NEUROMUSCULAR PERFORMANCE OF DOLLYO CHAGUI: COMPARISON OF SUBELITE AND ELITE TAEKWONDO ATHLETES.

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Aiming to compare the execution time, linear and angular speeds, ground reaction force (GRF) and electromyographic (EMG) parameters between taekwondo athletes of two different standards, 8 elite and 8 subelite black belt taekwondo athletes performed eighteen round house kicks, in two randomized height (Head and Chest), with their dominant lower limb, combining maximum impact and speed, in a selective reaction time design. Kinematic were recorded through 3D kinemetry. Timing parameters and EMG cocontraction index were significantly lower in elite group, while peak of linear (toe and knee), angular speeds (knee and hip), and GRF were significantly higher in elite group. We conclude that reaction time, duration and velocity of kick and cocontraction could be useful in selecting top level taekwondo athletes and monitoring their training status.

KEY WORDS: Martial arts, kinematic, cocontraction, round house kick

INTRODUCTION: Some researches have compared groups of martial athletes of different competitive level (*expertise level*) in their general physical and physiological profile (Bridge et al., 2014), but only a few researches realized such comparisons in specific movements of combat (Estevan & Falco, 2013; Quinzi et al., 2013) that therefore, are directly relevant to performance. About these movements, the roundhouse kicks deserve special attention because these are the most used techniques, consequently resulting in most points (Estevan & Falco, 2013). Among the roundhouse kick, the Dollyo Chagui (roundhouse kick directed to the Head) has improved in importance for the combat due to the actualization of official competition rules. These rules concede the triple of points to techniques realized to the head height, in relation to that directed to the chest height (Estevan & Falco, 2013).
Researches have demonstrated that the skill level of roundhouse kick derived from task dependent neuromuscular adaptations is a differential factor in the prediction of the competitive level of the athletes (Quinzi et al., 2013). These tasks can be assessed through diverse biomechanical parameters, as the reaction time, duration and velocity of kick and cocontraction. However, the researches with taekwondo had focused only in the effect of impact and temporal aspects of kick on the athlete expertise level (Estevan & Falco, 2013). Although Quinzi et al. (2013) had used electromyographic and kinematic parameters for this goal, their volunteer were karatecas **(**Quinzi et al., 2013**)**. Furthermore, researches whose the kick was executed with more than one option of response, in randomized order and with temporal intervals similar to the combat was not found. Therefore, our goal is to compare the execution time, linear and angular speeds, ground reaction force and electromyographic parameters between taekwondo athletes of two different standards, in a selective reaction time design, simulating the timing and number of techniques from a real combat.

METHODS:
Participants: The sample was composed by 16 black belt competitors, divided in 8 elite athletes (finalist or semifinalist in national competitions; 69 ±8,8 Kg; 169,8 ± 5,9 cm) and 8 subelite athletes (state level 65,9 ± 13,4 Kg; 173,3 ± 10,3 cm).
Experimental Design and Instruments: Each athlete had electrodes placed in 8 muscles (Gastrocnemius Lateralis: GL, Vastus Lateralis: VL, Rectus Femoris: RF, Biceps Femoris: BF, Adductor Magnum: AM, Tensor of Fascia Lata: TFL, Gluteus Maximus: GM and Gluteus Medium: Gmed), and 39 marker placed according to *Plugin Gait* marker set. Following, they performed 15 minutes of warm up (5 minutes of running at 8 Km/h plus 2 minutes of specific

