©Journal of Sports Science and Medicine (2009) **8(CSSI 3)**, 29-35
http://www.jssm.org

Research article

Comparison of two variants of a Kata technique (Unsu): The neuromechanical point of view

Valentina Camomilla [1]✉, Paola Sbriccoli [1], Alberto Di Mario [2], Alessandro Arpante [1] and Francesco Felici [1]
[1] Department of Human Movement and Sport Sciences, University of Rome, Italy
[2] FIJLKAM – National Judo, Karate, Wrestling and Martial Arts Federation, Roma, Italy

Abstract
The objective of this work was to characterize from a neuromechanical point of view a jump performed within the sequence of *Kata Unsu* in International top level karateka. A modified jumping technique was proposed to improve the already acquired technique. The neuromechanical evaluation, paralleled by a refereeing judgment, was then used to compare modified and classic technique to test if the modification could lead to a better performance capacity, e.g. a higher score during an official competition. To this purpose, four high ranked karateka were recruited and instructed to perform the two jumps. Surface electromyographic signals were recorded in a bipolar mode from the vastus lateralis, rectus femoris, biceps femoris, gluteus maximus, and gastrocnemious muscles of both lower limbs. Mechanical data were collected by means of a stereophotogrammetric system and force platforms. Performance was associated to parameters characterizing the initial conditions of the aerial phase and to the CoM maximal height. The most critical elements having a negative influence on the arbitral evaluation were associated to quantitative error indicators. 3D reconstruction of the movement and videos were used to obtain the referee scores. The *Unsu* jump was divided into five phases (preparation, take off, ascending flight, descending flight, and landing) and the critical elements were highlighted. When comparing the techniques, no difference was found in the pattern of sEMG activation of the throwing leg muscles, while the push leg showed an earlier activation of RF and GA muscles at the beginning of the modified technique. The only significant improvement associated with the modified technique was evidenced at the beginning of the aerial phase, while there was no significant improvement of the referee score. Nevertheless, the proposed neuromechanical analysis, finalized to correlate technique features with the core performance indicators, is new in the field and is a promising tool to perform further analyses.

Key words: Biomechanics, electromyography, technique analysis, karate.

Introduction

Karate is a martial art classified among those specialties requiring high technical skills such as a fine control of movement both in static and dynamic conditions, accompanied by a great ability to perform the main technical actions (strikes and kicks) as fast as possible (“ballistic actions”) (Mori et al., 2002; Sørensen et al., 1996; Wilk et al., 1983; Zehr and Sale, 1994; Zehr et al., 1997). A karateka is an athlete continuously challenged in the goal of performing very complex actions combining high movement velocities with high precision.

Karate is classically divided into two different specialties: *Kumite* and *Kata*. While *Kumite* is the classical combat between two opponents using punching, striking and kicking techniques, *Kata*, (literally: "form") represents a real combat with imagery opponents. For karate practitioners, *Kata* represents the essence of a martial art, as it includes not only a perfect knowledge of the main techniques (*Kihon*), but also rhythm and combat tactics elements (*Kumite*). In other words, from a technical point of view, the performance obtained during a *Kata* is of relevance for gaining an optimal performance in Karate.

Kata are classified as a function of their complexity in “basic” and “advanced”. The latter are characterized by acrobatic phases that make them more difficult to perform. Among the “advanced” *Kata*, the *Kata Unsu* includes an acrobatic element consisting of a rotation of 360° around the vertical axis combined to the execution (optional) of one or two kicking techniques. Due to the high complexity of this action, and to the technical skill required during its execution, this element can favor a high score by the referees.

A careful and precise description of this acrobatic element could help improving the relevant performance. However, to date, no published studies were located in the international literature as regards this technique and, more in general, on *Kata*. To the best of our knowledge, studies have investigated on the biomechanics and neuromuscular aspects of acrobatic jumps mainly in the context of on-ice skating (King et al., 2004; King, 2005; Lockwood et al., 2006) and of diving (Mathiyakom et al., 2006a; 2006b).

