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THE RELATIONSHIP BETWEEN BANDAL CHAGUI POWER WITH MECHANICAL EFFICIENCY IN TAEKWONDO ATHLETES

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ABSTRACT: *Objectives: Since the introduction of electronic body protectors in the taekwondo competition, the ability to generate enough kinetic impact in a fast way is a concern for taekwondo coaches and athletes. Since most points are accomplished with leg techniques using the so-called roundhouse kick (Bandal Chagui) it is important to relate the kinetic parameters to kicking power. The goal of this study was to verify the relationship between bandal chagui impact force with reactive force, reaction time, vertical jump and one maximum repetition leg's squat in taekwondo athletes. Methods: Seventeen male subjects (age 17.59 ± 4.34 years; body height 1.72m ± .07m; body mass 61.3kg ± 8.7kg and fat mass 11.9 ± 5.7 %) from the Taekwondo Portuguese national team participated in this study. Results: We found an important relationship between bandal chagui impact force and kinematic parameters (r = 0.57-0.88, p<0.01). Although the inverse relationship between bandal chagui impact force and reaction time was observed, in this sample the relationship was not statistically significant. Conclusion: The ability to generate impact force in the bandal chagui kick depends on 90% of the model with weight, one maximum repetition leg's squat and vertical jump (F=39.88; p=.000).*

Keywords: kinematic parameters, bandal chagui, impact force, taekwondo.

INTRODUCTION

Taekwondo, the Korean martial art, is characterized by fast, high and spinning kicks [1] and it´s considered a modern-day Olympic combat sport. Matches are typically structured across three 2-min rounds with a 1-min interval separating each round and are structured according to specific weight divisions [2]. The goal of a match is to overcome an opponent by obtaining either a greater quantity of points for the execution of kicking and punching techniques to permitted scoring areas or by achieving a technical knockout [2,3].

Taekwondo are complex and demand a high degree of the athletic ability by practitioners. It has been observed that agility, balance, coordination, power, speed, and reaction time [4,5] are very important and can be determinant in this sport. And therefore, the force of a punch or a kick delivered to a punching bag is a crucial element of special fitness [6,7]. Several systems to measure strike force have been described in the literature: a water-filled heavy bag [8], force plate [9], strain gauge-based measuring systems [10,11,12] and an accelerometer based measuring system [12].

Pieter and Pieter [8] recorded kick forces ranging from 461.8 ± 100.7 N to 661.9 ± 52.7 N. Balius [13] reported mean impact force of nearly 2130 N. Falco [10] measured the force of Bandal Chagi kicks using piezoelectric pressure sensors mounted on a boxing mannequin and recorded maximal forces of 2089.8 ± 634.7 N with the highest force being 3482 N. On the other hand, Pędzich [9] recorded kick forces on a force plate up to 9015 N.

The reaction time is described as the interval of time between presentation of a non-anticipated stimuli and the onset of response of the person [14], but it also represents individual's time to make decisions and initiate actions, which is considered one of the most important measures in human performance in many situations [15].

Previous studies investigated reaction time and response time during different kinds of taekwondo kick technique, including the effect of target distance during a roundhouse kick [16]. For the reaction time using the roundhouse kick, values were like 0.281±0.061seconds [17] or within the range of 0.461-0.575 ± 0.015-0.027 seconds [16].

Regarding the power, it can be defined simply as the rate of force production in a single movement or repetition [18,19]. Several studies reported data for the determination of muscular power of taekwondo athletes through the use of squat/static jump tests (SJ) [20,21,22] and counter-movement jump tests (CMJ) [23,24,25,26,27]. The mean SJ performances reported for national and international competitors in the literature ranged between 35.8–45.4 cm for males and 23.7–29.8 cm for females [223,23,28] whereas the CMJ performances ranged between 39.3–43.9 cm and 26.4–32.8 cm for national and international male and female athletes, respectively [22,23,24].

