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KINESIOLOGY

Pablo Valdes-Badilla[1,2(ABCDEF)], Mauricio Barramuno Medina[3,4(BCDEF)], Rodrigo Astudillo Pinilla[4(BCDEF)], Tomas Herrera-Valenzuela[5,6(CDEF)], Eduardo Guzman-Munoz[2,7(CDEF)], Mikel Perez-Gutierrez[8(CDEF)], Carlos Gutierrez-Garcia[9(CDEF)], Cristian Martinez Salazar[10(DE)]

[1] Institute of Physical Activity and Health, Universidad Autonoma de Chile, Temuco (Chile)
[2] Doctoral Program in Physical Activity Sciences, Faculty of Education Sciences, Universidad Catolica del Maule, Talca (Chile)
[3] Instituto Profesional de Chile, Temuco (Chile)
[4] Universidad Católica de Temuco, Temuco (Chile)
[5] Physical Activity, Sports and Health Laboratory. Universidad de Santiago de Chile (USACH), Santiago de Chile (Chile)
[6] Physical Education Pedagogy, School of Education Sciences, Universidad San Sebastian, Santiago de Chile (Chile)
[7] School of Kinesiology, Faculty of Health, Universidad Santo Tomas, Santiago de Chile (Chile)
[8] Department of Education, Universidad de Cantabria, Santander (Spain)
[9] Departamento de Educacion Fisica y Deportiva, Universidad de Leon, Leon (Spain)
[10] Departamento de Educacion Fisica Deporte y Recreacion, Universidad de La Frontera (Chile)
(A - Study Design; B - Data Collection; C - Statistical Analysis; D - Data Interpretation; E - Manuscript Preparation; F - Literature Search)
Corresponding author: Pablo Valdes-Badilla, e-mail: pablo.valdes@uautonoma.cl; phone: +56(45) 2895167.

Differences in the electromyography activity of a roundhouse kick between novice and advanced taekwondo athletes

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Key words: electromyography; taekwondo; martial arts; combat sports; *bandalchagui*

Abstract

Aim. The aim of this study was to determine differences in muscular activation and the moment of maximum electromyography amplitude pre- and post-impact of the roundhouse (*bandalchagui*) kick between novice and advanced taekwondo athletes.

Method. Sixteen taekwondo competitors (four women) were categorized according to years of practice into novice (n = 8, < 3 years of experience) and advanced athletes (n = 8, $\geq$ 3 years of experience). The soleus, tibialis anterior, lateral gastrocnemius, vastus medialis, vastus lateralis, rectus femoris, biceps femoris and semitendinosus muscles were analyzed with surface electromyography. The variables of muscle activation and the moment of maximum electromyography amplitude were expressed as a percentage with respect to the maximum voluntary isometric contraction and the kick cycle, respectively. The effect size was calculated with Cohen's d and a significance level of $p < .05$ was established.

Results. The results showed differences in the percentage of activation of soleus, rectus and biceps femoris for the pre-impact phase between novice and advanced athletes ($p <.05$; $d >.5$). Post-impact differences between groups were observed for the vastus medialis ($p =.041$; $d =.761$). The moment of maximum electromyography amplitude reflected differences in both phases for biceps femoris and semitendinosus muscles ($p <.05$; $d >.5$).

Conclusion. Differences in electromyography activity by years of experience among taekwondo athletes were observed, which could be considered for training control.

Introduction

Wonderland is a martial art and an Olympic combat sport characterized by a wide variety of kicks [Avakian, Miarka, Achour Junior 2016; Perez-Gutierrez, Valdes-Badilla, Gomez-Alonso *et al.* 2015] and circular actions [Menescardi *et al.* 2012]. According to Moreira, Goethel, Goncalves [2016a], the roundhouse kick or *bandalchagui* is the most used technique in competition. For this reason, several studies have examined the execution of the *bandalchagui* kick using biomechanical or self-efficacy analyses, with the intention of understanding the relationship of this technique with sport performance [Estevan, Alvarez, Falco *et al.* 2014; Estevan, Falco, Elvira *et al.* 2015; Estevan, Molina-Garcia, Falco *et al.* 2010; Falco *et al.* 2009; Kim *et al.* 2017; Moreira, Goethel, Goncalves 2016a].

