Journal of Electromyography and Kinesiology 23 (2013) 140–150

Contents lists available at SciVerse ScienceDirect

Journal of Electromyography and Kinesiology

journal homepage: www.elsevier.com/locate/jelekin

Differences in neuromuscular control between impact and no impact roundhouse kick in athletes of different skill levels

Federico Quinzi [a], Valentina Camomilla [b], Francesco Felici [a], Alberto Di Mario [c], Paola Sbriccoli [a,*]

[a] Exercise Physiology Lab, Department of Human Movement and Sport Sciences, University of Rome "Foro Italico", Rome, Italy
[b] Laboratory of Locomotor Apparatus Bioengineering, Department of Human Movement and Sport Sciences, University of Rome "Foro Italico", Rome, Italy
[c] FIJLKAM – National Judo, Karate, Wrestling and Martial Arts Federation, Rome, Italy

ARTICLE INFO

Article history:
Received 13 March 2012
Received in revised form 17 September 2012
Accepted 18 September 2012

Keywords:
Karate
Roundhouse kick
Muscle fiber conduction velocity
EMG
Kinematics

ABSTRACT

This study aimed at investigating two aspects of neuromuscular control around the hip and knee joint while executing the roundhouse kick (RK) using two techniques: Impact RK (IRK) at trunk level and No-Impact RK at face level (NIRK). The influence of technical skill level was also investigated by comparing two groups: elite Karateka and Amateurs. Surface electromyographic (sEMG) signals have been recorded from the Vastus Lateralis (VL), Biceps Femoris (BF), Rectus Femoris (RF), Gluteus Maximum (GM) and Gastrocnemious (GA) muscles of the kicking leg in six Karateka and six Amateurs performing the RKs. Hip and knee kinematics were also assessed. EMG data were rectified, filtered and normalized to the maximal value obtained for each muscle over all trials; co-activation (CI) indexes of antagonist vs. overall (agonist and antagonist) activity were computed for hip and knee flexion and extension. Muscle Fiber Conduction Velocity (CV) obtained from VL and BF muscles was assessed as well. The effect of group and kick on angular velocity, CIs, and CVs was tested through a two-way ANOVA ($p < 0.05$). An effect of group was showed in both kicks. Karateka presented higher knee and hip angular velocity; higher BF-CV (IRK: 5.1 ± 1.0 vs. 3.5 ± 0.5 m/s; NIRK: 5.7 ± 1.3 vs. 4.1 ± 0.5 m/s), higher CIs for hip movements and knee flexion and lower CI for knee extension. The results obtained suggest the presence of a skill-dependent activation strategy in the execution of the two kicks. CV results are suggestive of an improved ability of elite Karateka to recruit fast MUs as a part of training induced neuromuscular adaptation.

1. Introduction

The task specific demand to the central motor control system presents different levels of complexity if dealing with stereotyped (like walking and running) motor tasks, or with less familiar actions (such as those typical of many sport activities). As a consequence, the neuromuscular system has to find new solutions to cope with new and more demanding tasks, and this process progressively contributes to an improved motor learning. Among the interesting aspects related to the changes in neuromuscular control as a consequence of skill acquisition, muscular co-activation, intended as the concomitant intervention of pairs of antagonist muscles acting around a given joint to correct and possibly improve performance, has been largely investigated. To this respect, sport activities requiring a very high skill level, like martial arts are, represent a good yet challenging model to be investigated in depth and understood.

On a functional basis, it is well known that the concomitant activation of agonist and antagonist muscles about a given joint represents a powerful mechanism against possible injuries (Baratta et al., 1988). On the other hand, the acquisition of a specific motor skill can induce a progressive decrease of co-activation, as a consequence of motor learning (Basmajian, 1977; Bernstein et al., 1967) or of specific skill acquisition during an isokinetic (Bazzucchi et al., 2008; Sbriccoli et al., 2010) or a dynamic task, such as squat jumping (Masci et al., 2010).

As speed and complexity of movement increase, as when kicking, an increased level of agonist–antagonist co-activation is observed (Kellis and Katis, 2007a,b; Kellis et al., 2003; Sbriccoli et al., 2010). This mechanism is probably actuated not only to protect a given joint from possible injuries, but also to allow a finer control of movement (Sbriccoli et al., 2010). However, the most recent literature investigating kicks from a neuromuscular and biomechanical stand point, refers to single-plane movements. During the final phase of the instep kick in soccer, the simultaneous activation of large number of muscles was demonstrated (Dörge et al., 1999; Katis and Kellis, 2010; Kellis and Katis, 2007a,b). During the front kick, expert Karateka presented a peculiar activation strategy, with respect to amateurs consisting of higher knee flexors

* Corresponding author. Address: Department of Human Movement and Sport Sciences, Università degli Studi di Roma "Foro Italico", Faculty for Movement Sciences, Piazza Lauro de Bosis 6, Roma I-00135, Italy. Tel./fax: +39 06 376733 214.

E-mail addresses: fquinzi@libero.it (F. Quinzi), valentina.camomilla@uniroma4.it (V. Camomilla), francesco.felici@uniroma4.it (F. Felici), alberto_dimario@fastwebnet.it (A. Di Mario), paola.sbriccoli@uniroma4.it (P. Sbriccoli).

1050-6411/$ - see front matter © 2012 Elsevier Ltd. All rights reserved.
http://dx.doi.org/10.1016/j.jelekin.2012.09.006

co-activation during the leg extension phase, and an enhanced ability to gain full Motor Unit (MU) recruitment and to preferentially activate fast MUs, as suggested by higher Conduction Velocity (CV) values obtained for knee flexors during the knee extension as antagonists (Sbriccoli et al., 2010). Moreover, the expert athletes showed a completely different behavior in terms of agonist–antagonist co-activation as the motor task (isokinetic knee flexion–extension vs. front kick) and speed of movement (from 400°/s in isokinetic to 1470°/s during the dynamic task) change, suggesting the presence of a task dependent neuromuscular adaptation.

