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Elite female tae kwon do athletes have faster reaction time and longer movement time than males during a striking kick

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Abstract

Background & Study Aim: An important aspect of ap bal ap dolio tchagui kick in tae kwon do is that it is usually performed in reaction to a signal or event. That is, given a specific stimulus (i.e. the movement of the opponent), the tae kwon do athlete must react as quickly and accurately as possible to the stimulus. Reacting to a stimulus requires preparation and it is essential to determine this preparation of an elite athlete to perform a task. Therefore, to investigate this movement a reaction time paradigm is appropriate wherein the athlete accomplishes the kick in response to a stimulus. The study investigates the processing, reaction and motor response of male and female athletes in an ecological task. The purpose of this study was to verify the authenticity of the two hypotheses: (1) that the pre-motor time, response time and motor time would be the same for males and females; (2) that the magnitudes of the muscle activation would be different between males and females.

Materials & Method: The main method is an analysis and comparative study of empirical data. We collected data on 13 Brazilian national calibre tae kwon do athletes (6 male and 7 female) when performing a simple reaction time kicking manoeuvre. The experimental equipment included EMG electrodes placed on six muscles and an electrogoniometer placed on the knee of the kicking limb.

Results: We found that pre-motor and response times were faster for females than males for several muscles but the faster movement time for males was sufficient to equate the total time between males and females. These results suggest that quantification of biomechanical parameters from skilled athletes allows coaches to understand the movement which will ultimately improve the technique to establish training goals.

Conclusions: It is suggested that the knee extensors muscles are mainly responsible for a kicking movement. Our data showed that trunk stabilizers were activated prior to the main knee extensors muscles. In tae kwon do, athletes have to be very precise and fast in order to surprise their opponent, avoiding defence and counterattack. Monitoring pre-motor muscle activation during training sessions, potentially gives support for specific training and/or aiming movement optimization.

Key words: martial arts • pre-motor time • response time • EMG

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Taekwon-do – a Korean martial art based mainly on punches and kicks. In the scientific literature there are various forms of spelling: **taekwondo; tae kwon do; tae-kwon-do.**

Reaction time – the interval of time that elapses from the presentation of an unanticipated stimulus to the beginning of a person's response.

Taekwondo Foot Techniques – *Ap chagi*/ Front kick, *Dollyo chagi*/ Round kick, Yeop *chagi*/ Side kick, *Dwi chagi*/ Back kick, *Nerio Chagi*/ Axe kick, *Mom-dollyo Chagi*/ Turning kick [25]

INTRODUCTION

Tae kwon do is a Korean martial art that can be roughly translated to **the art of the foot and fist**. The world's most popular martial art is practiced at multiple levels including a high competitive level (e.g. Olympic Games) and at non-expert levels. In tae kwon do, there are several kicks that are usually used against an opponent. One of these kicks is the *ap bal ap dolio tchagui*. This kick has multiple purposes. It is applied to attack the opponent, for defence against an opponent or to counter-attack the opponent. Although it is not a high-scoring manoeuvre in tae kwon do, it is used in daily practice and in a tae kwon do competition. However, due to its simplicity, this particular kick is widely used in both practice sessions and in competition.

An important aspect of this kick in tae kwon do is that it is usually performed in reaction to a signal or event. That is, given a specific stimulus (i.e. the movement of the opponent), the tae kwon do athlete must react as quickly and accurately as possible to the stimulus. Reacting to a stimulus requires preparation and it is essential to determine this preparation of an elite athlete to perform a task. Therefore, to investigate this movement a reaction time paradigm is appropriate wherein the athlete accomplishes the kick in response to a stimulus.

The reaction time is the time between the presentation of a stimulus and the initiation of a muscular response to the stimulus [1]. The reaction time can be fractionated into pre-motor time and response time [2-4]. The pre-motor time is the period from the stimulus to the onset of muscle activation and it gives information about the preparation for the task, and the response time is the period from the onset of the muscle activation (i.e. EMG) to the initiation of movement. The movement time is the period from the initiation of movement to the completion of the task (Figure 1). This particular tae kwon do kicking manoeuvre is a task that is a reaction to a stimulus and may be evaluated using a simple reaction time paradigm. By fractionating the reaction time into the pre-motor time, response time and movement time components, a greater understanding of how this task is accomplished can be ascertained. This information may be useful for coaches in optimizing training methods and thus performance.