The characterization of acrobatic elements on a neuromechanical standpoint, along with the identification of possible changes to be applied in order to gain a higher score, could be of relevance not only to fill the gap on this topic, but also to provide useful suggestions to the technicians for improving karateka’s performance capacity. Therefore, in order to give a contribution in the described framework, the following questions must be raised:

1. Which are the kinematics and neuromuscular active-Tion features adopted by an expert athlete while

Received: 01 March 2009 / Accepted: 31July 2009 / Published (online): 01 November 2009

performing the acrobatic phase of the *Kata Unsu*?
2. Are there possible changes to the execution of this acrobatic element that could improve an already acquired technique? If so, could this change lead to a better performance capacity, e.g. a higher score during an official competition?

Discussion with a National Coach led to identifying a promising modification to the technique and to instruct high level athletes to perform both versions. A neuromechanical evaluation, paralleled by a refereeing judgment, was used to determine if the modified technique could lead to a higher score.

Methods

Four participants [age 22(2) years, stature 1.75(0.04) m, mass 71(5) kg], were selected at an excellence level, based on their performance in International Competitions: three participants were from the National Junior Team (Vice World Champions 2007), one was the Junior World Champion 2001. Athletes volunteered to participate in the study after signing a written informed consent form.

The participants were filmed from the right front, in analogy with the point of view of the fourth judge during official competitions refereed by five judges, using a video camera (Sony Handycam, DCR HC14E). An eight camera Vicon MX13 stereophotogrammetric system (Vicon, Oxford Metrics, UK, fs = 120 samples·s^{-1}) was used to reconstruct the 3D position of 39 retro-reflective spherical markers attached using adhesive tape to the participants skin according to the Plug-in Gait protocol [Superciliary arches (2), parietal bones (2), C7, T10 spinosus processes (2), jugular notch (1), xiphoid process (1), right back (1), acromion processes (2), humeral markers (2), lateral epicondyles of the humerus (2), radial and ulnar markers (2), radial and ulnar styloid processes (4), second metacarpal (2), posterior superior (2) and anterior superior (2) iliac spines, femoral wand markers (2), lateral epicondyles of the femur (2), tibial wand markers (2), lateral malleoli (2), second metatarsal head (2), posterior calcanei (2); Davis et al. 1991; Kadaba et al., 1990]. Anthropometric parameters were manually measured and marker positioning was performed by a single operator. Using these markers positions and inertial parameters estimated from anthropometric information, the body centre of mass (CoM) was calculated (Davis et al., 1991). Forces exchanged with the ground were measured using two six-components AMTI platforms 46x50cm. Due to the not uniform force absorption exerted by the *tatami*, the traditional Japanese flooring mat used during competitions, the participants were asked to perform the technique directly on the force platforms while wearing their shoes.

Surface electromyographic signals (sEMG) were recorded in a bipolar mode through a wi-fi transmission EMG amplifier (BTS Bioengineering Pocket EMG, Italy sf = 2000 samples·s^{-1}) from the vastus lateralis (VL), the rectus femoris (RF), the biceps femoris (BF), the gluteus maximus (GM), and the gastrocnemious (GA) muscles of both right and left side. The electrodes have been positioned in accordance with the rules proposed by Hermens et al. (2000). Before positioning the electrodes on muscle bellies, the skin was properly abraded with sandpaper and cleaned with ethyl alcohol. The ground electrode was placed on the wrist. The sEMG signals were A/D sampled at 2000 points per second at 12-bit resolution (amplitude range +/- 5V; band pass filtered, 10-500Hz); the raw signals were stored on a personal computer for further analyses. The EMG and kinematics signals were synchronized via a signal triggered by a shared switch.