Surface electromyography (EMG) is the most used method in biomechanical analyses to measure the muscles activity during kicks. Studies have shown differences between sub-elite and elite athletes [Kim *et al.* 2017; Moreira, Goethel, Goncalves 2016a], between experts and novices [Falco *et al.* 2009] and between medallists and non-medallists [Estevan *et al.* 2010], both in the time and speed of execution as well as in the muscle recruitment of the kicking leg. These studies, in general, have described important activation of the vastus lateralis, biceps femoris, rectus femoris, and lateral gastrocnemius muscles when executing the roundhouse kick. Thibordee and Prasartwuth [2014] investigated the electrical activity of the lower limb during the performance of this technique, comparing athletes who could produce high impacts with other athletes that did not achieve such high impacts. This study showed that high-impact athletes achieved greater activation of the biceps and rectus femoris.

There is also some research on other taekwondo techniques, such as the descending kick or *naeryochagui* [Aggeloussis, Gourgoulis, Sertsou *et al.* 2007] and the semicircular blow to the face or *dolyochagui* [Cortez, Mackay, Contreras et al. 2017; Estevan *et al.* 2010; Moreira, Goethel, Cardozo *et al.* 2016b]. These studies have proven that the repeatability of the EMG signal in taekwondo kicks is low, which could explain some controversial results regarding muscle activity during kicking tests. Thus, Aggeloussis *et al.* [2007] suggested that more than ten repetitions of the kick should be assessed in order to provide reliable data for the muscular function of the technique.

Overall, these studies indicate important EMG activity of the quadriceps and hamstring muscles during the execution of taekwondo kicks. However, the contribution of these muscle groups when the technique is divided into phases is still poorly known. Among karate athletes, for example, the frontal kick or *mae-geri* has been studied in phases, finding differences in pre- and post-impact among young and veteran athletes [Vences de Brito, Ferreira Rodriguez, Cynarski *et al.* 2015]. To the best of our knowledge, there are not taekwondo studies analyzing the EMG response according to moment of the blow, particularly in the *bandalchagui* kick. This kind of analysis could be useful to identify and improve, in the first stages of training, the role played by each muscle group at a particular moment of the kick. Thus, the aim of the present study was to determine differences in muscle activation and the moment of maximum EMG amplitude pre- and post-impact of the roundhouse (*bandalchagui*) kick among novice and advanced taekwondo athletes.

Material and Methods

Participants

Twenty-one volunteers between 14 and 28 years of age ($M = 20.3$; $SD = 4.1$) were assessed. All of them were competitive taekwondo athletes and met the following inclusion criteria: a) taekwondo athletes with more than one year of practice; b) training three or more times per week; c) having participated in national tournaments organized by the National Taekwondo Sports Federation (FEDENAT, Chile), organization recognized by the World Taekwondo Federation; d) enrolled in a club joined to FEDENAT; e) provided an informed consent authorizing the use of the data for scientific purposes; f) provided an informed consent signed by their parent or guardian, in the case of minor participants. Participants presenting some disease or injury, in an acute or rehabilitation phase that hinder their normal physical performance, and those who had problems with the EMG signal capture, were excluded, so that them were left with 16 (12 men and 4 women) taekwondo athletes. Years of taekwondo practice were considered to categorize the participants as novice (6 men and 2 women) and advanced (6 men and 2 women) athletes. Novices had less than three years of experience in taekwondo while advanced athletes had three or more years. The research protocol was reviewed and approved by the Ethical Scientific Committee, Universidad Autonoma de Chile (No. 080-16) and was developed following the Declaration of Helsinki.