Males and females participate in tae kwon do both competitively and recreationally. Both sexes perform the same skills in competition. Adam et al. [5] showed that males and females employed different information and processing strategies in a choice reaction time task which required a verbal response to a spatial location target stimulus with males having an overall reaction time advantage (i.e. a shorter

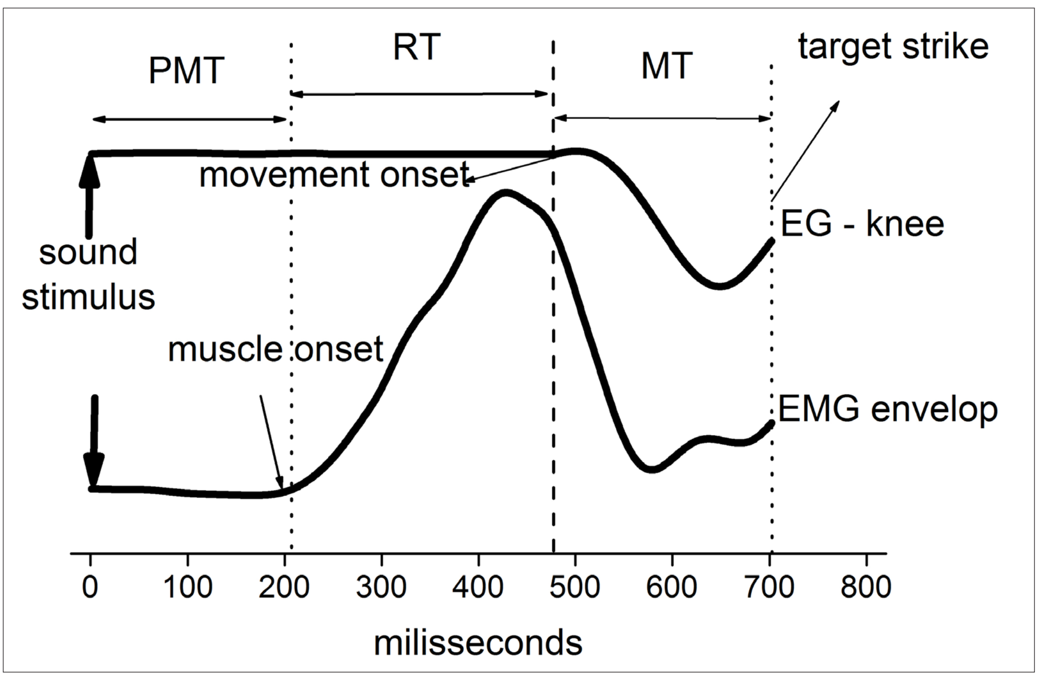


Figure 1. Pre-motor time (PMT), response time (RPT), movement time (MT), movement onset, muscle onset and target strike are illustrated using the biceps femoris (BF) EMG and knee angle from an electrogoniometer for one kick of one athlete.

reaction time). However, studies have yielded contradictory findings about the effect of sex on choice reaction time tasks involving finger dexterity [6], finger reaction time task [7] and visual reaction time task [8]. This study investigates the processing, reaction and motor response of male and female athletes in an ecological task.

Therefore, we find that improving the knowledge of these phenomena will bring closer to compare the reaction (pre-motor and response) times for the lower limb and lower back muscles; and to qualitatively compare the activation patterns of the muscles of the striking lower limb and the lower back of Brazilian national calibre males and females during the *ap bal ap dolio tchagui* kicking manoeuvre.