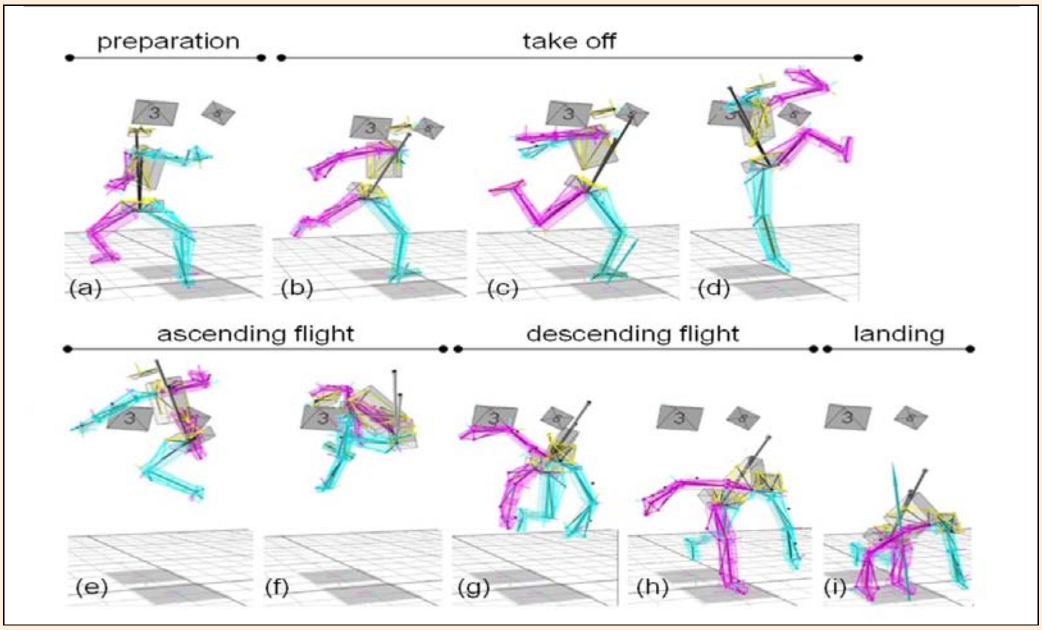

Figure 1. 3D representation of key instants of the Classical technique, with the relevant phase indicated above: (a) *Fudo Dachi*; (b) and (c) throwing leg movement and body twist; (d) take off; (e) throwing leg in tucked position; (f) CoM maximal height; (g) angular momentum trading, arms abduction; (h) push and throwing leg extension; (i) landing. The position of the two platforms and of two cameras is also shown.

Experimental protocol

Participants were asked to assume the initial posture, *Fudo Dachi*, with their anterior left foot (push leg) on one force platform, while the rear right foot (throwing leg) was placed outside, due to the wide feet separation of *Fudo Dachi*. The platform was chosen to allow the participant to land on a force platform; those performing the techniques with a forward landing, placed the push leg on the rear platform. They were first instructed to perform three times the classical jump in the *Kata Unsu* with the push foot still, then received a verbal description and performed three times the modified jump technique with the push foot anticipating the action through an extra-rotation of the forefoot.

Phase analysis

The *Unsu* jump was divided in five phases: preparation, take off, ascending flight, descending flight, and landing, Figure 1. To divide the different phases the following events were detected, using either force platform data, for ground contacts, or stereophotogrammetric data: take off begins when the throwing foot leaves the ground; the ascending flight starts when the push foot leaves the ground; the descending phase starts when the height of the CoM is maximal and finishes at the first contact of either a hand or a foot with the ground.

Performance and error indicators

Parameters were selected to characterize the initial conditions of the aerial phase related with the trajectory of the CoM, *i.e.* vertical and horizontal components of the CoM velocity at take off (v_{ap}, v_{ml}, and v_v), Figure 1d, and with the movement of the body around the CoM, *i.e.* the horizontal force exchanged with the ground before take off (F_{xy}) and the magnitude of the velocity vector of the throwing foot at take off (v_{toe}), Figure 1d. These parameters and the CoM maximal height (h), Figure 1f, were considered as performance indicators.

Among the elements having a negative influence on the arbitral evaluation, the most critical, as obtained from unstructured interviews to different referees, were associated to a quantitative assessment. The landing should take place in the plane where the take off took place and without landing forward or backward with respect to the start position. Since the technique took place having as line of progression the x axis of the laboratory reference frame, the antero-posterior and medio-lateral displacement of the anterior foot at landing (represented by the right toe marker) with respect to the anterior foot at take off (left toe marker) were considered as *in-plane* and *in-place* indexes for landing. Good balance at landing is described by, first, the *synchronicity* of hands and feet landings, associated to the time lag between the first and the last contact with the ground and observed from the markers placed on the extremities: RTOE, LTOE, RFIN, and LFIN and, second, by a wide oscillation of the pelvis after landing, associated to the vertical displacement of the sacrum in the landing phase (*cushioning*).

