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Anaerobic upper and lower body power measurements and perception of fatigue during a kick boxing match

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Aim. **Objective of the study was to determine the effects of a kick-boxing match on muscle power of the upper and lower body as well as the associated perceived exertion in young men.**

Methods. **Eighteen well trained kick-boxers volunteered to participate in a competitive sparring bout preceded and followed by three anaerobic tests as follow: squat jump (SJ) and counter movement jump (CMJ) for legs and 30-s Wingate test for arms. The sparring bout consisted of three 2 min rounds with 1 min recovery period in-between. Blood lactate (BL), heart rate (HR) and rating of perceived exertion (RPE) were analyzed before and after each round.**

Results. **The results showed that vertical jump distance in SJ and CMJ were significantly lower after the kick-boxing match (27.92±3.84 *vs*. 25.28±4.39 cm; 29.8±5.33 *vs* 28.48±4.64 cm, for SJ and CMJ respectively). Likewise, peak and mean power in the Wingate test decreased significantly after the sparring bout (5.89±0. 69 *vs.* 5.26±0.66 W•kg^{-1} and 4.51±0.53 *vs.* 4.12±0.51 W•kg^{-1} for PP and MP respectively; P<0.001). Moreover, we found a significant increase in BL, HR, and RPE after the kick-boxing match (P<0.001). BL increased significantly after the second and third round from the post round one values' (P<0.001).**

Conclusion. **These findings showed that a single kick-boxing match is of sufficient intensity to stress the anaerobic metabolism. Thus, training protocols should include exercises that train the anaerobic energetic pathways for upper and lower body.**

KEY WORDS: Boxing - Anaerobic threshold - Muscle fatigue.

Full contact is a discipline of kick-boxing where the intention of a fighter is to beat his opponent with full power and strength. Punches and kicks must be delivered to legal targets with focus, speed and determination, creating solid contact. Punches and kicks are allowed to the front and side of the head, the front and side of the body (above waist) and sweeping is also allowed. The fight is held in a ring. A typical match usually consists of 3 rounds of 2 min with a recovery period of 1 min in-between (World Association of kick-boxing organizations, WAKO). Full contact requires complex skills and tactical excellence for success. Matches are characterized by dynamic phases of short duration, during which athletes try to strike their opponent or defend themselves from each other's attacks.[1-9]

To the best of the authors' knowledge, there seems to be only one study about the physiological demands of a Muay Thai boxing match.[5] In this study,

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Crisafulli *et al.*[9] had evaluated the involvement of aerobic and anaerobic metabolism during a sparring simulation. The authors indicated that excess of CO_2 production, oxygen uptake, and heart rate values obtained after the match indicated that Muay Thai is a physically demanding activity with a great involvement of both aerobic and anaerobic energy turnover. Nevertheless, the effect of the kick boxing match on upper and lower body powers was not measured in this study. In this context, the ability to produce high rates of upper and lower body powers are important to athletes in many sports (*e.g.*, rugby, basketball, boxing, martial arts, etc.) where the ability to pass quickly or push away or strike opponents is paramount.[9-18]

To the author's knowledge, only one study had assessed the anaerobic metabolism of elite kick boxers.[18-26] In professional male kick boxers, the authors showed that during the Wingate test for the legs and arms the mean anaerobic capacities were of 10.5 W•kg^{-1} and 5.4 W•kg $^{-1}$ respectively.[26]

Therefore, the lack of research about this topic prompted us to investigate the effects of a kick boxing match on the anaerobic performances of upper and lower body and rating of perceived exertion (RPE) in elite kick boxers. In fact, information about this issue may potentially provide redundant information and help sport scientists and professional conditioning coaches in establishing performance oriented (*i.e.*, kick boxing) test batteries to enhance fitness assessment, and training prescription.

Materials and methods

Participants

Eighteen male kick boxers were recruited from a local sporting club to participate on this study. The mean (±SD) age, height, and weight of the subjects were 18.5±1.85 yrs, 174.44±7.68 cm and 63.22±9.11 kg, respectively. They were exercising for five days a week for average of 2 h per day. After receiving a thorough explanation of the protocol, they gave written consent to participate in this study. The study was conducted according to the Declaration of Helsinki and the protocol was fully approved by the University Ethics committee before the commencement of the assessments.

