ROUNDHOUSE KICK WITH AND WITHOUT IMPACT IN KARATEKA OF DIFFERENT TECHNICAL LEVEL

Valentina Camomilla[1], Paola Sbriccoli[1], Federico Quinzi[1], Elena Bergamini[1], Alberto Di Mario[2], Francesco Felici[1]

[1] Department of Human Movement and Sport Sciences, University of Rome "Foro Italico", Rome, Italy
[2] FIJLKAM – National Judo, Karate, Wrestling and Martial Arts Federation – Roma, Italy

The purpose of this study was to compare two different Karate roundhouse kicks performed by athletes of different technical level. The combination of high movement velocities and a high technical difficulty, qualify these actions as a good model to quantify the ability of a Karateka to execute complex movements. The first kick, directed to the face, entails a strong braking action to avoid the impact (NI), the other, directed to the chest, is concluded by an impact (IM). Technical aspects and the role of muscular co-activation as joint protector were investigated in six top level Karateka (KA) and six practicing karate amateurs (CO), by estimating joint kinematics and neuromuscular activity patterns. KA presented a faster execution for both tasks, prevalently due to a faster knee extension, supported by a low co-activation of the antagonist Biceps Femoris. This behaviour confirms that elite KA tend to lower the co-activation of antagonist muscles during fast movements, partially in contrast with the antagonists possible role in maintaining knee stability. The NI task, requiring higher technical competence and entailing a high target, is performed by KA athletes using a peculiar technique, based on a wide hip flexion-extension range, with a peak hip ab-adduction occurring earlier than in CO. A lower co-activation presented by CO during knee flexion is presumably due to their difficulty in mastering this complex kick.

KEYWORDS: Roundhouse kick, Karate, muscular co-activation

INTRODUCTION: Karate practice requires a fine control of movement associated to a great ability to perform the main technical actions as fast as possible (Zehr et al., 1997; Mori et al., 2002). While different studies dealt with front kick (Sørensen et al., 1996; Sforza et al.,2002), little attention has been devoted to roundhouse kicks (RK), despite their popularity and preferential use. Moreover, available doctoral theses and conference abstracts all focused on RK only in Taekwondo, whose practice does not include strong braking actions. Actually, these kicks seem to be a good model to quantify the ability of a karateka to perform complex actions since they combine high movement velocities with a high technical profile finalised to high precision. Thus, this work was designed to characterise top level karateka performance of two different roundhouse kicks: the first, directed to the face, entailing a strong braking action to avoid the impact (Mawashi Geri Jodan, No Impact - NI), the other, directed to the chest and concluded by an impact (Mawashi Geri Chudan, Impact - IM). Joint kinematics and neuromuscular activity pattern adopted by top level karateka and practicing karate amateurs were analysed to describe differences between the techniques. Muscular co-activation was analysed to investigate its role as joint protector in presence or absence of a braking action.

METHODS: Six top level Karateka (KA) (28±1yrs; 1.8±0.0m; 77±4kg) and six graduated students practicing karate as amateurs (Controls, CO) (25±1yrs; 1.78±0.03m; 73.8±4kg) were tested. After a visual trigger was delivered to the subjects, they performed with their preferred leg the two different roundhouse kicks, three times each: NI, directed to the face, and IM, directed to the chest and concluded by an impact on a punch bag.
Kinematic and electromyographic signals were obtained from the kicking leg. Surface electromyographic (sEMG) signals was recorded through a wi-fi transmission EMG amplifier (BTS Pocket EMG, Italy) from the Vastus Lateralis (VL), Rectus Femoris (RF), Biceps Femoris (BF), Gluteus Maximum (GM) and Gastrocnemious (GA) muscles. Magnetic field angular rate and gravity sensors (MTx, Xsens Motion Technologies, Enschede, The

