi: 10.3390/biomechanics3030034

12. Marković S, Kos A, Vuković V, Dopsaj M, Koropanovski N, Umek A. Use of imu in differential analysis of the reverse punch temporal structure in relation to the achieved maximal hand velocity. Sensors 2021; 21 (12): 4148. doi: 10.3390/s21124148
13. Vovkanych L, Kindzer B, Fedkiv M, Skalski D, Kreft P, Grygus I, et al. Recruitment of the Motor Units of Karatekas' Muscles during the Kick Performance. Int J Hum Mov Sports Sc 2023; 11: 886–92. doi: 10.13189/saj.2023.110424
14. Huenaerts C, Dewit T, Soentjens D, Monari D, Van Campenhout A, Desloovere K. Differences in surface electrode placement and its effect on duration of EMG activity. Gait Posture 2022; 97: S7–8. doi: 10.1016/j.gaitpost.2022.07.014
15. Wąsik J, Ortenburger D, Góra T, Shan G, Mosler D, Wodarski P, et al. The influence of gender, dominant lower limb and type of target on the velocity of taekwon-do front kick. Acta Bioeng Biomech 2018; 20: 133–8. doi: 10.5277/ABB-01085-2018-02
16. Vágner M, Maleček J, Hojka V, Kubový P, Stastny P. A carried military load increases the impact force and time of a front kick but reduces the peak velocity of the hip and shoulder of the kicking leg. Arch Budo 2020; 16: 69–76
17. Nadzalan AM, Janep M, Jahizi AAM, Mohamad NI, Rahim NA, Shalan NAAM, et al. the Effects of Wearable Resistance Loading on Kinematic of Front Kick Among Elite Taekwondo Athletes. Hum Sport Med 2022; 22: 92–9. doi: 10.14529/hsm220211
18. Vagner M, Cleather DJ, Olah V, Vacek J, Stastny P. A Systematic Review of Dynamic Forces and Kinematic Indicators of Front and Roundhouse Kicks across Varied Conditions and Participant Experience. Sports 2023; 11. doi: 10.3390/sports11080141
19. Milošević M, Mudrić R, Mudrić M. The biomechanical analysis of the karate kick (mae geri) in the function of defining educational training aims and methods. Sport – Science & Practice 2011: 2(4) 5-14.
20. Barnamehei H, Khazaee F, Safaei MA, Jabari H, Golfeshan N, Barnamehei M, et al. Motor learning and training strategy effect on motor control; Comparison between Taekwondo and Karate front kick (Ap Chagi and Mae Geri). Int J Martial Arts 2020; 6: 48–65. doi: 10.51222/injoma.2020.11.6.48
21. Estevan I, Falco C, Silvernail JF, Jandacka D. Comparison of Lower Limb Segments Kinematics in a Taekwondo Kick. An Approach to the Proximal to Distal Motion. J Hum Kinet 2015; 47: 41–9. doi: 10.1515/hukin-2015-0060
22. Wąsik J, Mosler D, Góra T, Scurek R. Conception of effective mass and effect of force – measurement of taekwon-do master. Phys Act Rev 2023; 11: 11–6. doi: 10.16926/par.2023.11.02
23. Portela BS, Barbosa MR, Cavazzotto TG, Tartaruga MP. Kinematics analysis of the front kick with and without impact on traditional karate. Arch Budo Sci Martial Arts Extrem Sports 2014; 10: 47–51
24. Wang H-C, Li J-D, Chien H-L, Hsieh F-H, Lu T-W. Muscle recruitment patterns and consistency, and their correlation with motor time during a karate front kick. Biomed Eng (Singapore) 2013; 25. doi: 10.4015/S1016237213500592
25. Barnamehei H. Neuromuscular characters influenced by knee flexion-extension during martial art techniques: Axial kick VS front kick. Gait Posture 2023; 106: S21–3. doi: 10.1016/j.gaitpost.2023.07.030
26. Khan, A. Waris, A. Ullah and S. Qammar, "Optimizing Feature Reduction and Selection Techniques for Surface Electromyography," 2023 3rd International Conference on Digital Futures and Transformative Technologies (ICoDT2), Islamabad, Pakistan, 2023: 1-9, doi: 10.1109/ICoDT259378.2023.10325778
27. Wąsik J, Shan G. Target effect on the kinematics of Taekwondo Roundhouse Kick - Is the presence of a physical target a stimulus, influencing muscle-power generation? Acta Bioeng Biomech 2015; 17: 115–20. doi: 10.5277/ABB-00229-2014-02
28. Wąsik J, Góra T. Impact of target selection on front kick kinematics in taekwondo – pilot study. Phys Act Rev 2016; 4: 57–61. doi: 10.16926/par.2016.04.07