free taekwondo displacement and 12 vertical jumps, finalized with 10 kicks, being the last 2 at maximal intensity, familiarizing with the mainly evaluation) and 5 minutes of rest. The principal evaluation was composed by 18 roundhouse kicks (9 *Bandal Chagui* and 9 *Dollyo Chagui*) with the rear and dominant leg, with the foot starting above a force platform AMTI OR-6, spaced in a horizontal distance from the dummy (BoomBoxe®) equivalent to the lower limb length. One LED in the dummy's head and another in the thorax (figure 1) was microcontrolled by MATLAB (Mathworks® 2012, Inc) routine. The order and time between stimulus was randomized in a Gaussian mode, with a mean of 7 ± 2 s between each one, during 2 minutes. The athletes were oriented to kick the more fast and forceful as possible each time the LEDs turned on. NEXUS motion capture system (Vicon®, v.2.0) recorded the kicks through 7 cameras at 250 frames for second. Then, Kinetic and Kinematic data was processed using NEXUS software (figure 1) and digital filtered with a *Butterworth zero lag low-pass* filter at 85Hz and 10 Hz, respectively, through MATLAB routine.
The *onset* of kinetic reaction for the preparation phase of kick was considered when the resultant ground reaction force (GRF) systematically started to improve above the baseline in 2.5% of the difference between the peak of GRF and the baseline value. The *onset* of kinematic reaction was when the Pelvis (anterior superior iliac spine) systematically started to move in at least 1 cm. The *offset* of preparation phase and the *onset* of kicking phase os when the GRF turned zero. The end of the kicking phase was when the foot touched the target i.e., when the contact sensor in the targets did start to improve the voltage. These events were automatically identified through MATLAB routine. Finally, the kinetic and kinematic reaction time, the preparation phase, the kicking phase and the total kick phase (between the LED *onset* to the start of impact) were determined. The rate of force development (RFD), and peak of antero-posterior, medio-lateral, vertical and resultant force were determined during preparation phase. RFD was calculated through equation RFD=ΔForce/Δtime, for Δtime being the time between when the resultant GRF turned 20% of peak until the moment when force turned 80% of peak. The peak of linear marker (in pelvis, knee, ankle and toe) and angular velocities (hip, knee and ankle) during the kicking phase was calculated. Finally, the cocontraction (CC) between hip extensor (GM) and flexor (TFL or TFL + RF), during hip flexion; between knee flexor (BF) and extensor (VL or VL + RF) during knee flexion and extension; and between hip adutor (AM) and abductor (Gmed) during hip abduction were calculated through the following equation: $CC=Antagonist_{LE}/(Agonist_{LE} + Antagonist_{LE})$, were "$Antagonist_{LE}$" and "$Agonist_{LE}$" is the agonist and antaghonist muscle activation through linear envelope (LE) processing (rectified EMG signal processed through Butterworth Low Pass filter at 10Hz), respectively. Finally, to calculate the "premotor time"(PMT), time between visual stiumus and *onset* of LE were determined. Onset of LE was defined as the sample when LE sistematically start to improve above 1% of peak.

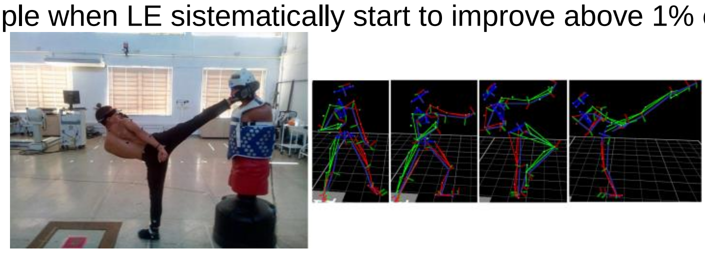

Figure 1 – Data collection and typical kinematic 3D reconstruction of Dollyo Chagui

Statistical analysis: *Shapiro Wilk* test was used to analyse data normality and independent *t-student* test to compare biomechanical parameters betwen groups of athletes. When there was not data normality , *Mann Withnney* test was used to compare groups.

RESULTS: In figure 2 are shown the plots of comparative analysis between groups of timing and linear velocity of kicks. We observed that elite athletes performed the kick with significant more velocity (for knee and foot) and expending less time for almost all the timing variables, except for the reaction time measured through ground reaction force *onset*.

