BIOMECHANICAL INVESTIGATION OF THE KIZAMI TSUKI IN KARATE ATHLETES

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The purpose of this study was to investigate the kinematics and kinetics characteristics of *kizami tsuki* karate punch technique. Punching actions represent the most frequently performed attacking techniques in karate combat competitions (75% of total actions, *kizami tsuki* being the most common). Six athletes were asked to perform three *kizami tsuki* against a hand-held target at their maximal speed. Punch kinematics and kinetics were recorded by means of stereophotogrammetry and forceplates. Power, lower and upper limb kinematics and their coordinative pattern during the punching actions were assessed to characterize the technique. A multiple linear regression model was devised to correlate punching kinematics and kinetic variables with maximal wrist velocity, considered as performance measure. Maximal net power, transformation time, average continuous relative phase between knee and elbow flexion-extension, and elbow peak flexion were significative predictors of wrist velocity ($R^2 = 0.84$), indicating them as key factors to a proficient-performance of the *kizami tsuki*.

KEYWORDS: punch, coordination, continuous relative phase, upper limb kinematics.

INTRODUCTION: Punching actions represent the most frequently performed attacking techniques in karate combat competitions (Chaabène, Franchini, Miarka, Selmi, Mkaouer, & Chamari, 2014) reaching approximately 75% of the total actions performed (Chaabène et al 2014). One of the most common punching techniques is the *kizami tsuki* (Chaabène et al 2014). This very specific technique is analogue to the jab of a boxer, but its impact is comparable to a fencing lunge, where all the body momentum is used to transfer speed to the fist. To be awarded points in karate combat competitions, a punch has to be performed with the proper technique and at maximal speed, without hitting the opponent forcefully. Scientific knowledge on these actions in karate is only at the early stages. Knowledge on the determinants of punching performance could orient training programs and consequently enhance punching performance.

Punches require coordinated action of arm, trunk, and leg muscle groups (Loturco, Artioli, Kobal, Gil, & Franchini, 2014). Punching performance has been extensively investigated in different combat sports (Filimonov, Koptsev, Husyanov, & Nazarov, 1985; Loturco et al 2014; Loturco, Nakamura, Winckler, Bragança, da Fonseca, Moraes-Filho,... & Pereira, 2016; Stanley, Thomson, Smith, & Lamb, 2018), but the vast majority of these studies focused on boxing. It was shown that the contribution of lower limb to punching force in novice boxers is approximately 38% (Filimonov et al 1985), with trunk rotations contributing almost equally. These contributions vary according the technical level of the performer, reaching 45% for trunk rotations and decreasing to only 16% for lower limb in expert boxers. However, Stanley and colleagues (2018) failed to show significant correlations between lower limb kinetics and peak resultant fist velocity during the rear-hand punch in amateur boxers. Conversely, Loturco and colleagues (2016) found an excellent correlation between punch impact force and lower leg maximal power in boxers. In karate, similar observations showed a positive correlation between lower limb maximal power and punching kinematics, both for single actions (Loturco et al 2014), or combinations of punching techniques (Quinzi, Rosellini, Sbriccoli, in press). However, in these studies maximal lower limb power was

assessed using unspecific tests, such as the back squat, reflecting the athlete power profile rather than the contribution of lower limb kinetics to punch kinematics. Moreover, information obtained in other combat sports and for specific techniques cannot be generalized, given possible different purposes, technical executions, and coordination strategies.

Proximal-to-distal sequencing of maximal joint velocities is one of the coordination strategies that can contribute to fist velocity, of course depending on the specific punch technique and execution style. Wing Chun straight reverse punches, for example, have different levels of simultaneous initiation and sequencing according to individual fighting style (Fuchs, Lindinger, & Schwameder, 2018). Rather surprisingly, no information exists on the coordinative patterns between lower and upper limb observed in punching technique, even if kinetic energy transfer from the lower limb to the fist should dramatically be related to such coordinative patterns.

Therefore, this study aims at investigating the contributions of conditional, technical and coordinative factors to a proficient performance of the *kizami tsuki.* To this aim, the correlation between punch velocity, considered as performance measure, and general and frictional power, upper- and lower-limb kinematics and upper- and lower-limb coordination was investigated.