Referee evaluation

An National Karate referee of the Italian National Judo, Karate, Wrestling and Martial Arts Federation (FIJLKAM), ex athlete of the Italian National Team, was asked to score all trials using the 1 to 12 scale used during Italian National Competitions, first analyzing the videos taken from a fixed position and, then, based on the 3D reconstruction of the trials, allowing their observation from all referees point of view. This evaluation must be interpreted in the framework of the following limitations, intrinsic to the experimental setting: the *Kata* competition entails a global evaluation, while a single technique is here taken into account; moreover, the absence of the *Karategi*, due to the need to place the markers directly on the skin to track the skeletal movement, allowed for the observation of subtle details, such as little unbalances at landing, that would not be detected in a normal setting and could negatively influence the evaluation.

Data analysis

The different phases underwent a qualitative observation, to describe the technique and to highlight its critical elements. In particular, coherence between Coach instruction and the execution of the modified technique was observed. Time intervals associated to the different phases were also evaluated and reported in terms of mean ± standard deviation.

To test if the modified technique entails an improvement in the already acquired technique, the dependency of the performance indicators from the jump technique was investigated through a paired T-test. Statistical significance was set to $p < 0.05$.

To test if the modified technique could lead to a better performance capacity, e.g. to a higher score during an official competition, the dependency of referee scores and of the error indicators from the jump technique was tested using the same statistical analysis as above.

Results

Phase analysis

Preparation: The athletes first reached the traditional static initial position, *Fudo Dachi*, with the left anterior foot pointing in the progression direction and the rear foot externally rotated of 45 deg (Figure 1a). Both hips and knees were flexed to lower the CoM position with respect to the ground of about 20cm. All athletes loaded their anterior foot with 40% to 60% of their body weight. The upper arms assumed a defensive position, *Tate Shuto Uke*, with the omolateral anterior arm extended and parallel to the ground, hand open and vertical, and the posterior elbow flexed to place the closed hand over the belt with the palm facing upwards, *Hikitè*. The head pointed forwards, whit trunk and pelvis rotated of about 45 deg towards the throwing leg, in the *Ammi* defense position. When the athlete is ready, the CoM started lifting paralleled by an unloading of the throwing leg and the posterior shoulder abducted. In the Classical technique, the anterior foot was externally rotated of up to 90 deg (Figure 2). In the modified technique, all participants complied with the verbal technical requirement and moved laterally the push foot with an emphasized external rotation of the forefoot (Figure 2).

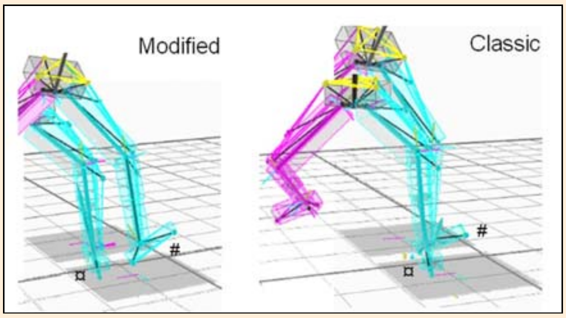

Figure 2. Focus on the difference between Classical and Modified technique. The push leg is shown in *Fudo Dachi* (¤) and right before the beginning of take off phase (#), when the throwing leg leaves the ground.

Take off: When the throwing leg left the ground and the take-off phase begun, in the Classical technique the push foot was on the ground while, in the modified technique, the push foot reached the ground after that the throwing leg had started his movement forward. In both techniques, the throwing leg and both arms swung in the sagittal plane, while the body twisted around the vertical axis (Figure 1b, 1c). Right before and after take off, the knee of the throwing leg was at the same height as the hips and the push leg was close to be extended (Figure 1d). During this phase, all participants rotated the trunk of about 90 deg about the vertical axis (Figure 3).

Ascending flight phase: During the flight, while the CoM follows its ballistic trajectory, the body rotates around it. Initially, the take off moment of the reaction force with respect to the CoM generates an angular momentum vector that leads the body to twist, while the throwing leg has a high angular momentum with respect to the centre of mass. When the throwing leg reaches a tucked position (Figure 1e), the push leg starts flexing until reaching the other leg, approximately at the same time as the centre of mass reaches the maximal height (Figure 1f). Consequently, the body orientation changes with respect to the angular momentum vector and the body rotates partially around the medio-lateral direction; while the reduction of the moment of inertia increases the angular velocity. During this phase the trunk undergoes a rotation of about 180° (Figure 3).