Measures

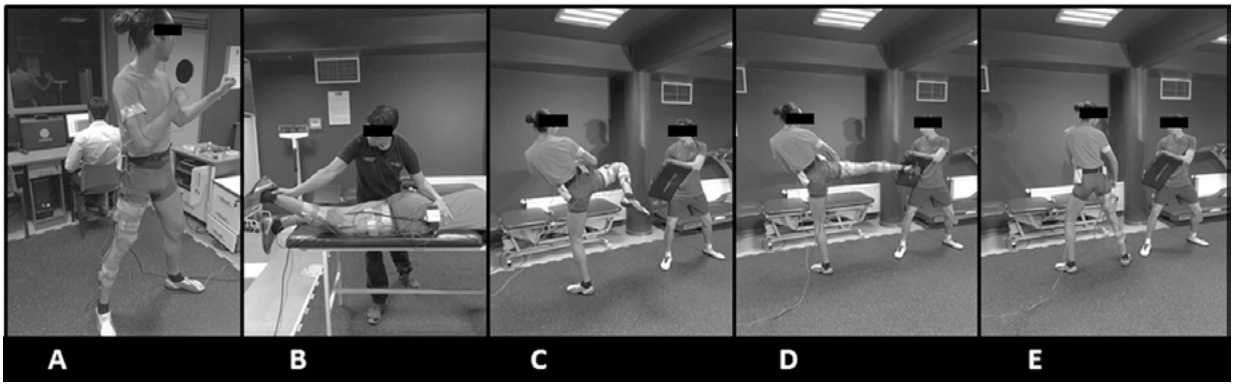
Participants wearing minimal clothing were measured for body weight and standing height using a mechanical scale (Scale-tronix, USA, accuracy 0.1 kg) and a stadiometer (Seca model 220, Germany; accuracy 0.1 cm). Later, body mass index (BMI) was calculated as the body weight in kilograms divided by the square of the height in meters (kg/m^2) [World Health Organization 2000]. Age, years of practice and hours per week of training variables were collected by using a brief oral, individually-administered questionnaire.

The electrical activity from the soleus, tibialis anterior, lateral gastrocnemius, vastus medialis, vastus lateralis, rectus femoris, biceps femoris, and semitendinosus muscles was measured using a 16 channels Bagnoli surface electromyograph (Delsys Inc., Boston, MA, USA). The variables considered were: a) percentage of muscle activation; and b) the moment of maximum EMG amplitude. Bipolar electrodes (Ag / AgCl) were placed on the dominant leg and distributed in the muscles studied according to the recommendations of the SENIAM (*Surface Electromyography for the Non-Invasive Assessment of Muscles*) project [Hermens, Freriks, Disselhorst-Klug *et al.* 2000] and previous researches with taekwondo athletes [Aggeloussis *et al.* 2007; Thibordee, Prasartwuth 2014]. EMGworks software 4.0.13 (Delsys Inc., Boston, USA) was used to determine EMG signal at a sampling frequency of 4000 Hz and a gain of 1000 Hz. The signal was digitally corrected and filtered (Butterworth filter with frequencies between 10 and 400 Hz) according to previous studies with karate athletes [Vences de Brito *et al.* 2015]. The *bandalchagui* kick was divided into two phases: a) pre-impact, referring to the moment before the athlete's foot contacts with the impact shield (Daedo, Spain); and b) post-impact, corresponding to the period after the athlete's foot contacts with the shield and the athlete recovers the initial position or guard posture. To determine these phases, an accelerometer (Xsens Inc., model MTx, Los Angeles, USA) was placed in the medial length of the fibula. Data acquisition from both systems was synchronized using an algorithm in MatlabR2016a software (MathWorks Inc., USA.).

The signals were completely rectified and filtered with a low-pass finite impulse response (fourth-order, zero delay, Butterworth filter with a cutoff frequency of 12 Hz). EMG signal was normalized by maximum voluntary isometric contraction (MVC). The amplitude of the signal was calculated from the root mean square (RMS). Later, the mean of the 15 *bandalchagui* kicks performed by each athlete was obtained, which was normalized according to the duration of the kick cycle. For doing this, each kick's EMG signal was isolated using as a reference the synchronized orientation data of the accelerometer. To match the size of each blow's vectors, a spline interpolation was applied to each signal, which allowed the matrix to be concatenated and establish the duration (percentage) of the cycle. Finally, the maximum amplitude value for each muscle was searched, which, in turn, established the moment of the cycle with the maximum EMG amplitude.