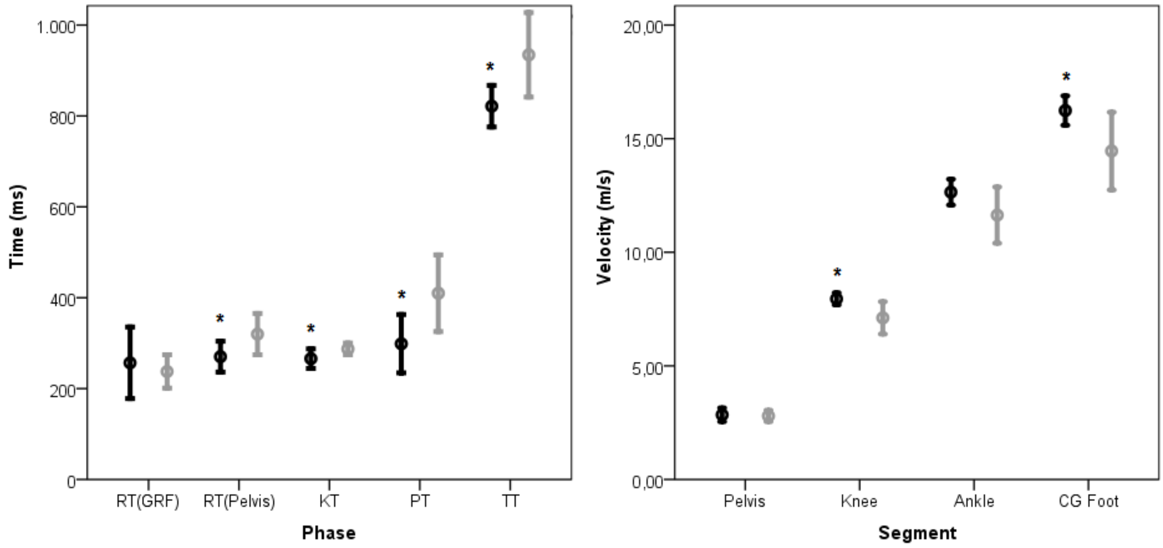

Figure 2 – Comparative plots of timing and linear velocity of kick between elite and subelite athletes. Circles represent means and bars represent 95% of confidence intervals of elite (Black) and subelite (Gray) athletes. ***:** p<0.05. **RT(GRF):** Reaction time using kinetic *onset*. **RT(Pelvis):** Reaction time using kinematic onset; **PT:** Preparation time; **KT:** Kickig time; **TT:** Total time.

Table 1 - Descriptive and comparative resultes between elite versus subelite athletes

EMG	Elite		Subelite			DYNAMIC	Elite		Subelite		
	Mean	Std	Mean	Std	p		Mean	Std	Mean	Std	p
PREMOTOR TIME (ms)						**ANGULAR SPEED (^{o}/s)**					
GL	170	69	285	121	0.02	Doorsiflexion	203	179	183	52	0.38
VL	365	197	491	172	0.06	Plantar Flexion	1100	370	1087	235	0.47
RF	399	169	449	215	0.31	Knee Flexion	788	144	621	200	<0.01
BF	195	55	233	90	0.17	Knee Extension	1443	110	1267	293	0.07
TFL	181	116	287	156	0.08	Hip Flexion	428	146	259	45	<0.01
GM	175	47	278	127	0.03	Hip Extension	296	232	236	161	0.28
Gmed	294	169	239	99	0.22	Hip Internal Rot	341	74	218	121	0.01
AM	308	84	331	147	0.33	Hip External Rot	296	233	231	123	0.18
COCONTRACTION (%)						Hip Abduction	457	107	358	58	0,02
BF/(VL+BF)	62	14	54	18	0.38	Pelvis ML	216	177	179	212	0.36
BF/(RF+VL+BF)	44	14	39	16	0.55	Pelvis AP	357	115	346	140	0.43
VL/(BF+VL)	49	22	41	13	0.20	Pelvis Lgt	706	150	627	143	0.15
(VL+RF)/(BF+VL+RF)	72	16	61	16	0.12	**GRF (BW%)**					
AM/(Gmed+AM)	47	11	43	18	0.56	Peak Force AP	76	25	58	10	0.04
AM/(Gmed+TFL+AM)	29	9	25	9	0.48	Peak Force ML	28	14	15	3	<0.01
GM/(GM+TFL)	27	13.0	43	16	0.02	Peak Force Z	185	66	139	30	0.047
GM/(GM+TFL+RF)	20	11	33	10	0.02	Peak Force res	200	70	150	31	0.044
						RFD (BW%*s^{-1})	2844	3523	541	266	0033