METHODS: Six elite karateka (age: 24.8 ± 1.0 years; stature: 1.78 ± 0.03 m; body mass: 73.8 ± 4.0 kg) volunteered to participate in the present study, after signing an informed consent approved by the institutional review board. All participants were athletes competing at national level, with at least 15 years of Karate experience. Participants were asked to perform six repetitions of the *kizami tsuki* punching technique against a hand-held target at their maximal speed. The kinematics of trunk, punching upper limb and contralateral lower limb was acquired using an upper limb model, best practice for dynamic overhead sport tasks (Wells, Donnelly, Elliott, Middleton, & Alderson, 2018). The elbow description required a static calibration trial in a flexed posture. Marker data were recorded with a 7 camera motion capture system (Mx and Mx+, Vicon Motion Systems Ltd, Oxford, UK, 100 samples/s) and software (Vicon Nexus V2.8). A six-component force platform (4080, Bertec Corp., Columbus, OH, 1000 samples/s) was used to record ground reaction forces (GRF). Fourth order low-pass Butterworth filter was applied ($f_{cut-off}$ = 7 Hz).

Variables of performance: Lower limb *power* (P) was obtained as by product of GRF and centre of mass velocity, obtained from GRF through forward dynamics. The two horizontal components were combined to determine *frictional power* (P_f). Centre of the wrist velocity (v_w), elbow (e_{fl-ex}) and knee flexion-extension (k_{fl-ex}) were obtained from a mechanical model using the joint coordinate systems defined as in the ISB standards (Wu et al, 2005).

These variables were used to obtain the following performance parameters using a custom written algorithm (Matlab, the Mathworks, v2019b): *maximal net power generated* (P_{net}^{max}), *maximal frictional power* (P_f^{max}); *maximal wrist velocity* (v_w^{max}); *maximal elbow flexion* (e_{fl}^{max}); *maximal knee flexion* (k_{fl}^{max}); *execution time* (t_e): time duration from the first movement to the instant when the punching fist hits the target. Start (t_0): time at the 15% of the maximal horizontal power development. End (t_{100}): time when the wrist joint centre decelerated below 1 m/s while fist hits the target; *power transformation time* (t_{lag}): time lag between P_f^{max} and v_w^{max}.

Lower limb-upper limb coordination: To investigate the coordination between the propulsive action of the lower limb and the upper limb punching movement, knee and elbow flexion–extension kinematics during the punching phase (t_0-t_{100}) were used to create phase plots (normalized angular velocity as a function of the normalized angular displacement, as described in Quinzi et al (2014). For any point of each phase plot, the phase angle (φ) was computed as the inverse tangent of the ratio between normalized angular velocity and angular displacement. The Continuous Relative Phase (CRP) is the difference between the phase angle of the knee segment (considered as proximal) and that of the elbow segment (distal) (range -π < φ < π). A positive CRP value reflects a greater phase angle of the knee with respect to the elbow, i.e. as faster movement or wider movement amplitude of knee, or a combination of both. For each CRP curve, the mean value was computed (CRP_{mean}) and used for further analyses.

Statistical analysis: After testing for normal distribution using the Shapiro-Wilk test, descriptive statistics was performed as mean and [standard deviation]. To investigate the relationship between v_w^{max}, considered as performance measure, and the other performance parameters, a three steps analysis was carried out: *(i)* a linear correlation of each variable with v_w^{max}; *(ii)* a multiple linear regression analysis on all variables not mutually correlated to identify predictors significantly contributing to v_w^{max}; *(iii)* a multiple linear regression of the identified predictors with v_w^{max}. For all statistical tests, α was set to 0.05.

RESULTS: Maximal wrist velocity and the above-mentioned conditional, technical and coordinative factors to the effectiveness of the *kizami tsuki* technique are reported in Table 1.