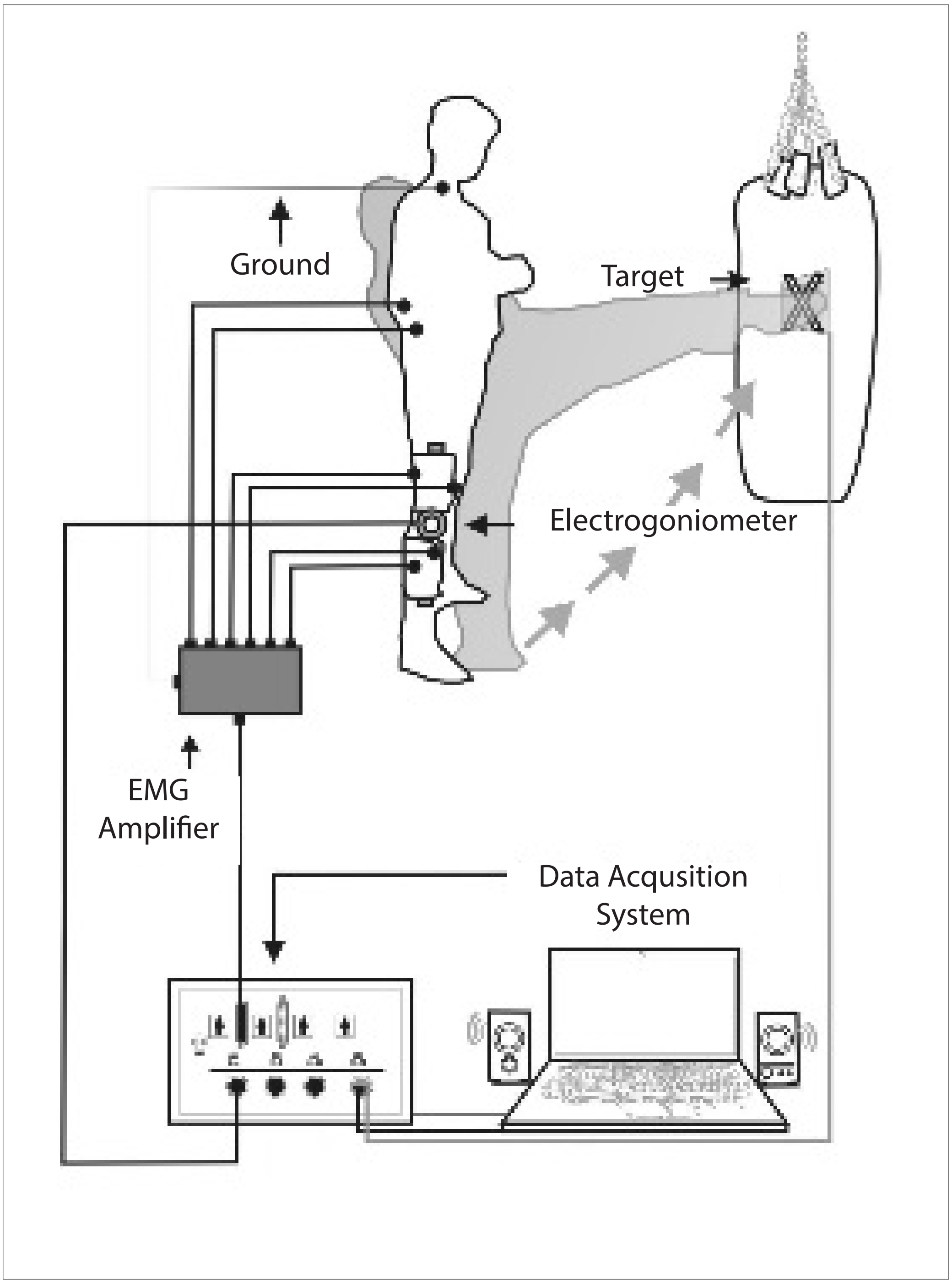


Figure 2. Experimental set-up. Electromyography for erectror spinae (right and left), vastus lateralis, biceps femoris, tibialis anterior, and gastrocnemius lateralis, as well as, knee angle, sound and a switch on the heavy bag were synchronously acquired at 1 kHz.

The purpose of this study was to verify the authenticity of the two hypotheses that the pre-motor time, response time and motor time would be the same for males and females, that the magnitudes of the muscle activation would be different between males and females.

MATERIALS AND METHODS

Participants

Thirteen experienced Brazilian tae kwon do athletes, 6 males (27±2.9 years old, 176.7±6.0 cm height, 66.5±9.6 kg mass and 14.5±3.3 years' experience in tae kwon do) and 7 females (20±1.5 years old, 163.3±4.5 cm height, 57.3±9.1 kg mass and 9.4±4.2 years' experience in tae kwon do) volunteered for the study. The participants were the entirety of national calibre tae kwon do experts in Brazil. They were informed about the experiment and gave their written consent in order to be included into the study. The study was conducted in accordance with the Helsinki Declaration and was approved by the local Ethics Committee.

Experimental Setup

A target with the switch sensor was glued on the heavy bag (mass 75 kg). The target was located 10 cm above the height of each athlete's iliac crest and denoted the end of the kicking trial. Surface electromyography (Noraxon Myosystem 1400, Scottsdale, AZ, USA) was obtained from two trunk and four leg muscles only on the kicking limb. The EMG amplifier had the following characteristics: Common Mode Rejection Ratio – 80 dB; high input impedance, band pass filter – 10-500 Hz; and gain – 100. The EMG signal was pre-amplified 10 times during data collection at the electrode level.

An electrogoniometer (EMG-System, Brazil) was used to measure the kicking leg's knee angle. The electrogoniometer was calibrated at four specific angles (90, 120, 150 and 180 degrees) using a goniometer to convert millivolt to degrees. A polynomial fit to the calibration data was then determined for use in the movement trials.