GL: Gastrocnemius Lateralis; **VL:** Vastus Lateralis; **RF:** Rectus Femoris; **BF:** Biceps Femoris; **AM:** Adductor Magnum; **TFL:** Tensor of Fascia Lata; **GM:** Gluteus Maximus; **Gmed:** Gluteus Medium; **GRF:** Ground Reaction Force; **BW%:** Body weight percent; **RFD:** Rate of force development in the preparation phase; **AP:** Antero-Posterior; **ML:** Medio-Lateral, **Z:** Vertical and **res:** resultant.

Statistical descriptions and test-*t* significance (p) for another variables are shown in Table 1. The group comparison analysis showed that for premotor time, there were differences in GL and GM, with the elite group expending less time. The cocontraction index only was significantly different in the control of hip flexion, with the subelite group coactivating the GM in a higher proportion. Finally, the angular speed of hip flexion, hip abduction, hip internal rotation and knee flexion were significantly higher in the elite group.

DISCUSSION: We found that elite athletes expend less time and perform the kick faster than athletes of inferior competitive level. There was no difference in the time to start to produce force in the ground, but elite athletes produced force in a more explosive way, reaching a higher peak, mainly in the horizontal plane. It can explain why elite athletes did start to move the pelvis first than subelite athletes and why the preparation phase was faster in this group, characterizing a more efficient impulse. GM and GL are posterior muscles important to propel the pelvis forward in the fight position due to their kinesiologic action i.e. plantar flexion and hip extension (Weiss et al., 2004). These muscles activated first in the athletes of higher level, contributing to generate a more efficient patter of impulse against the ground.
Another coordinative patter that did suffer influence from the expertise level was the cocontraction index. A higher cocontraction of hip muscles, found in athletes of inferior level could have influenced the efficiency of hip flexion acceleration. Accordingly, the elite athletes reached higher magnitude of angular velocity in the hip flexion. This also happened in the hip internal rotation, abduction and knee flexion. The higher hip cocontraction can explain the lower hip internal rotation velocity, because the GM is also an external rotator while the TFL is also an internal rotator muscle (Weiss et al., 2004). A minor activity of TFL or a greater activity of GM certainly can influences the internal rotation speed. The hip abduction is also a consequence of the combination of hip flexion and internal rotation. At the same way, the faster hip flexion contributes to generate a faster knee flexion, due to known phenomenon of motion dependent moment (Putnam, 1991). Quinzi et al (2013) also found superior knee flexor angular velocity in the elite group, but their elite athletes also had superior knee extension velocity than the subelite group and their two groups of athletes did not differ in the hip flexion velocity. Another important difference between our results is that their fighters of lower level had inferior cocontraction in the hip joint than the high level fighters. We believe that differences in results of our studies are due to coordinative pattern differences concern the specificity of modalities, because Quinzi et al (2013) evaluate karatecas.

CONCLUSION: As we found that timing parameters and cocontraction index were significantly lower in elite group, while ground reaction force parameters and velocities were significantly higher in elite group than in subelite athletes, we conclude that that these parameters could be useful in selecting top level taekwondo athletes and monitoring their training status and also which starting to contract posterior muscles early and perform the kicking phase with the GM more relaxed is associated with a more efficient kick performance.

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