Taekwondo is a full contact combat and one of the kicks most used in competition, like we attested before, is the Bandal chagui or roundhouse kick [12,29,30]. The roundhouse kick, a multiplanar skill starts with the kicking leg travelling in an arc towards the front with the knee in a chambered position. The knee is extended in a snapping movement, striking the opponent with metatarsal part of the foot extended. Nonetheless, since the introduction of electronic body protectors in the taekwondo competition, that the ability to generate enough kinetic impact [16] in a fast way [31] is a concern for taekwondo coaches and athletes. Since most points are accomplished with leg techniques using the so-called roundhouse kick (Bandal chagui) it is important to relate the kinetic parameters to kicking power in order to support coaches and sports scientists collect objective information about their players' physical performance capabilities to substantiate the objectives of training, establish short and long-term training programs, provide objective feedback.

Through comparisons between inexperienced athletes and experienced athletes one can note that the technical level may influence the performance of the impact force [32] however, when comparing athletes with the same technical level, it is not clear which variables are relate to the best kicking power performance. Therefore, the purpose of this study was to verify the relationship between bandal chagui impact force (BCIF) with reactive force, reaction time, vertical jump and one maximum repetition leg´s squat in taekwondo elite athletes.

MATERIALS AND METHODS

Subjects

Seventeen male subjects (age 17.59 ± 4.34 years; body height 1.72 ±.07 m; body mass 61.3 ± 8.7 kg and fat mass 11.9 ± 5.7 %) from the Taekwondo Portuguese national team participated in this study. According to the characterization survey, all subjects were high-level junior and senior taekwondo athletes with more than 5 years of experience (black belts) and trained 8.7 ± 1.4 sessions per week. The athlete's federal license was also verified to confirm the absence of any impediment to the practice of taekwondo.

All subjects and their parents (in the under-18-year-old subjects) were informed in advance about the procedures and asked to sign a term of consent that had been approved by the University of Beira Interior and carried out according to the Helsinki Declaration.

Instruments

Anthropometric measures

The anthropometric assessment was carried out according to the International Working Group of Kinanthropometry methodology [34]. To evaluate height (m) we used a stadiometer (SECA, model 225, Germany) with a range scale of 0.10 m. Weight and body fat were assessed using a Tanita body composition analyser (model TBF-200, Tanita Corporation of America, Inc. Arlington Heights, IL).

Maximum kicking impact force

The maximum kicking impact force was evaluated by performing the Bandal chagui technique (roundhouse kick) in a boxing bag. This technique is a turning kick and happens to be the most commonly used kick during competition [35,12,30].

The kick impact force was measured using a piezo sensor (LDT4-028K/L, Measurement Specialties Incorporation) incorporated into a strike shield (Mega-Strike, IMPTEC, United Kingdom). The result is expressed in units ranging between 0 and 255. Subjects were encouraged to exert their maximal force in three trials. The rest intervals between the consecutive measurements lasted 3 minutes. The maximum, value was chosen for analysis. These units resulting from the impact force, are determined by the degree of deformation of the sensor; its corresponding value in SI units is not known or disclosed by the manufacturer. Thus, it was necessary to establish a relationship between the force of impact registered by the piezo sensor and the corresponding kicking power in an SI unit (in watts,). For that purpose, a 3D motion tracking technology (Xsens, MTi 1-series, Netherlands) was used to analyze body movement in order to determine the peak kicking power of each athlete. Seventeen sensors were placed in all body, particularly in lower limbs in precisely locations (hip, knee and ankle). Each sensor consists in its interior by a small gyroscope, an accelerometer and a magnetometer [35].

The MVN Studio Pro software was used to transform the data enabling their use in Visual 3D software, in a way that allowed us to define the segment to be analyzed through the Compute Model Based Tool.

We calculated the power and then we defined the segment of interest (ankle) and the reference segment (leg). For this calculation, power was the result of the multiplication between the angular velocity (rad/s) and moment of inertia.

Kinetic Parameters

The countermovement jump was measured by the Optojump Next System (Microgate, SARL, Italy) and gave us the maximum height in CMJ test [36].

The reaction time and reaction force was a specific test and for this purpose was created in the Optojump NextSystem (Microgate, Bolzano, Italy). At the sign, athletes had the dominant foot inside the space created by the two infrared gutters, and in front of them, in a white wall, a red ball was projected and as soon the ball turn green, the athlete performed the bandal chagui as quick as possible and with maximum strength. Three attempts were allowed for each athlete, and we used the correspondent better value for reaction force and reaction time.

The one maximum leg´s squat repetition was measured using the T-Force Dynamic Measurement System 2.35 (Ergotech, Murcia, Spain).