Table 1: Performance parameters and their correlation coefficient (*r*) with wrist maximal velocity
(*Denotes significant correlations)

At.	P_{net}^{max}	P_h^{max}	e_{fl}^{max}	k_{fl}^{max}	$CRP_{(mean)}$	t_e	t_{lag}	v_w^{max}
	[W/kg]	[W/kg]	[deg]	[deg]	[rad]	[s]	[s]	[m/s]
1	40.1 [7.7]	6.4 [2.0]	101 [1]	54.8 [6.7]	1.1 [0.3]	0.35 [0.03]	0.15 [0.02]	6.3 [0.4]
2	36.3 [5.8]	4.4 [1.6]	95 [8]	56.6 [1.2]	-1.9 [2.3]	0.27 [0.02]	0.13 [0.02]	7.1 [0.4]
3	39.6 [0.3]	7.0 [0.6]	109 [2]	63.2 [1.2]	-3.5 [0.4]	0.34 [0.04]	0.17 [0.04]	7.6 [0.0]
4	39.0 [0.2]	4.7 [1.1]	95 [3]	49.8 [2.1]	0.7 [0.6]	0.36 [0.07]	0.15 [0.02]	6.0 [0.1]
5	47.3 [4.9]	5.9 [1.8]	87 [8]	49.5 [3.3]	0.6 [2.2]	0.34 [0.03]	0.16 [0.03]	5.9 [0.4]
6	38.8 [2.6]	5.9 [0.4]	84 [18]	77.1 [19.0]	-1.9 [0.5]	0.41 [0.04]	0.23 [0.01]	5.3 [0.7]
r	-0.12	0.08	0.75*	-0.13	-0.40*	0.49*	-0.38*	-

(i) e_{fl}^{max}, t_e, CRP, and t_{lag} were significantly correlated with the maximal wrist velocity (Table 1);
(ii) when performing a multiple linear regression analysis using all variables to predict wrist velocity, e_{fl}^{max}, CRP, t_{lag}, and P_{net}^{max} were the significant predictors of wrist velocity.
(iii) a second multiple linear regression model was devised using only the latter variables (*r* = 0.92, $r^2 = 0.84$, *n* = 36): $v_w^{max} = 1.68 + 0.04 \cdot P_{net}^{max} - 9.72 \cdot t_{lag} + 0.05 \cdot e_{fl}^{max} - 0.22 \cdot CRP$
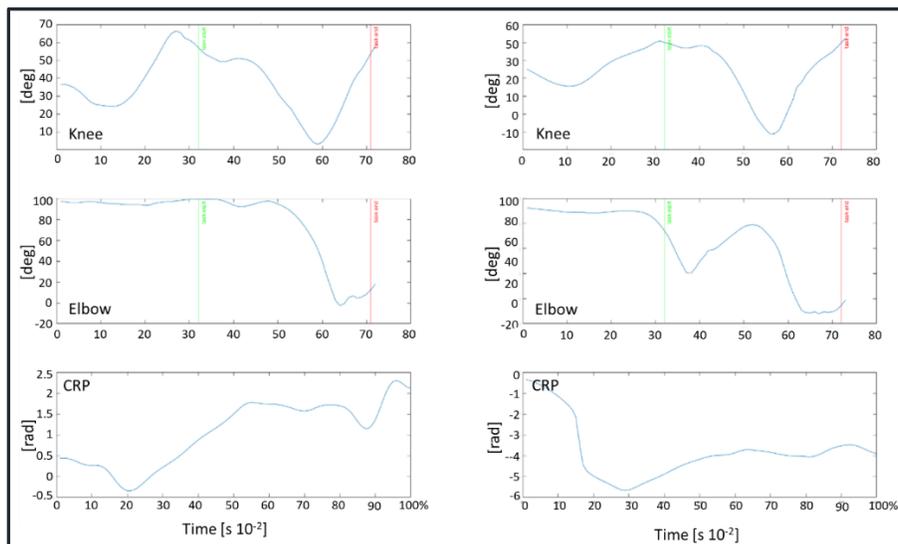

***Figure 1** Data for two paradigmatic subjects are depicted. Upper and middle panels: knee and elbow flexion-extension. Lower panel: continuous relative phase (CRP)*

DISCUSSION: The kinematics and kinetics characteristics of Kizami Tsuki karate punch technique, representative of conditional (P_{net}^{max}, P_h^{max}), technical (e_{fl}^{max}, k_{fl}^{max}) and coordinative (t_{lag}, CRP) domains, were investigated and their relationship with its performance analysed.