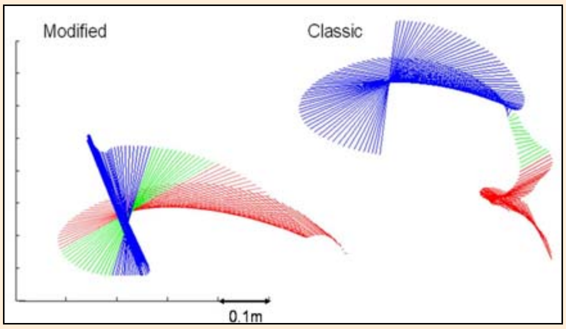

Figure 3. The projection on the ground of the spine markers, C7 and T10, is shown for participant 1 during Modified and Classical jumps. In each panel, bottom right is the beginning of the take off phase, top left is the end of the descending phase. The color changes when changing phase.

Descending flight phase: The rectus abdominis muscle trades the angular momentum, slowing the trunk rotation while increasing that of the lower limbs. In the same time lag the arms are abducted (Figure 1g). The push and throwing legs leg are extended, posteriorly and

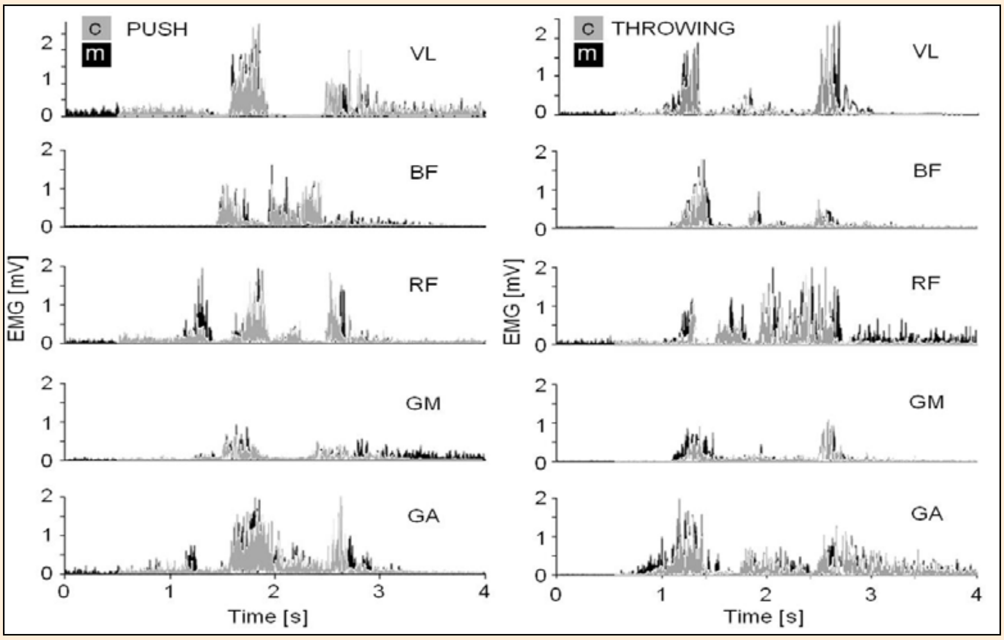

Figure 4. sEMG traces recorded during the *Kata Unsu* jump performed with the classical (c) and modified (m) technique from the Vastus Lateralis (VL), Biceps Femoris (BF), Rectus Femoris (RF), Gluteus Maximum (GM) and Gastrocnemious (GM) muscles. Pushing leg (Left Panel); Throwing leg (Right Panel).

anteriorly respectively, right before landing, to avoid increasing the moment of inertia (Figure 1h). During this phase, the trunk rotated of about 135 deg about the vertical axis (Figure 3).

Landing: The metatarsal portion of the feet went in contact with the ground with a wide base of support, the hands were placed at the sides of the anterior foot, at about 1m from each other. The trunk was bended on the anterior knee, while the shank was kept vertical and the knee was flexed at about 90 deg (Figure 1i).