All data were interfaced to an analogue to digital converter and collected on a microcomputer at 1 kHz. Figure 2 illustrates the experimental set-up.

Protocol

The experimental protocol involved a simple reaction time experiment in which the participant was given an auditory cue to begin the task. When the cue was given, the participant then completed the *ap bal ap dolio tchagui* kicking manoeuvre. Each trial ended when the participant struck the heavy bag.

Prior to performing the task, the participant walked for ten minutes at a comfortable speed on a treadmill and warmed up for other ten minutes performing the movements/exercises they were used to in daily training. Pairs of differential, self-adhesive surface electrodes, 8 mm in diameter were placed 2 cm apart on the muscle bellies after a conventional skin preparation (shaving, cleaning, and abrasion of keratinized epidermis). The skin preparation was accomplished in accordance to the protocols of the International Society of Electrophysiological Kinesiology for surface electromyography for non-invasive assessment of muscles [9]. The EMG electrodes were placed on the right and left erector spinae, 2 cm lateral to the spinous process; vastus lateralis, 2/3 of the distance along a line between the anterior superior iliac spine to the lateral border of the patella; biceps femoris, 50% of the distance on a line the ischial tuberosity and the lateral epicondyle of the tibia; tibialis anterior, 1/3 of the distance between the medial fibular head and the medial malleolus; and gastrocnemius lateralis, 1/3 of the distance between the head of the fibula and the heel. All electrodes were place parallel to the line of action of the respective muscles.

The electrogoniometer were placed on the participant at this time. Each arm of the electrogoniometer was tightly attached to the thigh and leg respectively with the centre of rotation at the lateral femoral epicondyle.

Each participant was asked to strike a boxing heavy bag, applying a tae kwon do kick technique *ap bal ap dolio tchiagui*, using their dominant or preferred kicking leg. Prior to the experimental trials, each participant chose a comfortable distance from the heavy bag in order to reach the bag with a kick. Subsequently, markers were placed on the floor to guarantee that they could return to the initial position after each kick.

We collected 22 trials (kicks) to ensure consistency of the movement pattern. We eliminated the first and last trials to ensure: 1) that the participants understood the task completely; and 2) so that they would not be fatigued on the last trial. The time between trials was randomized to give the participants enough time to get ready for the next trial and to simulate a practice session in which they would be required to accomplish the movement in a random time. A sound was triggered to indicate that the participant should kick as fast and hard as possible; then, a second sound indicated that they should return to the initial position and wait for the next starting sound. The time between the first and second sounds was fixed to 1.9 s and the time between the trials was randomized in a range from 7 to 13 s.

Data Analysis

Digital pre-amplified EMG signals were band pass filtered from 20 to 400 Hz using a 4th order zero-lag Butterworth filter. The signals were then full-wave