Since, in martial arts, the front kick is the most simple, but not the most common, and the only kick performed on a single-plane, it was important to investigate differences in neuromuscular activation strategies when performing multi-plane movements, like in the roundhouse kick (RK). With respect to the front kick, in this action more that one joint acts on more than one plane.

In karate, the roundhouse kick can be performed differently depending on target height. Namely, according to karate combat competition rules imposed by the World Karate Federation (WKF), a contact with the opponent is allowed exclusively for the roundhouse kick directed to the trunk (Impact RK, IRK), whereas no contact (No Impact RK, NIRK) is permitted if the kick is directed towards a higher target (face and neck). It may be expected that the possibility of hitting/non-hitting a target influences the muscular activation strategy used to perform the different RKs. Moreover, to score points, the no-impact RK execution has to be "convincing", i.e. swift and precise enough to be judged as if the kicking foot was hitting the target. This is a very demanding task for the motor control system in terms, at least, of aiming precision.

So far, the RK has been analyzed essentially estimating its impact forces (Falco and Alvarez, 2009; Jae-Woong et al., 2010; O'Sullivan et al., 2009; Pieter and Pieter, 1995) or determining velocity and acceleration of selected lower limb segments (Tsai et al., 2007; Boey and Xie, 2002; Serina and Lieu, 1991; Schwartz et al., 1986). The neuromuscular aspects, including the differences in co-activation of muscles acting about hip and knee joint while performing a different kick have not been considered yet. The analysis of both joints might in fact provide a better understanding on how the motor control of more than one joint is actuated, and to what extent this can characterize and/or differentiate between Karateka and Amateurs.

Thus, the present study was aimed at studying the neuromuscular response obtained during the execution of impact/no impact roundhouse kick in elite Karateka and amateurs using a neuromechanical approach.

2. Methods

2.1. Subjects

Subjects selected for the present study (six Elite Karateka and six Amateurs) were the same chosen for the study performed in 2010 by this research group (for a reference, see Sbriccoli et al., 2010).

3. Measurements

3.1. Experimental protocol

3.1.1. Roundhouse kick: IRK and NIRK

Karateka and Amateurs were asked to perform the RK immediately after a visual trigger, starting with the kicking leg positioned backwards on the sagittal plane, with the knee slightly flexed. Two different conditions were tested. The subjects were asked to impact at their abdomen level (Impact RK, IRK) or not to impact at their face level (Non Impact RK, NIRK) against a padded target. The same phase analysis applies to both kicks:

Phase1 – Loading Phase. During this phase, in both IRK and NIRK, the knee of the kicking leg was raised to the position in which the thigh was almost horizontal and the knee maximally flexed; thus, during the Loading Phase both knee and hip flexion occurred.

Phase 2 – Kicking Phase. This phase consists of a hip internal-rotation and abduction at the kicking leg, paralleled by a sudden extension of the knee in the IRK, and of both hip and knee in the NIRK. During the IRK (Fig. 4), subjects were asked to make contact through the dorsal part of the kicking foot with the target. At the time of the impact, foot, knee, and pelvis were horizontally aligned. For the NIRK (Fig. 5), the kicking leg was straightened as quickly as possible towards the target, but no impact of the kicking foot was allowed, in accordance with the rules. In both IRK and NIRK subjects were asked to kick as fast as possible.

Each subject performed three attempts for IRK and NIRK. All IRK and NIRK performed by each subject were analyzed as it will be described in the followings (data processing).

4. Data acquisition

All kinematics and EMG measurements detailed in the following paragraph were performed on the dominant leg. The relevant signals were synchronized, via a synchronization signal triggered by a shared switch.

4.1. Kinematics acquisition

During IRK and NIRK, lower limb kinematics was acquired with a stereophotogrammetric system (Vicon System, Oxford Metrix, UK, 120 samples per second). All subjects were provided with retro reflective markers (14 mm) placed on the main anatomical landmarks of the pelvis and of the dominant limb. For each segment under analysis, the location of relevant anatomical landmarks was identified by an expert through manual palpation and marked with permanent ink.

Pelvis markers were placed on the right and left Anterior Superior Iliac Spinae and on the right and left Posterior Superior Iliac Spinae. The Great Trochanter, the Lateral Epycondyle and the Medial Epycondyle were chosen as anatomical landmarks for the thigh, while the Head of the Fibula the medial and lateral Malleoli for the shank. Foot markers were placed on the Calcaneal Tuberosity and on the first and the fifth metatarsal heads. Using these anatomical landmarks, the position and orientation in space for any given instant of time of the standard anatomical reference frames defined by the International Society of Biomechanics were obtained (Wu et al., 2002).

4.2. EMG acquisition

Surface EMG (sEMG) signals depicted from the kicking leg were recorded during the IRK and NIRK using a portable wi-fi transmission EMG amplifier (BTS Pocket EMG, Italy). The sEMG signals were A/D sampled at 2000 points per second at 12-bit resolution (amplitude range +/−5 V; band pass filtered 10–500 Hz). Before electrodes' positioning, the skin was properly abraded with sandpaper and cleaned with ethyl alcohol.

The sEMG signals were collected in a differential mode from the vastus lateralis (VL) and biceps femoris (BF) with two linear four array electrodes (silver bars 5 mm long, 1 mm thick, inter electrodes distance 10 mm, LiSIN, Torino, Italy). The array elec-