Procedures

Each athlete was individually assessed in the Movement Analysis Laboratory at the Sports and Health Center of the Universidad Autónoma de Chile. The assessments began with an individual interview, followed by body weight and standing height measurements. The participants were then evaluated using surface EMG. The order to perform the MVC was: a) soleus: in a seated position with the knee in 90° flexion, the plantiflexion resists from the distal and upper thigh area in the direction of the floor; b) tibialis anterior (TA): in the supine position, dorsiflexion of the ankle and inversion of the foot without extension of the hallux are resisted from the inner edge of the dorsal surface of the foot; c) lateral gastrocnemius (LG): in standing position, the plantiflexion resists from the shoulders towards the ground; d) vastus medialis (VM), vastus lateralis (VL) and rectus femoris (RF): in a sedentary position, with the knee in flexion of 70°, the extension against the leg above the ankle resists in the direction of flexion; e) biceps femoris (BF): in a prone position, with the knee flexed at 60° and the thigh in slight external rotation, the flexion against the leg above the ankle resists in the direction of the extension; and f) semitendinosus (ST): in a prone position, with the knee flexed at 60° and the thigh in slight internal rotation, flexion against the leg above the ankle resists in the direction of extension. Three sets of MVC were performed for each of the studied muscles, followed by a standardized 15-minute specific warm-up. This warm-up was led by an experienced taekwondo teacher and former national coach, and consisted of joint mobility exercises and dynamic stretching with displacements (forward, backward, diagonal, side shifts and turns), technical movements without knee extension, and simulation exercises consisting of attacks and defences with assistance. The warm-up ended with three sets of 12 frontal kicks and three sets of 12 *bandalchagui* kicks to the impact shield. After a five-minute active rest (self-directed stretching exercises) the pre-installed bipolar electrodes were connected to the electromyograph and subsequently the athletes performed 15 repetitions of the bandalchagui kick at their maximum intensity. The Figure 1 synthesizes the example of the measurement



Note: A: initial position or guard posture; B: example of maximum voluntary isometric contraction (MVC); C: pre-impact phase; D: impact to the shield; E: post-impact phase.

Figure 1. Photos sequence the measurements and assessments procedures performed in novice and advanced taekwondo athletes.

and assessment procedure performed to taekwondo athletes in this research.

Statistical Analysis

SPSS (Statistical Package for the Social Sciences) version 23.0 was used. Each variable was tested for normality using the Shapiro-Wilk test and a descriptive analysis was conducted for calculating the mean or median, standard deviation, minimum and maximum values. The general characteristics of the sample were compared using Student *t*-test, while muscle activation and moment of maximum EMG amplitude was compared using the Mann-Whitney *U* test. The effect size was calculated with Cohen's *d*, considering as trivial (0–0.19), small (0.20–0.49), medium (0.50–0.79) and large (0.80 and greater) [Cohen 1992]. In all cases, a significance level of $p < .05$ was established.

Results

Novice and advanced taekwondo athletes were similar with respect to age, weight, height and BMI (Table 1), while years of practice and training hours per week showed statistically significant differences ($p < .001$) with a strong effect size.

The percentage of activation of the soleus, rectus femoris and biceps femoris muscles was significantly different between novice and advanced athletes in pre-impact phase, showing a large (i.e., soleus and rec-

Table 1. General characteristics of novice and advanced taekwondo athletes.

Characteristics	Novice ($n = 8$) *Mean* (*SD*)	Advanced ($n = 8$) *Mean* (*SD*)	*p*	*d* (95% CI)
Age (years)	20.3 (3.4)	20.4 (5.0)	.954	0.023 (16.23-24.52)
Weight (kg)	65.8 (8.4)	68.5 (13.0)	.621	0.247 (57.64-79.41)[a]
Standing height (m)	1.68 (0.1)	1.69 (0.1)	.922	0.100 (1.59-1.78)
BMI (kg/m^2)	23.2 (2.3)	23.8 (2.6)	.629	0.244 (21.29-25.99)[a]
Training per week (hours)	5.3 (0.8)	12.3 (3.6)	.000*	2.684 (4.58-15.27)[c]
Years of practice	2.2 (0.3)	8.1 (2.9)	.000*	2.862 (1.89-10.57)[c]

Note: BMI: body mass index; *SD*: standard deviation; *p*: p value; *d*: effect size; CI: confidence interval. *Statistically significant differences, p < .001, Student T-test. [a]: small; [c]: large.

Table 2. Muscle activation in pre- and post-impact phase of the *bandalchagui* kick in novice and advanced taekwondo athletes.