Procedures

Participants were tested in one session. All athletes had been competing regularly, exhibiting, at the time of this study, a good overall performance.

In the 48 hours before the first session, subjects were instructed to refrain from physical activity and underwent one familiarization session. During this familiarization session all athletes were counseled on proper exercise technique, as well as stretching and an appropriate warm up in order to prevent the large gains that tend to occur as the subjects learn the testing procedure and also to verify the protocol acceptance and applicability in this group. Data collection started with anthropometric measurements, followed by the evaluation of maximum kicking impact force (leg strikes in the boxing bag) just after 10 minutes of a specific warm up. Five minutes rest were given between the counter movement jump (CMJ), reaction time (RT) and reaction force (RF) performance. Each athlete performed 3 trials with 3 minutes between then for each attempt in all tests. After 10 minutes rest after the last trial for RF, athletes performed the one maximum leg´s squat repetition test (MLSR).

Statistical Procedures

Statistical analysis was carried out using SPSS 18.0 (SPSS Inc., Chicago, IL). Intraclass correlation coefficient (ICC) and the coefficient of variation (CV) were used to determine reliability and variation in the tests. Correlations were determined using *Spearman's r*. To analyze the ability to generate impact force a multiple linear regression analysis was performed between the weight, MSLR, VJ, and the impact force. Statistical significance was accepted at $p \leq 0.05$ for all analysis.

RESULTS

Table I and II shows the within-subject variation and between-subject reliability, respectively, for the tests. The variability between individuals was low and the test reproducibility higher (ICC). CV values demonstrate a reasonably homogeneous data set.

The results showed relationship between BCIF and kinetics parameters (r = 0.57-0.88, p<0.01). Although the inverse relationship between BCIF and RT was observed, in this sample the relationship was not statistically significant.

Table I. Descriptive statistics (mean and standard deviation), Intraclass correlation coefficient (ICC) and coefficient of variation (CV) from kinetics variables: reaction time, reactive force, VJ Height (vertical jump height), MLSR (maximum leg´s squat repetition).

	Mean ± SD	ICC (range)	CV (%)
Reaction	0.650±0.052	0.817 (0.627-	14.2
Time (s)	385.3±79.7	0.918	20.9
Reactive	35.6±5.9	0.952 (0.903-	24.8
Force (w)	91.3±11.1	0.971)	13.8
VJ Height		0.991 (0.982-	
(cm)		0.996)	
MLSR (kg)		0.834(0.767-	
		0.923)	

Table II. Correlation between Bandal Chagui impact force and selected temporal and kinetic variables: reaction time, reactive force, VJ Height (vertical jump height), MLSR (maximum leg´s squat repetition).

	Bandal Chagui Impact Force (W), r
Reaction Time (s)	-0.18 NS
Reactive Force (w)	0.83*
VJ Height (cm)	0,57*
MLSR (kg)	0.88*

Differences for **p≤ 0.01.*

Through the linear regression, we realized that the ability to generate impact force in the bandal chagui kick depends 90% of the model with weight, MLSR and VJ (F=39.886; p=.000), being the MLSR the variable that most influences the value of the impact force.

DISCUSSION

The aim of this study was to verify the relation between bandal chagui impact force with kinetics and temporal parameters. The main finding was that kinetics parameters can be a good predictor for BCIF, but, through the correlations values, the maximum leg´s force was the most relates to BCIF.

Bandal Changui Impact Force

According to World Taekwondo Federation (2015), in each weight division category it is necessary a minimal threshold of impact for scoring points. In this study, the average impact was lower than what is required (385.3±79.7 watts), once the energy absorbed by the electronic body protector during taekwondo official competitions ranges from 211 ± 34 joules in junior <51kg athletes to 262 ± 49 joules in senior 67-78kg athletes[37]. When athletes have the capacity to reach high enough kick impact magnitudes to gain points in competition, they can concentrate on obtaining high velocity, faster reaction times and kick executions [38]. Therefore, this suggest that these athletes are not in conditions to focus their training in another important variables of taekwondo performance (such as distance and technical issues) and they should focus in the development of lower limbs strength.

