33rd International Conference on Biomechanics in Sports, Poitiers, France, June 29 - July 3, 2015
Floren Colloud, Mathieu Domalain & Tony Monnet (Editors)
Muscle-Skeleton-Mechanics

MUSCLE RECRUITMENT SEQUENCE AND TOTAL REACTION TIME DURING A KARATE ROUNDHOUSE KICK

Chih-Chung Hu[1,2], Jia-Da Li[1], Fu-Hsiu Hsieh[3] and Tung-Wu Lu[1,*]

Institute of Biomedical Engineering, National Taiwan University, Taipei, Taiwan[1]
Department of Mechanical Engineering, Ming Chi University of Technology, Taipei, Taiwan[2]
Department of Exercise Science-Martial Arts, Taipei Physical Education College, Taipei, Taiwan[3]

The purpose of the current study is to quantify the muscle recruitment sequence and total reaction time of fourteen national karate athletes and fourteen college karate athletes while performing upper level roundhouse kick. A 16-channel electromyography was used to measured the muscle activities and an instrumented target was for the evaluation of the response time. The experimental results show that both groups recruited the biceps femoris on the kicking (right) side, followed by the right gastrocnemius, but the subsequent muscle firing sequence was slightly different. This resulted in smaller total reaction time of the national group (736.32 ms) than the time of the control group (770.28 ms) because of different across skill level.

KEY WORDS: Kicking, firing, electromyography, response time.

INTRODUCTION: Karate is a striking art using punching, kicking, knee strikes, elbow strikes, and open-handed techniques. The roundhouse kick, a multiplanar and complex skill, starts with the kicking leg travelling towards the front target. Biomechanical factors have been identified in karate athletes based on the observed kinematic and kinetic changes, but how these changes affect the muscle firing sequences and reaction time of upper level roundhouse kick remains unclear. The purpose of the current study was to investigate the muscle firing sequences and total reaction time of national karate athletes performing upper level roundhouse kick and compared to college karate athletes (control group).

METHODS: Subjects: Fourteen national karate athletes (age: 23.67 ± 2.64 years; height: 174.57 ± 7.13 cm; mass: 72.75 ± 10.65 kg) and fourteen age-matched college karate athletes as controls (age: 22.83 ± 3.44 years; height: 173.48 ± 7.54 cm; mass: 65.87 ± 7.45 kg) participated in the current study with informed written consent as approved by the Institutional Research Board. Subjects were all free of neuromusculoskeletal dysfunction and trained more than three years.

Experimental protocol: In a gait laboratory, each subject standing with each foot on a forceplate performed upper level roundhouse kick (Fig. 1) towards an instrumented kicking target in the front (Fig. 2). The subjects were asked to prepare themselves before the kicking target generating a flash light to indicate the 'start' sign. As soon as the start light was on, the subject performed the upper level roundhouse kick as fast as he/she could to hit the kicking target that was instrumented with a pressure sensor to record the instance of the hit. The electromyography (EMG) of sixteen muscles, namely bilateral gluteus maximus, gluteus medius, rectus femoris, biceps femoris, tensor fasciae latae, tibialis anterior, and gastrocnemius, as well as the right erector spinae and right rectus abdominis were measured at a sample frequency of 1080 Hz (EMG, Zero-Wire, U.S.A., Fig. 3). Before the kicking tasks, the subjects performed 3-4s maximum voluntary contractions (MVCs) during which the command stimuli were imposed. The three-dimensional (3D) trajectories of the markers were measured with a 7-camera motion analysis system (VICON 512, Oxford Metrics, U.K.) at a sampling rate of 120 Hz. The ground reaction forces (GRF) were measured synchronously

with two force platforms (AMTI, Mass., U.S.A.) at a sampling rate of 600 Hz. Five successful trials of upper level roundhouse kicks were obtained for each subject. The onsets are defined as the valuse from signal in EMG above threshold and reaction time is time from visual signal to hitting target. The mean EMGs of all five trials were calculated from onsets identified in trials and then the discrete data averaged.

(A) (B)

Figure 1: (A) A subject of the national group at the combat stance, and (B) the subject performing upper level roundhouse kick with his right leg at an instrumented kicking target as soon as the 'start' light was on.

Figure 2: The instrumented kicking target and the starting signal for the karate athlete.

Data analysis: The EMG signals were fully rectified and low-pass filtered at a cutoff frequency of 9Hz to obtain the linear envelopes. The amplitudes of the EMG were normalized to the MVC for the respective muscle and subject. For subsequent statistical analysis, values of the muscle firing sequences and total reaction time were extracted.

Statistical analysis: For all calculated variables, independent *t*-tests were performed to compare between the national and control groups. All significance levels were set at α= 0.05. SPSS version 14.0 (SPSS Inc., Chicago, USA) was used for all statistical analyses.