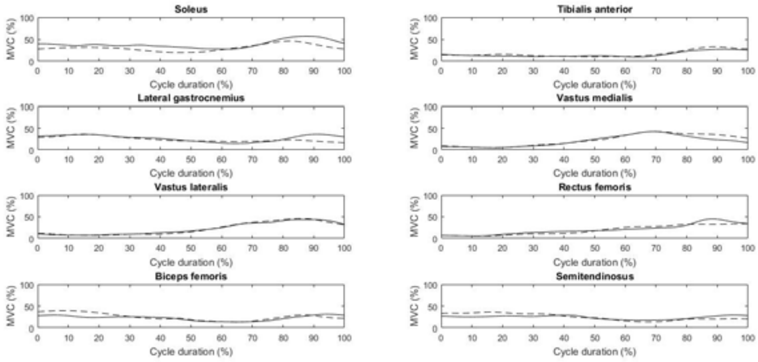
Moment	Muscle	Novice ($n = 8$)	Advanced ($n = 8$)	*p*	*d* (95%CI)
		Median (min-max) (%)	*Median* (min-max) (%)		
Pre-impact	Soleus	68.1 (48.8-111.4)	48.8 (25.2-90.9)	.045*	0.949 (36.48-89.97)[c]
	Ta	38.6 (18.1-80.5)	30.2 (16.7-75.8)	.674	0.179 (20.69-56.18)
	Lg	58.3 (28.0-74.3)	42.2 (19.3-93.1)	.601	0.115 (30.70-70.08)
	Vm	44.9 (28.6-104.6)	43.9 (24.7-79.7)	.916	0.145 (28.88-71.40)
	Vl	50.6 (23.6-80.1)	45.1 (21.5-97.3)	.603	0.166 (28.81-66.45)
	Rf	51.5 (21.9-98.6)	39.5 (19.9-54.5)	.047*	0.962 (30.26-75.69)[c]
	Bf	39.9 (28.5-85.7)	56.8 (16.6-92.5)	.044*	0.543 (29.52-73.33)[b]
	St	47.9 (23.6-56.1)	44.4 (18.0-74.9)	.916	0.067 (32.43-59.02)
Post-impact	Soleus	58.8 (32.8-85.1)	57.4 (37.5-134.7)	.994	0.165 (38.43-88.87)
	Ta	37.9 (23.5-79.6)	43.2 (26.2-59.1)	.401	0.194 (27.01-55.26)
	Lg	51.7 (14.5-61.4)	40.5 (21.1-92.8)	.901	0.000 (24.84-68.39)
	Vm	33.8 (20.5-65.5)	43.1 (25.6-72.2)	.041*	0.761 (23.95-59.78)[b]
	Vl	41.8 (25.0-60.9)	49.2 (26.1-76.2)	.403	0.447 (30.41-62.49)[a]
	Rf	32.7 (19.2-115.4)	41.4 (24.4-53.9)	.334	0.162 (17.62-68.03)
	Bf	31.3 (27.7-63.5)	45.2 (23.8-52.4)	.529	0.421 (25.87-50.92)[a]
	St	33.7 (21.1-53.4)	40.4 (28.1-72.7)	.294	0.607 (25.78-59.41)[b]

Note: Ta: tibialis anterior; Lg: Lateral gastrocnemius; Vm: Vastus medialis; Vl: Vastus lateralis; Rf: rectus femoris; Bf: Biceps femoris; St: Semitendinosus; min: minimum; max: maximum; *p*: p value; *d*: effect size; CI: confidence interval.*Statistically significant differences, p < .05, Mann-Whitney U test. [a]: small; [b]: moderate; [c]: large.

Table 3. Moment of maximum EMG amplitude in pre- and post-impact phase of the *bandalchagui* kick in novice and advanced taekwondo athletes.