Netherlands) were used to acquire pelvis, thigh, and shank orientation and angular velocity. The synchronization of the systems was provided by a switch connected to the visual trigger.
Hip and knee angular kinematics were estimated first obtaining for each body segment, through a point-based anatomical calibration of the inertial sensors (Picerno et al. 2008), the time-invariant orientation of each anatomical frame with respect to the sensor technical frame and, then, combining this information with the time-variant orientation of the sensor technical frame with respect to global reference frame, measured by the inertial sensors. Joint angular kinematics was determined from the relative orientation of the proximal and distal anatomical frames using the Cardan convention (Grood and Suntay, 1983).
From the joint kinematics the following quantities were determined: the loading and kick phase, associated to knee flexion and knee extension, were identified in knee flexion-extension with an algorithm for peaks detection. Peak to peak knee flexion-extension (K_{fe}), hip flexion-extension, and ab-adduction (H_{fe}, H_{aa}) angles were determined within these two phases. The time interval from trigger to full knee extension (t_{task}) and the length of the knee extension phase (t_{KE}) were determined, as well as the time interval between the peak of hip ab-adduction and peak knee flexion-extension (t_{H-K}).
The raw EMG signal of each muscle was full-wave rectified and, for each subject and each muscle, normalized using the highest value within trials. Given the good signal to noise ratio of the EMG signal, a simple threshold-based method was used to detect the muscle activation onset (Staude et al., 2001). In each phase, a threshold was set equal to the average plus three times the standard deviation of the first 50 ms of the EMG signal; the onset was associated with the first sample of a 15ms window above threshold. The area underneath the EMG signal curve across the activation period was used to quantify the intensity of the contraction of a muscle from the onset, t_j, to the end of the above threshold period, t_f:

$$I_{muscle} = \sum \int_{t_i}^{t_f} EMG_{muscle}(t)dt \qquad (1)$$

In order to quantify the activity of agonists and antagonists around the knee joint, a co-activation index (CI) was calculated as a percentage (0-100%) of the ratio between antagonist muscles and all muscle, with 100% indicating full coactivation (Kellis et al., 2003):

$$CI = \frac{I_{ant}}{I_{ago} + I_{ant}} \times 100\% \qquad (2)$$

A CI index was calculated for knee extension, CI_E, and knee flexion, CI_F:

$$CI_E = \frac{I_{BF}}{I_{RF} + I_{VL} + I_{BF}} \times 100\% \qquad CI_F = \frac{I_{VL}}{I_{BF} + I_{VL}} \times 100\% \qquad (3)$$

In CI_F the RF was excluded as antagonist due to its agonist role at the hip.
All data have been reported as Mean (Standard Errors, SE), in text, Table and Figure. Joint peak to peaks, K_{fe}, H_{fe}, H_{aa}, time intervals, t_{task}, t_{KE} , t_{H-K}, and co-activation indices, CI_E, CI_F were submitted to statistical analysis. Differences between groups of Karateka and Controls were tested through an unpaired T-Test. Differences between IM and NI kicks were investigated on the same variables using a paired T-Test. Statistical significance was set to $p<0.05$ for all tests performed. t_{H-K} was tested with a one-sample t-test, alpha = 0.05.

RESULTS: KA subjects presented shorter timings from the trigger to the full knee extension, t_{KE}, for both kicks, Table 1. This difference was more evident for the NI condition. When comparing kicks, no difference in time to task completion, t_{task}, was evidenced for KA subjects, while for CO subjects significantly higher times were necessary in the NI condition. For these subjects, the difference between IM and NI increased when focusing only on the length of the knee extension phase t_{KE}.
When observing joint kinematics, Table 1, no significant difference was evidenced for knee flexion extension range (KA: 138±9deg, CO: 118±8deg). Conversely, KA and CO subjects

adopted different hip strategies. Hip flexion-extension range was wider in KA subjects, especially for NI kicks with respect to the IM condition ($p = 0.0003$). The hip ab-adduction range was not different between groups; however, it increased in both groups when changing from IM to NI condition ($p<0.001$). The hip ab-adduction peak happened consistently before maximal knee flexion for KA subjects ($p < 0.04$). CO subjects showed a consistent intra-subject behaviour, while presenting either an anticipation or a delay with respect to the peak knee flexion.