Phases length: All athletes were very consistent in the timing of the different phases that did not show any statistical difference between techniques. The Take-off phase lasted on average 3.5s and showed the highest standard deviation, 0.55s, corresponding to a faster or slower throwing leg oscillation of the different athletes. The ascending and descending phase lasted 0.20 ± 0.03s and 0.47 ± 0.05s, respectively. The descending phase lasted longer since, before touch down, the body was partially leaned forward and not extended as at take off, and the centre of mass was consequently lower than at take off. The landing phase lasted 1.12 ± 0.36s; the latter variability being ascribable to different ability of the athletes to land with hands and feet synchronously.

sEMG data: The pattern of sEMG activation VL, BF, RF, GM, and GA muscles during the execution of the *Kata Unsu* jump with the two different techniques, was consistent in all tested participants. Results for participant 1 are shown in Figure 4.

As it was expected considering the different motor task performed by the push and throwing leg, the EMG activity observed between the left and right side was different in terms of EMG amplitude as well as timing of each muscle intervention during the jumping action. When comparing the techniques, no difference was found in the EMG activity of the throwing leg muscles, while the push leg showed an earlier activation of RF and GA muscles at the beginning of the modified technique.

Performance and error indicators and referee evaluation

Only three performance parameters relative to the take-off phase (v_v, v_{TOE}, F_{xy}) differed significantly between techniques (Table 1). As far as v_v is concerned, it is to note that its increase did not determine a significant increase in the maximal height (h) reached by the centre of mass. The effect of the variation of the parameters correlated with the movement of the body around the centre of mass (F_{xy}, v_{TOE}) can be qualitatively observed also in Figure 3, depicting a typical projection of the trunk on the ground in the different phases of the two techniques: in the modified technique a wider portion of the 360 deg rotation entailed in the jump is covered in the take off phase as well as in the ascending phase, due to a better orientation or a higher intensity of the angular momentum.

While, according to a qualitative evaluation of the referee, the modified technique entailed poorer landing stability and lower or equal quality of the jump, the referee scores did not show any dependency from the technique. This result is supported by the absence of statistical differences of the error indicators.

Discussion

The neuromuscular activation features adopted by an expert athlete while performing the acrobatic phase of the *Kata Unsu* were characterized and a promising modification of the technique was analyzed. For the investigated athletes, the only significant improvement associated with the modified technique was evidenced at the beginning of the aerial phase. Although the tested modification was not able to determine a significant improvement of the referee score, the neuromechanical analysis finalized to correlate technique features with the core performance indicator is new in the field and could be used to perform further analysis.

The results of this study, performed on a acknowledged small sample size, but none the less representing high level athletes, must be analysed in the framework of the following considerations. The EMG activity showed an overall consistency between techniques. It can be hypothesized that the Central Nervous System (CNS) doesn't substantially modify the muscle activation strategy adopted for the execution of the *Kata Unsu* jump except for accomplishing the requirement imposed by the modified technique (dorsi-flexion and extra-rotation of the anterior foot). As we are dealing with expert athletes, their ability to keep constant the already planned and learned motor task is somewhat prevalent with respect to the necessity to suddenly modify the specific motor task substantially. It might also be hypothesized that this external imposition of performing a given task using a different (not acquired) technique, is perceived by the CNS as a perturbation not necessarily leading to an improvement of the jumping technique. The earlier activation of RF and GA muscles of the push leg at the beginning of the modified technique can probably be ascribed to the specific action of dorsiflexion and extrarotation imposed to the front foot for the initiation of the *Kata Unsu* jump. Although the specific features described may be typical of the selected athletes, it is to note that they were recruited among the ten best National kata athletes. Therefore, their performance constitutes a valuable reference for coaches.

An accurate estimate of angular momentum at take off was impossible due to the wide initial position not allowing the measure of the ground reaction forces below both feet. The absence of this parameter limits the understanding on the impact of the technique on the aerial phase. The parameters associated to the beginning of the aerial phase discriminated the two techniques, but this result did not imply a better performance in the subsequent phases. This may be due to the fact that the athletes, during the modified preparation and take off phase, acquired an angular momentum higher than the one dealt with in their usual planning of the motor task. If this was the case, the athletes could not take advantage of the improved initial conditions. Alternatively, it may be hypothesized that the modification and the consequent improvement of the initial conditions are not enough to improve the final score.