RESULTS: The first muscle recruited in the national group was the biceps femoris (184 ms) on kicking (right) side followed by the right gastrocnemius (219 ms after visual signal) (Fig. 3). The first two firing muscles in control group were the right biceps femoris (206 ms) and the right gastrocnemius (222 ms). The national group recruited thirdly the left tibialis anterior

(237 ms) while the control group recruited the right tibialis anterior (253 ms). The subsequent muscle recruitments were slightly different. The ensemble-averaged firing time of the shank muscles in both groups were significantly smaller than those for the hip and thigh muscles ($p<0.05$). The total reaction time of the national group (736 ms), defined as the time from kicking target flashed to the contact of the kicking foot with the target, was significantly less than that of the control group (770 ms) ($p<0.05$).

DISCUSSION:

The muscle recruiment sequences: The first two firing muscles were the right biceps femoris and the right gastrocnemius both in the national group and control group (Fig. 3). After these two muscles were the right tibialis anterior, the left tibialis anterior and the left biceps femoris. In the national group, the left tibialis anterior was fired firstly, the left biceps femoris secondly and the right tibialis anterior last in the three muscles. In the control group, two tibialis anteriors were almost at the same time, then followed by the left biceps femoris. The national athletes use the left tibialis anterior to speed up their kicking action. For the final three firing muscles in the national group, the left gastrocnemius was earlier than the right rectus abdominis, in the control group vice versa. Compared to the control group, significantly reduced total reaction time and earlier start firing time suggest that the national karate athletes could hit the front target significantly earlier than the control group. These may resulted from the significantly ealier muscle start firing time of the lower limb, as well as the subtle diffrences in the mucle recruitemtn patterns of the other muscles.

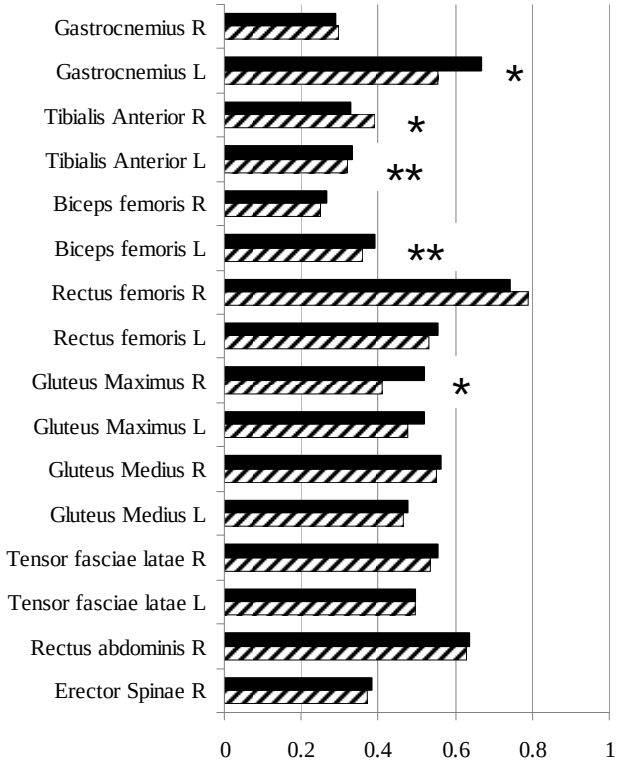

Figure 3: Ensemble-averaged start firing time of muscle recruitment in national karate athlete's group (dash bars) and control group (solid bars) performing upper level roundhouse kick. All values were normalized to total reaction time.

CONCLUSION: The muscle recruiment sequences and total reaction time of two-group karate athletes while performing upper level roundhouse kick were investigated in the current study. Both national and control groups first recruited the biceps femoris on the kicking (right) side followed by the right gastrocnemius but the subsequent recruitment patterns were

slightly different. The national theletes would like use the left tibialis anterior as the third firing muscle followed by the left biceps femoris, and in the final stage the left gastrocnemius was earlier than the right rectus abdominis. These subtle differences in muscle recruitment patterns and significantly ealier firing time of the first few muscles recruited may contribute to the significantly reduced total reaction time in the national group. The current data and findings will be helpful for the training of the left tibialis anterior and the left gastrocnemius of the karate altheletes.

REFERENCES:

Falco, C., Alvarez, O., Castillo, I., Estevan, I., Martos, J., Mugarra, F., & Iradi, A. (2009). Influence of the distance in a roundhouse kick's execution time and impact force in Taekwondo. *Journal of Biomechanics*, 42(3), 242-248.

doi: http://dx.doi.org/10.1016/j.jbiomech.2008.10.041

Schwartz, M., Hudson, A., Fernie, G., Hayashi, K., & Coleclough, A. (1986). Biomechanical study of full-contact karate contrasted with boxing. *Journal of neurosurgery*, 64(2), 248-252. Retrieved from http://thejns.org/doi/abs/10.3171/jns.1986.64.2.0248@col.2012.116.issue-6

Song, K., & An, J. (2004). Premotor and motor reaction time of educable mentally retarded youths in a Taekwondo program. *Perceptual and motor skills*, 99, 711-723. doi: 10.2466/pms.99.2.711-723

Sorensen, H., Zacho, M., Simonsen, E., Dyhre-Poulsen, P., & Klausen, K. (1996). Dynamics of the martial arts high front kick. *Journal of Sports Sciences*, 14(6), 483-495. doi: 10.1080/02640419608727735

Acknowledgement

The authors gratefully acknowledge the financial support from the Ministry of Science and Technology of Taiwan.