Journal of Electromyography and Kinesiology 24 (2014) 353–358

Contents lists available at ScienceDirect

Journal of Electromyography and Kinesiology

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

Effectiveness of roundhouse kick in elite Taekwondo athletes

Sutima Thibordee, Orawan Prasartwuth *

Department of Physical Therapy, Faculty of Associated Medical Sciences, Chiang Mai University, Chiangmai, Thailand

ARTICLE INFO

Article history:
Received 2 July 2013
Received in revised form 4 February 2014
Accepted 7 February 2014

Keywords:
Joint angle
Impact force
Electromyography
Roundhouse kick
Taekwondo

ABSTRACT

The roundhouse kick is a powerful attack in Taekwondo. Most athletes intently perform this kick for scoring in competition. Therefore, kinematic and kinetic analyzes of this kick were the topics of interest; however, they were separately investigated and rarely recorded for impact force. Our objectives were to investigate knee and ankle joint kinematics and electromyographic (EMG) activity of leg muscle and compare them between high-impact (HI) and low-impact (LO) kicks. Sixteen male black-belt Taekwondo athletes performed five roundhouse kicks at their maximal effort. Electrogoniometer sensors measured angular motions of ankle and knee joints. Surface EMG activities were recorded for tibialis anterior, gastrocnemius medialis, rectus femoris, and biceps femoris muscles. Based on maximal impact forces, the athletes were classified into HI and LO groups. All athletes in both groups showed greater activation of rectus femoris than other muscles. The HI group only showed significantly less plantarflexion angles than the LO group during preimpact and impact phases ($P < 0.05$). During the impact phase, the HI group demonstrated significantly greater biceps femoris activation than the LO group ($P < 0.05$). In conclusion, rectus femoris activation could predominantly contribute to the powerful roundhouse kicks. Moreover, high biceps femoris co-activation and optimal angle of ankle plantarflexion of about 35° could help achieve the high impact force.

1. Introduction

To perform the Taekwondo roundhouse kicks, the kicking leg is basically lifted in an arc towards the front of the body and then the knee is rapidly extended until the instep of the foot hits the target (Park et al., 2009). In competition, the roundhouse kick is frequently used to get scores as it is a fast movement and provides a powerful attack (Falco et al., 2011; Li et al., 2005; Luk et al., 2001; Matsushigue et al., 2009). Previous studies showed that impact forces of roundhouse kicks were approximately 1000 N–3000 N in Taekwondo players (Estevan et al., 2011; Falco et al., 2009; Li et al., 2005). Higher impact forces (1994.03 ± 537.37 N) were shown in the competitors as compared with the non-competitors (1477.90 ± 679.23 N) (Falco et al., 2009). Even in the similar skill level athletes, the medalists performed stronger kicks than the non-medalists (Estevan et al., 2011). Therefore, several researchers have investigated influential factors for powerful kicks regarding to kinematics and kinetics of the kicking leg.

Concerning kinematics analysis, the kicking leg undergoes a wide range of motion of up to 100° knee flexion, and 45° ankle plantarflexion (Ha et al., 2009; Kim et al., 2010, 2011; Kong et al., 2000; O'Sullivan et al., 2009). During impact phase, knee flexion angle was significantly greater in highly skilled players (about 31°) than in unskilled ones (about 20°) whereas similar ankle plantarflexion was about 44° in both groups (Ha et al., 2009). Although highly-skilled athletes could be assumed to have high impact force and vice versa, lacking values of impact forces is still critical. Therefore, in this study, we monitored kinematics of kicking leg and recorded the impact force to compare between high- impact and low-impact kicks in highly-skilled athletes.

According to electromyographic (EMG) studies of kicking movements, EMG recording showed that activation in quadriceps muscle was relatively higher than other muscles (Brophy et al., 2007; Sørensen et al., 1996). This predominant activation of quadriceps corresponded with knee extension movement during soccer kicks (Brophy et al., 2007) and Taekwondo front kick (Sørensen et al., 1996). However, in the roundhouse kick, only one study reported greater activation of biceps femoris and gastrocnemius muscles than other muscles (Luk and Hong, 2000). This discrepancy could be due to methodology of analyzes since the EMG activities were averaged throughout the kick without classifying

* Corresponding author. Address: Department of Physical Therapy, Faculty of Associated Medical Sciences, Chiang Mai University, 110 Intawaroroj Rd., Sripoom, Chiangmai 50200, Thailand. Tel.: +66 53 94 9239; fax: +66 53 94 6042.

E-mail addresses: sjan002@gmail.com (S. Thibordee), orawan.pr@cmu.ac.th (O. Prasartwuth).

http://dx.doi.org/10.1016/j.jelekin.2014.02.002
1050-6411/

into phases. In addition, impact forces were not reported and skill level of the participants was not specified.

Taken together, previous studies investigated kinematics and EMG activity of kicking leg separately (Ha et al., 2009; Kim et al., 2010, 2011; Kong et al., 2000; Luk and Hong, 2000; O'Sullivan et al., 2009) and these limited the application of knowledge. To overcome these limitations, this study investigated synchronously kinematics and kinetics in highly-skilled athletes. We chose to analyze them in each phase and compared them between high-impact and low-impact kicks. Therefore, the objectives were to investigate knee and ankle kinematics and EMG activity to detect differences between high- impact and low-impact kicks.