The measured punch velocity confirmed previous results on similar punch actions (Loturco et al 2014). The elbow peak flexion (e_{fl}^{max}) was the best single predictor of punch velocity and a good candidate for visual qualitative monitoring, along with execution time (t_e). Conversely, the power transformation time related to power transfer from the lower limb to the fist (t_{lag}) and CRP, although correlated to wrist velocity, aren't easily quantifiable in a training scenario. Surprisingly, the horizontal generated power was not directly correlated to wrist velocity. Nevertheless, the peak net power, with a power vertical component predominant over the horizontal one, was one significant predictor in the optimized multifactorial model.

Moreover, CRP values clearly depict a role for knee and elbow coordination as a determinant of performance. In fact, a positive value of CRP implies better elbow-knee coordination, being the elbow extension efficiently subsequent to the knee extension. We can hypothesize that the elbow pre-loading (its flexion) is propaedeutic to a better forward action, thanks also to a coordinated knee and elbow extension, which in turns leads to an efficient power transfer to wrist velocity.

CONCLUSION: *Kizami tsuki* is a very versatile technique with a wide gamma of uses, going from various combination to single strike situations. This study highlighted the predominant role of lower limbs net power generation and elbow flexion pre-load on fist velocity, describing the strength intensity of the stroke, and of the efficiency of its transfer to the upper limbs in terms of coordination and time of transfer, more related to the technical quality of the *kizami tsuki*. Knowledge on these determinants of punching performance could orient training programs and consequently help enhancing punching performance.

REFERENCES

Chaabène, H., Franchini, E., Miarka, B., Selmi, M. A., Mkaouer, B., & Chamari, K. (2014). Time–motion analysis and physiological responses to karate official combat sessions: is there a difference between winners and defeated karatekas. *International J Sports Physiology and Performance*, 9(2), 302-308.

Filimonov, V. I., Koptsev, K. N., Husyanov, Z. M., & Nazarov, S. S. (1985). Boxing: Means of increasing strength of the punch. *Strength & Conditioning Journal*, 7(6), 65-66.

Fuchs, P. X., Lindinger, S. J., & Schwameder, H. (2018). Kinematic analysis of proximal-to-distal and simultaneous motion sequencing of straight punches. *Sports biomechanics*, 17(4), 512-530.

Loturco, I., Artioli, G. G., Kobal, R., Gil, S., & Franchini, E. (2014). Predicting punching acceleration from selected strength and power variables in elite karate athletes: a multiple regression analysis. *The Journal of Strength & Conditioning Research*, 28(7), 1826-1832.

Loturco, I., Nakamura, F. Y., Artioli, G. G., Kobal, R., Kitamura, K., Abad, C. C. C., Cruz, I. F., Romano, F., Pereira, L. A., Franchini, E. (2016). Strength and power qualities are highly associated with punching impact in amateur boxers. *Journal of Strength and Conditioning Research*, 30(1), 109-116.

Quinzi, F., Sbriccoli, P., Alderson, J., Di Mario, A., & Camomilla, V. (2014). Intra-limb coordination in karate kicking: Effect of impacting or not impacting a target. *Human Movement Science*, 33, 108-119.

Quinzi, F., Rosellini, G., Sbriccoli, P. (in press). Lower limb maximal power predicts punching speed in different static and dynamic attacking techniques in karate. Journal of Strength and Conditioning Research.

Stanley, E., Thomson, E., Smith, G., & Lamb, K. L. (2018). An analysis of the three-dimensional kinetics and kinematics of maximal effort punches among amateur boxers. *International Journal of Performance Analysis in Sport*, 18(5), 835-854.

Wells, D. J. Donnelly, C. J., Elliott, B. C., Middleton, K. J., & Alderson, J. A. (2018). The inter-tester repeatability of a model for analysing elbow flexion-extension during overhead sporting movements. Medical & Biological Engineering & Computing,1 –8.

Wu, G., Van der Helm, F. C., Veeger, H. D., Makhsous, M., Van Roy, P., Anglin, C., ... & Werner, F. W. (2005). ISB recommendation on definitions of joint coordinate systems of various joints for the reporting of human joint motion—Part II: shoulder, elbow, wrist and hand. *Journal of biomechanics*, 38(5), 981-992.