To investigate these hypotheses, a specific training on the two techniques should be planned to understand if a more efficient planning of the new motor task could be

Table 1. **Performance and error indicators and score relative to both jump techniques.**

		PERFORMANCE INDICATORS										ERROR INDICATORS										SCORE	
		TAKE-OFF PHASE										FLIGHT		LANDING				WHOLE JUMP					
		v_{ap} [m·s^{-1}]		v_{ml} [m·s^{-1}]		v_v [m·s^{-1}]		v_{TOE} [m·s^{-1}]		F_{xy} [N]		h [m]		cushion [m]		synchro [m]		in-place [m]		in-plane [m]			
	t	*c*	*m*	*c*	*m*	*c*	*m*	*c*	*m*	*c*	*m*	*c*	*m*	*c*	*m*	*c*	*m*	*c*	*m*	*c*	*m*	*c*	*m*
	1	.27	.05	-.18	.21	1.97	2.50	3.24	3.75	551	756	1.50	1.53	-.33	.28	.13	.11	.13	.17	.36	.09	10	9
p1	*2*	.10	.34	.03	-.19	2.41	2.31	3.15	4.57	598	586	1.55	1.48	-.29	-.35	.06	.13	-.11	-.01	.48	.33	10	9
	3	.14	.19	-.32	.01	2.04	2.40	3.07	3.75	551	756	1.52	1.53	.16	.28	.28	.16	-.15	.17	.22	.09	11	12
	1	-.27	-.16	.20	-.10	2.09	2.15	2.39	3.42	303	530	1.63	1.63	-.39	-.37	.23	.14	-.12	-.06	.55	.33	8	8
p 2	*2*	-.30	.15	.51	-.17	2.06	2.35	3.32	3.58	373	540	1.62	1.63	-.13	-.41	.18	.21	-.12	.02	.59	.29	9	8
	3	-.17	-.01	.02	-.14	1.98	2.25	2.53	3.35	396	592	1.61	1.63	-.39	-.36	.17	.12	.06	.06	.47	.31	9	8
	1	-.18	-.37	.04	-.31	2.10	2.15	3.98	3.94	306	564	1.52	1.53	-.20	.09	.48	.43	-.04	.15	.68	-.02	10	8
p 3	*2*	-.36	-.31	.13	-.15	1.94	2.71	3.58	3.79	245	491	1.50	1.20	-.17	-.32	.59	.33	-.18	-.22	.73	.49	12	8
	3	-.29	-.32	-.06	-.42	1.87	2.29	3.08	5.36	302	585	1.44	1.48	-.19	-.19	.23	.40	-.25	.16	.67	-.88	11	10
	1	.82	.20	-.19	-.05	2.73	2.66	2.50	3.98	490	461	1.64	1.65	-.38	-.34	.18	.23	.25	-.33	.17	.57	8	10
p 4	*2*	.53	.32	.13	-.22	2.59	2.66	3.09	3.04	435	535	1.57	1.66	-.36	-.21	.26	.23	.11	-.20	.46	.50	9	8
	3	.14	.26	-.25	-.14	2.93	2.66	2.66	3.51	535	498	1.67	1.65	-.13	-.28	.24	.23	.24	-.26	-.96	.53	9	9
Significance level		.926		.146		**.040**		**.002**		**.001**		.624		.456		.420		.875		.474		.108	

t = trial, *c* = classic technique, *m* = modified technique, *p* = participant.

obtained or if the technique should be further changed. However, such program can not be proposed to high level athletes with the risk of altering highly efficient planned motor tasks.

Conclusion

The proposed neuromechanical analysis finalized to correlate technique features with the core performance indicator can be used to test the impact of other modifications to *Kata* techniques on relevant performance and, consequently, of general performance in Karate. Besides, it can provide useful suggestions to the technicians for improving karateka's performance capacity.

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". The authors wish to thank FIJLKAM (National Judo, Karate, Wrestling and Martial Art Federation) in the name of the coach Francesco Penna for his helpful technical suggestions and support provided throughout the study with the karateka. A special thank goes to all karateka for their active co-operation in the study. The help of Federico Quinzi and Elena Bergamini in data acquisitions is gratefully acknowledged.

References

Davis, R.B., Ounpuu, S., Tyburski, D. and Gage, J.R. (1991) A gait analysis data collection and reduction technique. *Human Movement Science* **10**, 575–87.