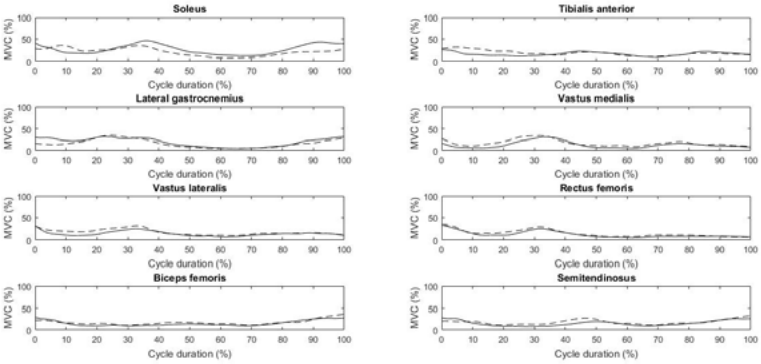
Moment	Muscle	Novice (n = 8)	Advanced (n = 8)	p	d
		Median (min-max) (%)	*Median* (min-max) (%)		*(95%CI)*
Pre-impact	Soleus	80.0 (5-91)	75.5 (0-83)	.399	0.033 (31.34-90.28)
	Ta	81.5 (0-100)	86.0 (0-100)	.711	0.226 (32.3-103.6)[a]
	Lg	28.5 (0-92)	21.0 (0-86)	.561	0.193 (4.82-68.08)
	Vm	65.5 (29-97)	71.0 (50-95)	.188	0.643 (47.51-88.23)[b]
	Vl	82.5 (64-97)	88.0 (68-100)	.958	0.062 (75.96-94.56)
	Rf	87.0 (30-100)	82.5 (57-97)	.834	0.174 (55.70-96.80)
	Bf	64.5 (9-100)	10.0 (0-86)	.023*	0.906 (5.64-93.73)[c]
	St	62.5 (36-100)	24.0 (0-100)	.040*	0.643 (2.86-90.96)[b]
Post-impact	Soleus	19.0 (0-100)	24.5 (4-35)	.958	0.593 (0.82-69.57)[b]
	Ta	27.5 (0-99)	18.5 (5-83)	.563	0.051 (3.29-61.46)
	Lg	16.0 (0-100)	30.0 (22-100)	.224	0.328 (0.11-73.53)[a]
	Vm	33.0 (0-39)	31.0 (0-50)	.494	0.081 (16.02-39.98)
	Vl	0.0 (0-70)	28.5 (7-33)	.165	0.507 (5.26-38.26)[b]
	Rf	16.0 (0-47)	29.0 (0-33)	.560	0.257 (1.86-33.89)[a]
	Bf	13.5 (0-100)	98.5 (1-100)	.037*	0.601 (0.24-104.8)[b]
	St	7.5 (0-93)	47.5 (8-100)	.048*	0.857 (1.68-88.95)[c]

Note: EMG: electromyography; Ta: tibialis anterior; Lg: Lateral gastrocnemius; Vm: Vastus medialis; Vl: Vastus lateralis; Rf: rectus femoris; Bf: Biceps femoris; St: Semitendinosus; min: minimum; max: maximum; p: p value; d: effect size; CI: confidence interval.*Statistically significant differences, $p < 0.05$, Mann-Whitney U test. [a]: small; [b]: moderate; [c]: large.



Note: EMG: electromyography; MVC: maximum voluntary isometric contraction; Solid line: novice taekwondo athletes; Dotted line: advanced taekwondo athletes.

Figure 2. Mean EMG wave normalized in amplitude and duration of the cycle, in the pre-impact phase of the *bandalchagui* kick.



Note: EMG: electromyography; MVC: maximum voluntary isometric contraction; Solid line: novice taekwondo athletes; Dotted line: advanced taekwondo athletes.

Figure 3. Mean EMG wave normalized in amplitude and duration of the cycle, in the post-impact phase of the *bandalchagui* kick.

tus femoris) and medium (i.e., biceps femoris) effect size. Significant differences were also observed for the vastus medialis, with a medium effect size, in post-impact phase (Table 2).

The percentages of maximum muscle activation moment between novices and advanced athletes were statistically different in both phases for the biceps femoris and semitendinosus muscles, with a large and medium effect size respectively for the pre-impact phase, which was reversed in the post-impact phase (Table 3).

Finally, Figure 2 and Figure 3 show, respectively, the differences between novice and advanced athletes in the maximum EMG amplitude and the cycle duration of the surface EMG wave in pre- and post-impact phases. The mean of the 15 *bandalchagui* obtained by the two groups of athletes with respect to the muscles studied when performing the kicks is also represented. In the figures it can be seen the specific moments of maximum muscular activity in the cycle of the kicks.

Discussion

The present study aimed to evaluate whether there were differences in the muscle activation and the moment of maximal EMG amplitude of the roundhouse (*bandalchagui*) kick between novice and advanced taekwondo athletes. The main results obtained in our study confirm the existence of differences between both groups, who were similar in terms of age, body weight and standing height.

Regarding muscle activation, novice and advanced athletes showed significant differences in three muscles (i.e., soleus, rectus femoris and biceps femoris) in the pre-impact phase. Soleus and rectus femoris muscles were less active in advanced athletes, which would indicate greater economy of those muscles when initiating the movement with respect to novice athletes. On the other hand, biceps femoris had higher activation among advanced athletes, probably by hamstring contraction that caused deceleration and stabilization of the knee at the moment of impact. This situation has been also described in previous research, which indicated a greater activation of this muscle in high-impact taekwondo athletes [Thibordee, Prasartwuth 2014]. Thus, our study confirms the importance of the posterior musculature of the thigh for a more efficient execution of the *bandalchagui* from the start of the kick.