2. Methods

2.1. Participants

Sixteen male Taekwondo athletes with black belt certifications and with experience in national-level competitions were recruited. None had neurological or musculoskeletal disorders that would influence their performances during the tests. All provided written informed consent according to the experimental procedure approved by the institutional review board committee of the Faculty of Associated Medical Sciences at Chiang Mai University.

2.2. Procedure

Before the tests, the athletes were allowed to warm-up and perform practice trials at minimal effort using their dominant leg for kicking. The target was set at a proper execution distance and adjusted to the height of the umbilicus for each athlete. The athletes stood in ready stance with their kicking leg placed behind. They were instructed to kick as strongly as possible in response to the verbal instruction "Go", and avoid using any body momentum to maximize the impact. They were also asked to kick in a natural movement pattern with no restriction on trunk or upper limb movements. After hitting the target, they returned to a stable standing position with the kicking leg placed in the front. Five roundhouse kicks were performed with 15 s rest between each kick.

2.3. Data collection

Recording of angular motions and EMG activities were performed on the kicking leg. The synchronization of all recording devices was performed manually by switching the devices "ON" at the same time. The event marker connected to the electrogoniometer recording device was pressed while verbally instructing "Go" in order to mark the beginning of each kick. The foot switch connected to the EMG recording device was attached to plantar surface of the foot under the heel and the hallux and used to recheck the synchronization of angular motion and EMG signals. If onset of angular motion and EMG signals were not synchronously recorded by showing greater than 50 ms deviations, the kicks were repeated.

2.3.1. Joint angle

Angular motions of the ankle and knee joints were recorded by twin-axial electrogoniometer sensors (DataLOG W4X8, Biometrics Ltd., UK). Sensors were attached to the athlete's skin on lateral aspect of the leg. The sensor was attached at the distal one third of the lower leg and below the lateral malleolus (ankle joint). Another sensor was attached at the distal one third of the thigh and upper half of the lower leg (knee joint). Prior to the data collection, the sensors were calibrated relative to the standard goniometer. At the onset of recording, all signals were set to zero value in anatomical position. The signals were collected at 1000 Hz by DataLOG software (Biometrics Ltd., UK).

2.3.2. Electromyography

EMG activities were recorded from kicking leg muscles including tibialis anterior, gastrocnemius medialis, rectus femoris and biceps femoris. Prior to electrode placement, the skin was shaved, abraded, and cleaned with alcohol. Disposable self-adhesive electrodes (8 mm diameter, Ag/AgCl discs; Red Dot, 3 M) were taped over muscle bellies approximately 20 mm apart and aligned parallel to the direction of muscle fibers. Electrode placement for tibialis anterior was at proximal one third on the line between the tip of the fibula and the medial malleolus. For gastrocnemius medialis, electrodes were placed on the most prominent bulge of the muscle. For rectus femoris, electrodes were placed midway of the distance from the anterior superior iliac spine to superior pole of the patella. For biceps femoris, electrodes were placed at midway on the line between the ischial tuberosity and the lateral epicondyle. These locations were identified during maximal contractions in the seated (tibialis anterior and rectus femoris) and prone (biceps femoris and gastrocnemius medialis) positions. To ensure correct electrode placement, EMG signals were checked during resting and sub-maximal contractions. The EMG signals were sampled at 1000 Hz and pre-amplified (gain 4000 for tibialis anterior and gastrocnemius medialis and gain 1000 for rectus femoris and biceps femoris, 12 bits resolution, CMRR > 110 dB with frequency response 6–6000 Hz at 3 dB) using MyoDat software (MIE Medical Research Ltd., UK).

2.3.3. Impact force

A rectangular-shaped ($0.3\ m \times 0.3\ m \times 0.1\ m$) kicking target was constructed by spongy foam and covered with a polyvinyl chloride sheet. It was fixed to the wall and attached to a mono-axial force transducer (2 kN; LC 1205-K200, A&D Co Ltd., Japan). Calibration was performed by applying several standard weights on the center of the force transducer. The relationship between voltage and weight was linear. The attack area was marked at the center of the target in order to provide visual feedback for the accuracy site of the kicks. The force signal was collected at 200 Hz by Powerlab system (ADInstruments Pty Ltd., Australia).

2.4. Phase determination

The pattern of the roundhouse kick begins with the kicking leg remained in slightly ankle dorsiflexion and knee flexion (Fig. 1B and C, top panels). The lifting of the kicking leg was started by gradually plantarflexing the ankle until reaching maximal angle. With the ankle maintaining in maximal plantarflexion, the knee joint subsequently reached maximal flexion angle. Then, the knee rapidly extended until the foot hit the target. While the foot moved towards the target, the ankle joint extended until reaching less plantarflexion angle at the impact. After the impact, the ankle joint abruptly plantarflexed and then irregularly moved until returning to the floor.

Based on marked changes in the ankle and knee angles, the roundhouse kick was divided into four phases defined by five events (Fig. 1). The lift-off phase was defined as a period from minimal ankle dorsiflexion angle to maximal ankle plantarflexion angle. Then, the preparation phase followed and ended at maximal knee flexion angle. The pre-impact phase subsequently occurred and ended at less ankle plantarflexion angle. Finally, the impact phase began and ended at greater ankle plantarflexion angle.