As attested before, several studies have evaluated the bandal chagui impact force (BCIF) kick, however, we have also confirmed the difficulty of comparing our results on a descriptive level with previous studies because of the diversity of units of measurement used [39,17,37,40,41]. Regarding Matsushigue [42], the Bandal chagui speed values were in order of 0.31 seconds, when comparing the values from Del Vechio [37] (assuming that watts=joules*time of execution) we realize that ours results are smaller than those recorded in that study (680 watts vs. 418 watts). In our point of view, it is clear that the difference is explained by how the impacts are assessed, the material used, the contact time, and probably the weight categories with the sample heterogeneity, and also other factors not described in this work.

Nevertheless, we found that kinetics parameters can be a good predictor for BCIF, but, through the correlations values, the maximum leg´s force was the most relates to BCIF. It seems that the taekwondo training is substantially jumping and stepping justified with plyometric training [43]. This results seems to be agreeing with Hakkinen [44] when he attests that if heavy resistance training was stopped for too long (5.5 weeks) and only explosive strength training was performed, then, decrements in both maximal strength and explosive strength were register, which highlighting the continuity importance of strength training in taekwondo training.

Reaction Time

For the reaction time analyses, we found an average time of 0.650±0.052 seconds, very similar with the findings of Pieter and Heijmans [45] in American female elite Taekwondo athletes (0.68 s), Sung [46] in Korean elite male athletes (0.65 s) and also according the study of Tang [47] that reached 0.6 s for the bandal chagui kick.

Since the kick is a ballistic and complex movement, and it can be influenced by the production of muscle strength and by the coordinate level of the athletes [48] we should consider the time or velocity to perform the technique. Thus, when analyzing the relation between RT-BCIF and RT-RF, we didn´t find an association, although the strength used to respond a stimulus is an additional dependent variable of considerable interest in the interpretation of RT [49].

Reaction time is a relevant factor to score in a taekwondo match because it refers to how fast can an athlete kick efficiently [50]. The rate of reaction of an individual is genetically predisposed, and it is possible to improve it through training and this improvement can reach 15% [51]. But this reaction time test was the physiological response toward a neutral sense stimulus, where a receptor excitation (e.g. of the eye) initiates a signal which is transmitted via the central nervous system to the motor cortex [52]. Its response triggers a signal that stimulates the muscles and initiates the mechanical activity. In this study, as expected, an inverse correlation between strength and RT was found. However, the significance that we expected to verify between strength and RT, supported by the increased ability to faster recruit muscle fibers in individuals with more muscle strength, was not verified, which can suggests that RT is more linked to the ability of the brain to turn the action into a more economic situation through a technical skill level.

The lack of correlation between RT and RF can be explained because RF is related physically to the speed of response, and vary independently of RT [53]. Therefore, there is a need to develop more studies in order to understand the relationship between the reaction time and muscular activity/strength during kick execution in taekwondo athletes.

CMJ – vertical jump

When testing maximum vertical jumps, we presume that this variable reveals the maximum power and explosive characteristics of lower limb muscles [54]. We intended to assess the power output produced in the CMJ and verify its relationship with BCIF assuming that the performance of ballistic movements depends upon the maximum power that our muscular system can exert under the given mechanical conditions [55].

In the results obtained on the vertical jump (VJ) assessed through the CMJ we founded values of 35.6±5.9 cm respectively, that were in line with the results of CMJ founded by Bridge [3] for national and international taekwondo athletes (35.0 - 41.0 cm). These results are in the same range of values, with a positive and moderate correlation with the BCIF. It seems that this association is supported by the stretch-shortening cycle, that is, when performing the *Bandal chagui* there is a knee flexion before a leg extension (when the foot hits the bag), a movement that mimics the one performed in the CMJ test.

We also verify that weight, maximum force through squatting and CMJ height can respond for 90% of bandal chagui impact force. With this, we understand that muscular power alone is not enough to determine the performance capacity of an athlete, and a muscular recruitment analysis, which was not addressed in this study should be used to understand the neuromuscular mechanisms of performance [56].

CONCLUSIONS

Our findings suggest that, there were significant correlations between bandal chagui impact force with maximum strength and height jump. Thus, coaches and athletes in order to achieve adequate levels of impact force, should address to their training regimen a more integrate work through strength and plyometric exercises. The reaction time training has an important role on the athlete success, and must be endorsed considering the specific neuromuscular aspect, joint stabilization, muscular balance and taekwondo technique.

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