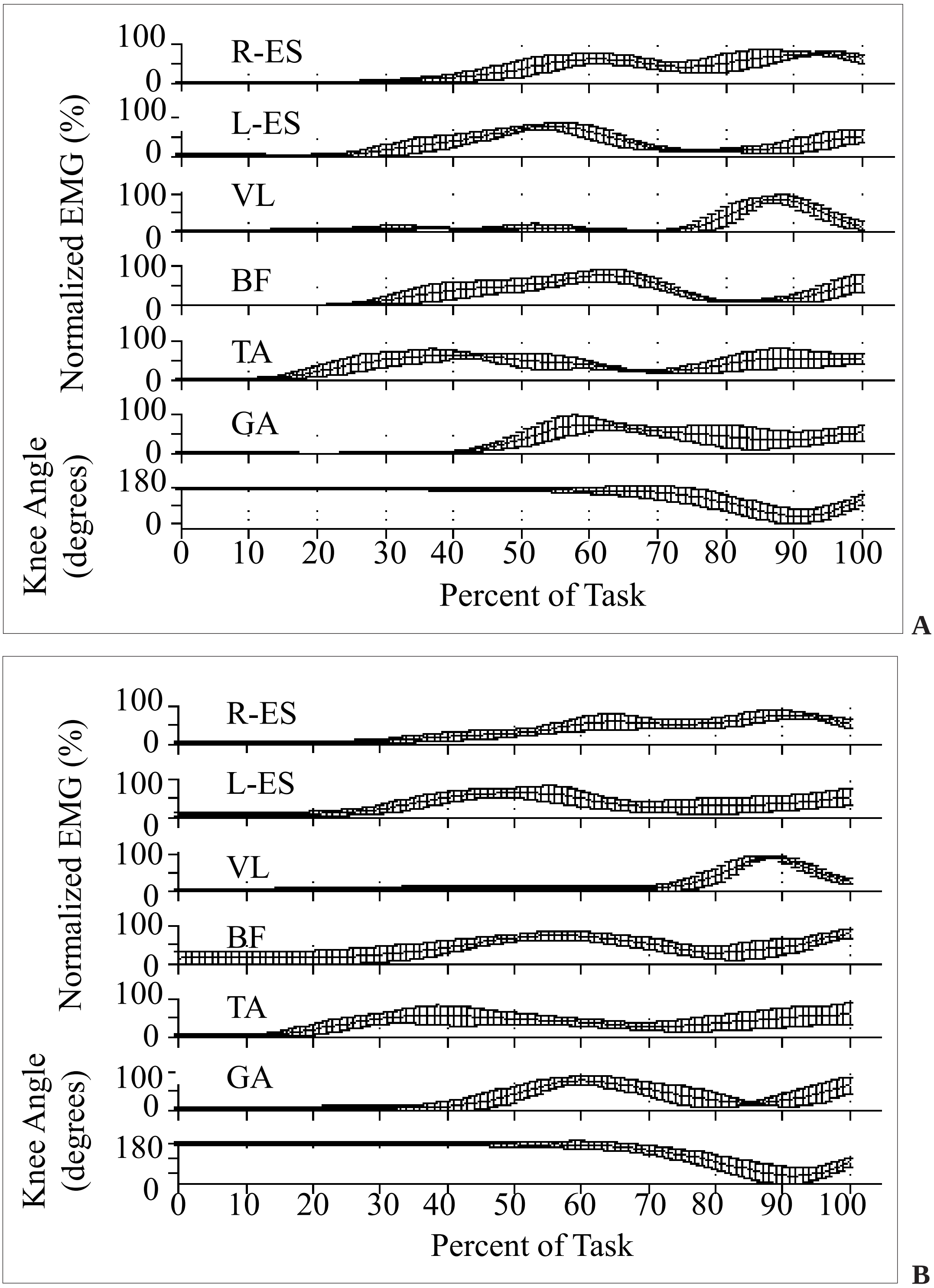


Figure 3. Knee angle and the EMG profile, mean (±sd), time normalized (% of the task) and normalized in amplitude by the peak EMG obtained in every kick for a) males (n=6) and b) females (n=7).

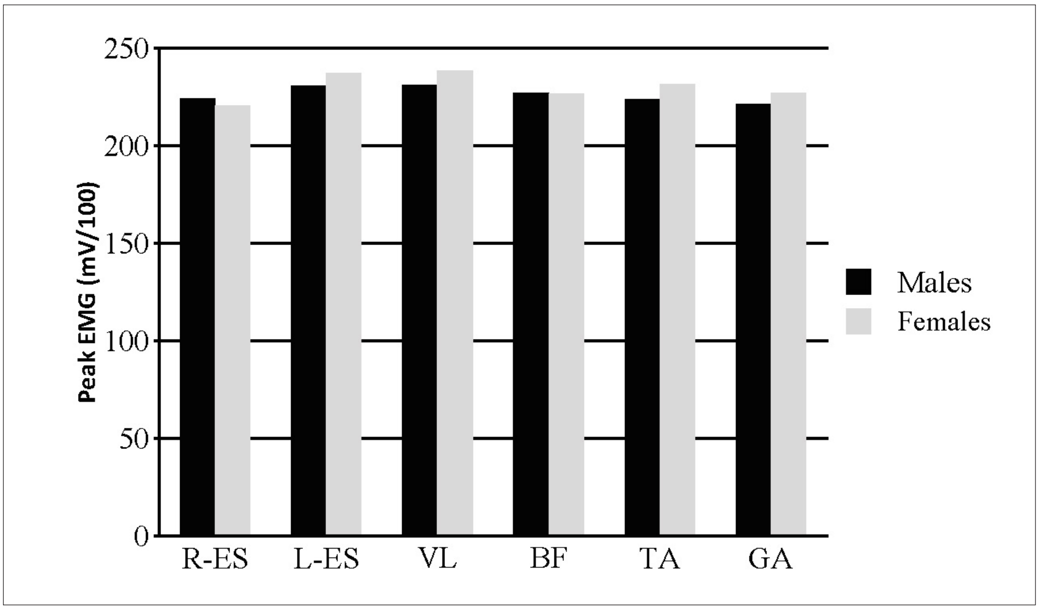


Figure 4: Mean (±sd) peak EMG value for all muscles over all trials for males (n=6) and female (n=7) participants.

rectified, low-pass filtered with a 4th order Butterworth filter with a cut-off frequency of 20 Hz and normalized by the maximal intensity obtained in the trials.