Table 1. Joint kinematics parameters and time intervals for both groups and kicks.

	Joint kinematics peak to peak [deg]						Time intervals [s]					
	K_{fe}		H_{fe}		H_{aa}		t_{task}		t_{KE}		t_{H-K}	
	IM	**NI**	**IM**	**NI**	**IM**	**NI**	**IM**	**NI**	**IM**	**NI**	**IM**	**NI**
KA	140 (9)	135 (10)	68 (12)	87 (18)	23 (3)	32 (5)	0.66 (0.03)	0.71 (0.06)	0.12 (0.02)	0.12 (0.02)	-0.04 (0.02)	0.00 (0.03)
CO	116 (8)	119 (8)	39 (3)	69 (10)	28 (4)	44 (6)	0.78 (0.02)	0.85 (0.04)	0.11 (0.00)	0.19 (0.02)	0.02 (0.02)	0.04 (0.02)

For KA subjects, a typical EMG activity pattern was observed, consisting of a biphasic and synergic activation of GM and VL muscles during both IM and NI kicks, the BF activation being shifted in time with respect to VL and GM muscles. A delayed activation of RF muscle was also observed. For CO subjects, no typical EMG activation pattern was observed.

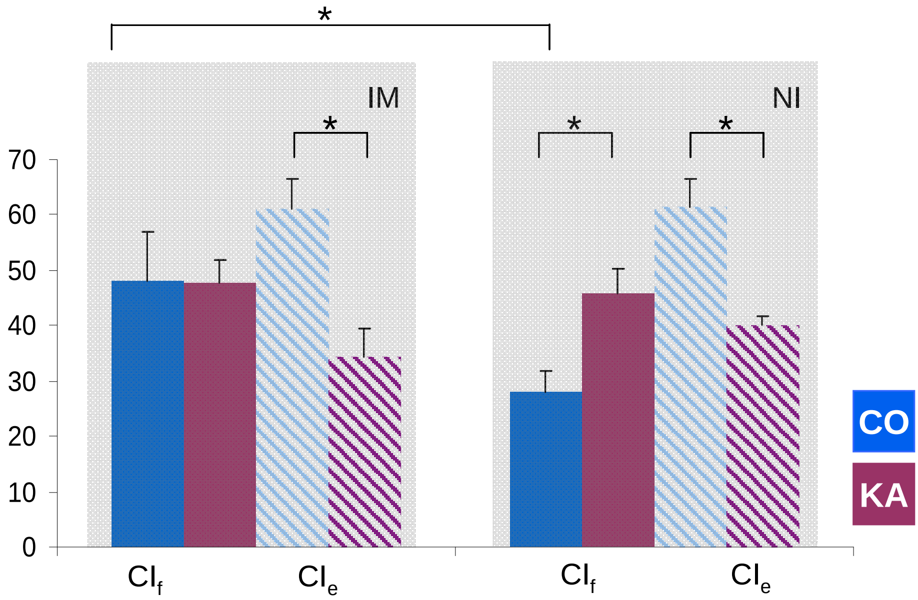

Figure 1: Co-activation indices in % for IM and NI kicks, during extension (full bars) and flexion (dashed bars) of CO (blue) and KA (magenta) athletes.

Co-activation strategies during flexion were different between groups only during NI kick, KA subjects presenting a positive 20% difference with respect to CO ($p = 0.02$). When comparing the kicks, no differences were evidenced for KA subjects, while a 17% decrease was evidenced in CO subjects when moving from IM to NI condition ($p = 0.01$). During extension, KA subjects had significantly lower CI_E in both conditions ($p<0.004$). No difference was evidenced between kicks.