Hermens, H.J. (2000) SENIAM – *European Recommendations for Surface Electromyography.* Roessingh Research and Development, Netherlands.

Kadaba, M.P., Ramakrishnan, H.K. and Wootten, M.E. (1990) Measurement of lower extremity kinematics during level walking. *Journal of Orthopaedic Research* **8**, 383-392.

King, D. (2005) Performing triple and quadruple figure skating jumps: implications for training. *Canadian Journal of Applied Physiology* **30**, 743-53.

King, D., Smith, S., Higginson, B., Muncasy, B. and Scheirman, G. (2004) Characteristics of triple and quadruple toe-loops performed during the Salt lake City 2002 Winter Olympic Games. *Sports Biomechanics* **3**, 109-23.

Lockwood, K.L., Gervais, P.J. and Mccreary, D.R. (2006) Landing for success: a biomechanical and perceptual analysis on on-ice jumps in figure skating. *Sports Biomechanics* **5**, 231-41.

Mathyyakom, W., McNitt-Gray, J.L. and Wilcox, R. (2006a) Lower extremity control and dynamics during backward angular impulse generation in backward translating tasks. *Experimental Brain Research* **169**, 377-88.

Mathyyakom, W., McNitt-Gray, J.L. and Wilcox, R. (2006b) Lower extremity control and dynamics during forward angular impulse generation in backward translating tasks. *Journal of Biomechanics* **39**, 990-1000.

Mori, S., Ohtani, Y. and Imanaka, K. (2002) Reaction times and anticipatory skills of karate athletes. *Human Movement Science* **21,** 213-30.

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

Wilk, S.R., McNair, R.E. and Feld, M.E. (1983) The physics of karate. *American Journal of Physics* **51,** 783-790.

Zehr, E.P., Sale, D.G. and Dowling J.J. (1997) Ballistic movement performance in karate athletes. *Medicine & Science in Sports & Exercise* **29**, 1366-73.

Zehr, E.P. and Sale, D.G. (1994) Ballistic movement: muscle activation and neuromuscular adaptation. *Canadian Journal of Applied Physiology* **19**, 363-78.

Key points

- A quantitative phase analysis, highlighting the critical features of the technique, was provided for the jump executed during the *Kata Unsu.*
- Kinematics and neuromuscular activity can be assessed during the *Kata Unsu* jump performed by top level karateka.
- Neuromechanical parameters change during different *Kata Unsu* jump techniques.
- Appropriate performance capacity indicators based on the neuromechanical evaluation can describe changes due to a modification of the technique.

AUTHORS BIOGRAPHY

Valentina CAMOMILLA

Employment

Assistant Professor at the University of Rome “Foro Italico”.

Degree

PhD

Research interests

Devising methodologies to move from the laboratory to the field a reliable quantification of biomechanical features critical for the performance.

E-mail: valentina.camomilla@iusm.it

Paola SBRICCOLI

Employment

Associate Professor at the University of Rome “Foro Italico”.

Degrees

MD, PhD

Research interests

Non-invasive assessment of muscle damage and repair, linear and non-linear analysis of sEMG signals in healthy humans, neuromechanics in sedentary participants and top level athletes, and exercise physiology.

E-mail: paola.sbriccoli@iusm.it

Alberto DI MARIO

Employment

Physical trainer of the National Judo Team, Italian National Judo, Karate, Wrestling and Martial Arts Federation, FIJLKAM.

Degree

BSc, MSc

E-mail: alberto_dimario@fastwebnet.it

Alessandro ARPANTE

Employment

Post graduate student, University of Rome.

Degree

BSc

Research interests

Describing karate techniques.

E-mail: alex.arpante@alice.it

Francesco FELICI

Employment

Assoc. Prof. Human Physiology and Exercise Physiology, University of Rome.

Degree

MD

Research interests

The human movement area – from energetic to control – focused mostly on: neuromuscular control, non linear analysis of surface electromyograms, neuromuscular effects of exercise and sport, exercise physiology in healthy and pathological subjects.

E-mail: francesco.felici@iusm.it

✉ **Valentina Camomilla, PhD**

Piazza Lauro de Bosis, 15 – 00135 Rome, Italy