EMG onset was defined as the point at which the signal deviated from the baseline by more than three standard deviations and was visually confirmed on each EMG profile. Movement onset was determined as the first change in angle of the knee electrogoniometer. The key parameters pre-motor time, response time and movement time were calculated as follows: 1) pre-motor time was determined from the initiation of the stimulus to the onset of the EMG of each muscle; 2) response time was determined from muscle onset to movement onset; and 3) movement time was determined from movement onset to target strike. To present the EMG and kinematic parameters, data were time normalized by interpolating it into 101 points.

Statistical Analysis

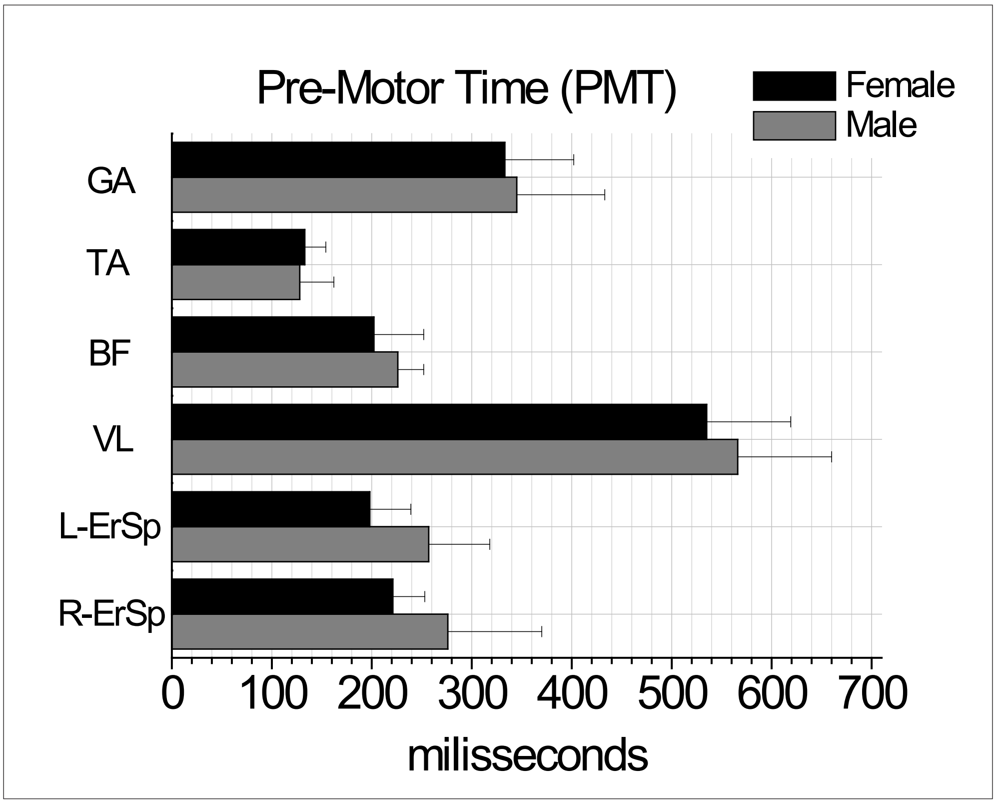
The subject pool represented all of the national calibre tae kwon do athletes in Brazil. Because of this, we did not conduct inferential statistics. Instead we used effect size (ES) to determine meaningful differences between groups for the reaction and movement time parameters and muscle activation [10]. Cohen [10] proposed that ES values of 0.2 represent small differences; 0.5, moderate differences; and 0.8 large differences.

RESULTS

The mean (±sd) knee angle and time normalized EMG profiles for all muscles are presented in Figure 3 for all males and females. There were no differences between males and females in terms of the magnitude of the muscle activations for any muscles (Figure 4).

There were only moderate to small differences (0.14<ES<0.57) between males and females for three of the muscles (GA, TA, and VL) during the pre-motor time. There were strong effect sizes (ES>1.07) for the right and left ES and the BF with the males having a longer pre-motor time than the females (Figure 2). For reaction time (pre-motor time + response time), there were relevant differences between males and females with females having shorter pre-motor time than males (ES>0.86) for all muscles, except TA. For response time, the right and left ErSp presented shorter time for the males than the females (ES<0.80) while the VL, BF, TA and the GA showed a shorter time for females (ES>1.22). There were no differences in motor time between the males (322.8±116.1 ms) and females (362.1±146.7 ms) (ES=0.30). In terms of response time, there were few differences between males and females for the activation onset of certain muscles (figure 5A). There was no difference in movement time between males and females.