DISCUSSION: Karateka presented an obvious faster execution for both tasks. Apart from presumably faster reaction times, not analysed in the present study, KA higher velocities with respect to CO subjects can prevalently be attributed to a faster knee extension. This velocity can be ascribed both to a higher extension activity of KA subjects or, as suggested by the CI_E behaviour, to a lower co-activation of the antagonists. This behaviour during knee extension confirms that elite KA tend to lower the co-activation of antagonist muscles during fast movements (Bazzucchi et al., 2008), partially in contrast with a possible role of antagonists in maintaining knee stability (Baratta et al, 1988). During knee flexion, conversely, CO subjects presented a lower co-activation with respect to KA when performing the NI kick. This result should be interpreted in the light of the following considerations. The IM task requires lower technical competence and entails a target positioned at a lower height. To accomplish the NI kick, a wider hip flexion-extension as well as ab-adduction range of movement is required with respect to the IM kick. KA athletes show a wider hip flexion-extension range and their peak hip ab-adduction occurs earlier than in controls, suggesting that KA use a different technique. Presumably, the lower proficiency of CO subjects in performing the NI technique leads to a lower hip angular velocity, accompanied a general lower co-activation strategy (Kellis and Katis, 2007).

CONCLUSION: This study provided insight in technical aspects typical of elite Karateka in the execution of Mawashi Geri Jodan and Mawashi Geri Chudan, different in target and as impact or no-impact tasks. Top elite athletes confirmed to perform fast ballistic movements with a co-activation strategy that favours the velocity to a little disadvantage in terms of safety of the knee joint. Further speculations will be formulated by analysing hip muscles co-activation strategy and observing the activity of each muscle involved.

REFERENCES:

Baratta, R., Solomonow, M., Zhou, B.H., Letson, D., Chuinard, R., D'Ambrosia, R. (1988). Muscular coactivation. The role of the antagonist musculature in maintaining knee stability. *Am J Sports Med*., 16, 113-22.

Bazzucchi, I., Riccio, M.E., Felici, F. (2008). Tennis player show a lower coactivation of the elbow antagonist muscles during isokinetic exercises. *J Electromyogr Kinesiol*., 18, 752-9.

Grood, E.S., Suntay, W.J. (1983). A joint coordinate system for the clinical description of three-dimensional motions: application to the knee. *J Biomech Eng*, 105, 136–44.

Kellis, E., Arabatzi, F., Papadopoulos, C. (2003). Muscle co-activation around the knee in drop jumping using the co-contraction index. *J Electromyogr Kinesiol*, 13, 229-38.

Kellis E., Katis A. (2007). Biomechanical characteristics and determinants of instep soccer kick. *J. Sports Science Med*, 6, 154-165.

Mori, S., Ohtani, Y. Imanaka, K.. (2002). Reaction times and anticipatory skills of karate athletes. *Hum. Mov. Sci.*, 21, 213-230.

Picerno, P., Cereatti, A., Cappozzo, A. (2008). Joint kinematics estimate using wearable inertial and magnetic sensing modules. *Gait Posture*, 28, 588–95.

Sforza, C., Turci, M., Grassi, G. P. Shirai, Y. F., Pizzini, G., Ferrario, V. F. (2002). Repeatability of mae-gaeri-keage in traditional karate: a three-dimensional analysis with black-belt karateka. *Percept. Mot. Skills.* 95, 433-444.

Sørensen, H., Zacho, M., Simonsen, E.B., Dyhre-Poulsen, P., Klausen, K. (1996). Dynamics of the martial arts front kick. *J Sports Sci*., 14, 483-95.

Staude, G., Flachenecker, C., Daumer, M., Wolf, W. (2001). Onset Detection in Surface Electromyographic Signals: a Systematic Comparison of Methods. *EURASIP J Appl Signal Process*., 2, 67–81.

Zehr, E. P., Sale, D. G., Dowling, J. J. (1997). Ballistic movement performance in karate athletes. *Med. Sci. Sports Exerc.*, 29, 1366-1373.

Acknowledgments

The experiments comply with the current Italian laws. Work partially founded by the Department of Human Movement and Sport Sciences, University of Rome “Foro Italico”. A special thanks goes to all karateka for their active co-operation in the study.