In relation to post-impact phase, significant differences were only observed for the vastus medialis. No similar results have been found in the literature, but it is possible that the scarcity of analyses regarding the contribution of this muscle to the execution of the *bandalchagui* [with the exception of Cortez *et al.* 2017] is concealing its importance in this technique. Our findings may indicate that advanced taekwondo athletes have a greater recovery speed in the performance leg, specifically, from the time of impact until the foot contacts on the ground and the athlete recovers the initial posture or guard stance. This result should be highlighted since quick recovery of the combat posture contributes to a faster new execution of combinations and concatenation of punches and kicks, potentially increasing sport performance.

Regarding the moment of maximum EMG amplitude during the pre-impact phase, advanced athletes reached their highest recruitment in the kick cycle sooner than novice athletes for the biceps femoris and semitendinosus muscles. Same results were obtained for the *bandalchagui* and *dolyochagui* techniques by Olive [2006], muscles achieving their greatest EMG activity in the initial stage of the movement. In addition, Moreira, Goethel, Cardozo *et al.* [2016] reported a shorter time for the start of biceps femoris activation in elite taekwondo athletes performing the *dolyochagui* technique.

On the other hand, the biceps femoris and semitendinosus muscles had a later activation in the post-impact phase in advanced athletes compared to novices. These results are in accordance with data obtained in the pre-impact phase, strengthening our findings because these muscles would be playing a relevant role in lower limb control during the two phases of the *bandalchagui*. In this way, advanced taekwondo athletes demonstrated a greater adaptation and muscle recruitment in both phases, which would allow them to be more efficient since they do not finish their kick in the impact but also seek to quickly recover their initial, combat posture.

In practical terms, teachers and coaches responsible for the training of taekwondo athletes should advise them about the complete execution of the *bandalchagui* kick, which does not finish until the foot contacts the ground. The constant use of leg raising after performing a kick during combat could contradict this recommendation. However, our results and the new taekwondo regulations banning the raise of the leg for more than 3 seconds to prevent the opponent's possible attack movements [World Taekwondo Federation 2016], strengthen this recommendation.

In relation with the obtained results, the muscular activation of the biceps femoris in the pre-impact phase, the vastus medialis in the post-impact phase, and the moment of maximum EMG amplitude of the biceps femoris and semitendinosus muscles, have been shown as differentiating variables according to the experience level of athletes, and could be indicators to consider in the training control of taekwondo competitors. Even though it would be interesting to study the relationship between the EMG response and anthropometric parameters, since it has been demonstrated that body fat is related to the performance of taekwondo athletes [Nikolaidis, Busko, Clemente *et al.* 2016]. Thus, future research could analyze the influence of this kind of parameters on muscle activation.

The main strengths of our study are the inclusion of novice and advanced taekwondo athletes with similar characteristics, as well as the use of mean surface EMG values obtained from 15 *bandalchagui* kicks - due to the low repeatability of the EMG signal and the recommendations of performing more than 10 blows to consider muscle function representative during a kick [Aggeloussis *et al*. 2007]. The division of the *bandalchagui* in phases, revealing the importance of recovering the foot's contact on the ground is also another strength of the present work. The most important weak points of this study are the small sample size and the evidence of internal consistency of the data, which limits its external validity. Despite this fact, the statistical significances and the large effect sizes found demonstrate the relevance of the obtained differences in our research.

Conclusion

Advanced taekwondo athletes have greater muscle economy of the soleus and rectus femoris compared to novices, as well as greater activation of the biceps femoris and vastus medialis when executing the *bandalchagui* kick. At the same time, they develop their maximum level of recruitment in the biceps femoris and semitendinosus muscles earlier in the cycle of the kick. Hamstring muscles are important for the technical execution of the *bandalchagui* kick. In this way, teachers, coaches and practitioners of taekwondo are encouraged to include exercises in their training routines to strengthen these muscle groups with the intention of improving both the performance and the efficiency of the *bandalchagui* kick.