For reaction time (pre-motor time + response time), there were relevant differences between males and females with females having shorter pre-motor time than males (ES>0.86) for all muscles (figure 5). For response time, the vastus lateralis presented shorter time for the males than the females (ES<0.80) while the biceps femoris, tibialis anterior and the gastrocnemius lateralis showed in shorter



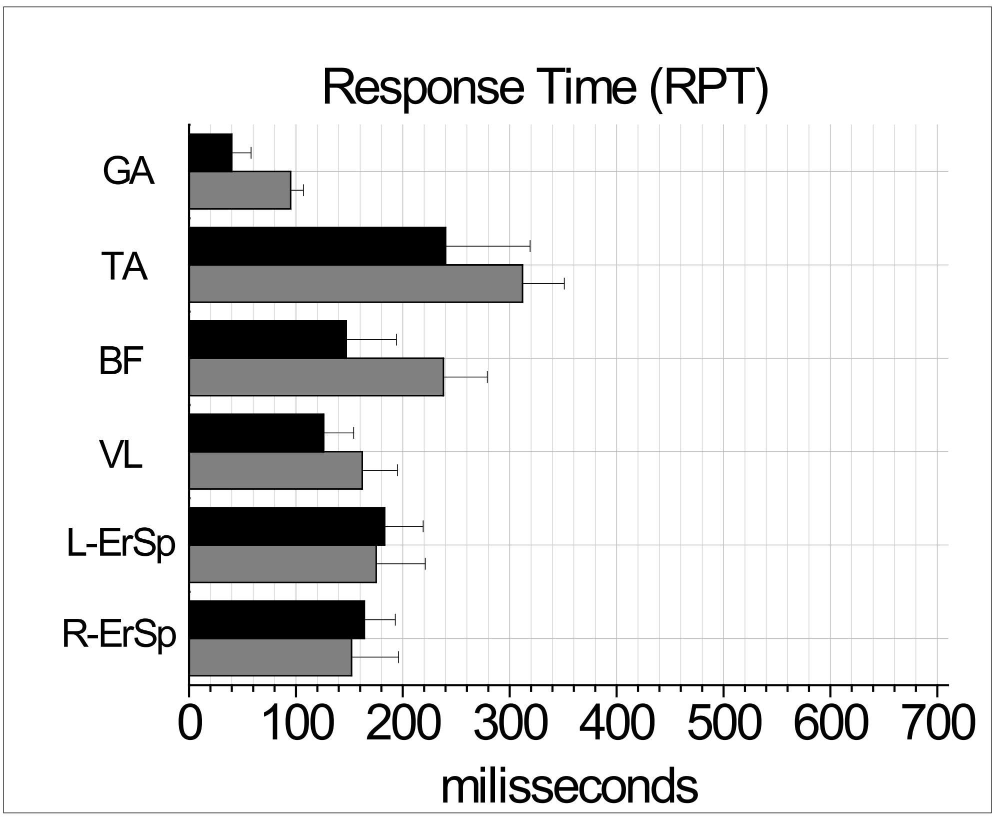


Figure 5. Mean (+SD) pre-motor time and response time for all muscles erector spinae (ErSp) left and right, vastus lateralis (VL), biceps femoris (BF), tibialis anterior (TA), and gastrocnemius lateralis (GA) for males (n = 6) and females (n=7).

time for females (ES>1.22, figure 5B). There were no differences in motor time between the males (322.8±116.1 ms) and females (362.1±146.7 ms) (ES=0.30).

DISCUSSION

The purpose of this study was twofold. First, we compared the reaction (pre-motor and response) time and movement time for the lower extremity and lower back muscles between national calibre males and females during a tae kwon do kicking manoeuvre referred to as *ap bal ap dolio tchagui*. Second, we qualitatively compared the magnitude and the activation patterns of the muscles of the striking lower limb and the low back in male and female athletes. We hypothesized that the pre-motor time and the response time (i.e. reaction time) and movement time would be different between males and females. Our first hypothesis was partially supported by the results of this study. In fact, there was a difference in pre-motor time for five of the six muscles studied with the females having a shorter pre-motor time than the males. In terms of response time, there were some differences between males and females for the activation onset of certain muscles. There was no difference in movement time between males and females.

Many reaction time studies indicated differences in reaction time between sexes [11] although few of these studies have used a fractionated reaction time paradigm. In almost every age group, males had lower reaction times than females and the female disadvantage has not been reduced by practice [5,12,13].

Blough & Slavin [14] reported that mean time to respond to a visual task was 510 ms for males and 640 ms for females; for an auditory signal, as in the current study, the reaction time was 190 ms (males) to 200 ms (females). In comparison, Engel et al. [15] reported 227 ms (male) and 242 ms (female) as the sound reaction time. Spierer et al. [16] reported that when male soccer players were compared with female lacrosse players, males were able to respond faster to both visual and auditory stimuli. In the current study, because of the rather complicated task, the reaction times for both males and females were markedly greater than in the literature. We found that females responded to the auditory stimulus much faster than males.

In our study, both the males and females were highly skilled athletes having at least 9 years in the practice of tae kwon do. All of the participants were highly trained in the particular task required in this study. The major difference between groups, however, was that the males were much taller and heavier than the females. In fact, on average, the males were 13 cm taller than the females. This may account for the difference in the pre-motor time and thus reaction time responses between males and females. Conduction velocity, that is, the speed with which an electrical impulse can be transmitted through excitable tissue is a function of distance and may account for this difference. With shorter distances to travel, the muscle activation times for females would be shorter and thus reaction times would also be shorter.

Few studies on reaction time have fractionated the reaction time into pre-motor time and response time. Botwinick & Thompson [2] found that almost all of the male-female difference was accounted for by the lag between the presentation of the stimulus and the beginning of muscle contraction. Pre-motor time was different between males and females indicating a shorter pre-planning time for the females. Differences in response time, on the other hand, may be explained by the difference in muscle conduction velocity. While there was no relevant difference in movement time between the sexes, males did have approximately 40 ms faster movement than females to make the total stimulus to contact time very comparable. The 40 ms difference could be accounted for by the difference in muscle mass between the males and females.

Our second hypothesis regarding muscle activation could not be accepted. In the current study, there was no difference in the activation of the individual muscles between males and females. This suggests that, for male and female athletes, the trunk stabilizing and lower limb postural muscles were activated during the kicks. Because this particular movement is a key aspect of tae kwon do attack and/or defence strategy, it would be natural to move as quickly as possible and thus to maximally activate these muscles.

Our data showed that trunk stabilizers were activated prior to the main knee extensors muscles. It has been previously shown that anticipatory postural adjustments, measured by trunk and lower limb muscles activation prior to the pointing movements, are modulated by the size of the target [17] when humans are pointing to a target in the upright standing position or by the presence of back pain [18,19]. Interestingly, the magnitude of the EMG activity of lower limb muscles decreases with a smaller target size (increased task accuracy), while that of the erector spinae increases, indicating a strategy that enhances trunk muscles activation at the same time that decreases lower limb muscles postural control influence in order to achieve more accurate tasks.

More than 2000 years ago, oriental warriors developed fighting techniques that allowed nearly optimal use of the human body as a deadly weapon, showing its inherent destructive capability [20]. These techniques were improved by observing and mimicking wild animals and insects movements that were transformed into exercise forms. In addition, militaristic and religious doctrines made the so-called '*martial arts*' an expressive part of the Oriental culture. Since ancient times, optimization of the techniques was based on movement repetition [21]. Therefore, quantification of biomechanical parameters obtained in studies involving high level, skilled athletes potentially gives support for these sports modalities, allowing coaches to understand the physics of the movements, which will ultimately improve the technique, and also to compare beginners and middle level practitioners with top level athletes in order to establish training goals.

The results of our research on the one hand are the empirical evidence of the genius of the ancient masters of martial arts and distinguished followers. On the other hand, increasing the knowledge about optimizing fighting techniques used in tae kwon do, which are analysed from different perspectives of physics and biomechanics, and in the aspect of increasing the effectiveness of the training [see, among other things: 22-27].

CONCLUSIONS

It is suggested that the knee extensors muscles are mainly responsible for a kicking movement. In the present study, we did not measure the major hip flexors so we cannot confirm this suggestion. Our data showed, however, that trunk stabilizers were activated prior to the main knee extensors muscles. Lower limb postural muscles were also pre-activated, meaning that tibialis anterior, biceps femoris, and gastrocnemius lateralis were recruited prior to the knee extensor vastus lateralis. In tae kwon do, athletes have to be very precise and fast in order to surprise their opponent, avoiding defence and counterattack. Monitoring pre-motor muscle activation during training sessions, potentially gives support for specific training and/or aiming movement optimization. Moreover, kinematic parameters obtained during highly skilled athletes performance should be used as a goal to be researched.

COMPETING INTERESTS

The author(s) declare that they have no competing interests.

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