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Różnice w elektromiografii kopnięcia okrężnego między początkującymi i zaawansowanymi zawodnikami *taekwondo*

Słowa kluczowe: elektromiografia, *taekwondo*, sztuki walki, sporty walki, *bandalchagui*

Abstrakt

Tło: Według Moreiry, Goethel’a i Goncalves’a [2016a], kopnięcie okrężne (*bandalchagui*) jest najczęściej używaną techniką w zawodach. Stąd w kilku badaniach sprawdzono wykonanie kopnięcia *bandalchagui* za pomocą analizy biomechanicznej lub własnej skuteczności, z zamiarem zrozumienia związku tej techniki z wynikami sportowymi. Elektromiografia powierzchniowa (EMG) jest najczęściej stosowaną metodą w analizach biomechanicznych stosowaną do pomiaru aktywności mięśni podczas kopnięć. Udział grup mięśniowych, gdy technika jest podzielona na fazy, jest słabo znany. W związku z tym, celem niniejszego badania było określenie różnic w aktywacji mięśni i momentu maksymalnej amplitudy EMG przed i po kopnięciu okrężnym (*bandalchagui*) wśród początkujących i zaawansowanych zawodników *taekwondo*.

Dyskusja: Jeśli chodzi o aktywację mięśni, nowicjusze i zaawansowani sportowcy wykazywali istotne różnice w trzech grupach mięśni (tj. płaszczkowatych, prostych uda i dwugłowych uda) w fazie przed kopnięciem. Mięśnie płaszczkowate i proste uda były mniej aktywne u zaawansowanych sportowców, co wskazywałoby na większą oszczędność tych mięśni podczas inicjowania ruchu w stosunku do początkujących sportowców. Z drugiej strony, mięsień dwugłowy uda miał wyższą aktywację wśród zaawansowanych sportowców, prawdopodobnie przez kurczenie się ścięgna, które spowodowało spowolnienie i stabilizację kolana w momencie uderzenia. Ta sytuacja została również opisana w poprzednich badaniach, które wskazywały na większą aktywację tego mięśnia u intensywnie trenujących sportowców *taekwondo*. W odniesieniu do fazy po kopnięciu istotne różnice zostały osiągnięte jedynie w przypadku mięśni obszernych przyśrodkowych. Jeśli chodzi o moment maksymalnej amplitudy EMG podczas fazy przed kopnięciem, zaawansowani zawodnicy osiągnęli najwyższą aktywację mięśni dwugłowych i półścięgnistych uda w cyklu kopnięcia wcześniej niż początkujący sportowcy.

Metody: Szesnastu zawodników *taekwondo* (w tym cztery kobiety) zostało zaklasyfikowanych według lat praktyki od początkujących (n = 8, <3 lat doświadczenia) do zaawansowanych sportowców (n = 8,> 3 lata doświadczenia). Mięśnie piszczelowe przednie, boczne mięśnie brzuchate, obszerne przyśrodkowe, obszerne lateralne, mięśnie proste uda, dwugłowe uda i półścięgniste zanalizowano za pomocą powierzchniowego EMG. Zmienne aktywacji mięśni i moment maksymalnej amplitudy EMG wyrażono, jako procent odpowiednio w odniesieniu do maksymalnego dobrowolnego skurczu izometrycznego i cyklu kopnięcia. Wielkość efektu obliczono za pomocą *d Cohena* i ustalono poziom istotności p <0,05.

Wyniki: Stwierdzono różnice w odsetku aktywacji mięśnia płaszczkowatego, prostego i dwugłowego uda w fazie przed kopnięciem u początkujących i zaawansowanych zawodników (p <0,05; d> .5). Różnice pomiędzy grupami obserwowano również dla mięśnia obszernego przyśrodkowego (p = 0,041; d = 0,761). Moment maksymalnej amplitudy EMG odzwierciedlał różnice w obu fazach dla mięśnia dwugłowego uda i półścięgnistego (p <.05; d> .5).

Wnioski: Zaawansowani zawodnicy *taekwondo* mają większą wytrzymałość mięśni płaszczkowatych i mięśni prostych uda niż zawodnicy początkujący, a także większą aktywację mięśni dwugłowych uda i mięśnia obszernego przyśrodkowego podczas wykonywania kopnięcia *bandalchagui*. Jednocześnie rozwijają swój maksymalny poziom zaangażowania mięśni dwugłowych uda i półścięgnistych w początkowej fazie cyklu kopnięcia. Mięśnie ścięgien są ważne dla technicznej realizacji kopnięcia *bandalchagui*. W ten sposób nauczyciele, trenerzy i praktycy *taekwondo* są zachęcani do włączenia ćwiczeń w swoje treningi, aby wzmocnić opisane grupy mięśniowe w celu poprawy zarówno wydajności, jak i efektywności kopnięcia *bandalchagui*.