Procedures

Subjects were tested on two different occasions using identical protocols (SJ, CMJ, and Wingate test with a recovery period of 2-min in-between): before and immediately after a kick boxing match. Heart rate (HR) (Polar Vantage S620), blood lactate (BL) (Blood lactate analyzer: Lactate Pro), and RPE (Borg Scale from 6 to 20) were recorded after each round of the match. One week before the commencement of the assessments, the subjects were familiarized with the experimental testing procedures on a control day.[6, 7] Body composition was determined by bioelectric impedance using a Tanita Body Composition Analyzer (Tanita Corporation, Tokyo, Japan). All assessments were performed at the same time-of-day to reduce the effect of any diurnal variation on muscle performances.[6, 7]

Warm-up

Before tests, participants performed a 5 min warm-up protocol consisting of submaximal running, active stretching, and jumping exercises. This warm-up was chosen because of its positive effects on power production.[20] For the upper body, a warm-up session was suggested for optimal performance on the Wingate anaerobic test. The warm-up included 5 min of low to moderate intensity pedaling at about 50 to 60 rpm, interspersed by four or five all-out sprints of 4-s to 6-s duration.[19] Warm-up was followed by a 3 min rest before the testing.

Wingate test for upper body

Kick boxers completed one bout of the upper-body Wingate test. Load was set at 4.9 N·kg^{-1} of body weight. Peak power (PP), mean power (MP), and fatigue index (FI) were calculated as previously reported.[3, 10, 11] The Wingate test is a cycle-ergometric all-out test that lasts 30-s. Maximal load is accomplished by a built-in air-resistance system on the wheels. Load registration was in real time, using a computer with a module for measuring the number of wheel turns.[8, 9]

Squat jump test (SJ)

For the SJ, the subjects were instructed to start at a static knee angle of 90°. Prior to the jump the

position was controlled with a manual goniometer. During the jumps, hands were kept on the hips. The jumping test protocols were carefully explained and shown to each participant.

Countermovement jump (CMJ)

A CMJ test was used to assess explosive strength of the lower extremity muscles. During the CMJ, the subject was instructed to rest his hands on his hips while performing a downward movement followed by a maximal effort vertical jump. All subjects were instructed to land in an upright position and to bend the knees following landing.

The SJ and CMJ tests were performed using an infrared jump system (Optojump, Microgate, Bolzano, Italy) interfaced with a microcomputer. During each test, three trials were completed with 1 min interval in-between, and the best performance trial was used for the subsequent statistical analysis.

Kick boxing match

The kick boxing match is held in a ring and consists of three 2 min rounds separated with 1 min of recovery in-between. During each match, athletes were organized by couple with similar characteristics according to rules of WAKO (same age categories, weight categories, equipment for competitions). All participants did not present any sanitary restriction and all fights were carried out safely, in an official ring with the presence of a national central referee according to the general rules of ring sports of WAKO.

Statistical analyses

All statistical tests were processed using STATISTICA Software (StatSoft, France). Mean and standard deviation (SD) were calculated for the selected variables. The Shapiro-Wilk *W*-test of normality revealed that the data were normally distributed. Once the assumption of normality was confirmed, parametric tests were performed. Paired Student's *t*-tests were used to compare the data of the Wingate test, CMJ, and SJ performances. Values of HR, BL, and RPE were analyzed using a one-way analysis of variance with repeated measures (3 [Rounds]). When appropriate, significant differences between means were assessed using the Tukey's HSD test procedure. The probability level accepted for statistical significance was set at $P<0.05$.

TABLE I.—*Muscle performances (mean±SD) during the Wingate test (i.e., PP, MP, and FI) and during the vertical jumps tests (i.e., SJ and CMJ) recorded before and after a kick boxing match in youth division kick boxers (N.=18).*

	Before match	After match
SJ (cm)	27.92±3.84	25.28±4.39**
CMJ (cm)	29.8±5.33	28.48±4.64*
MP (W•kg $^{-1}$)	4.51±0.53	4.12±0.51***
PP (W•kg $^{-1}$)	5.89±0.69	5.26±0.66***
FI (%)	0.51±0.09	0.45±0.13*

*, **, ***: Significant difference between before and after the match at the levels of P<0.05, P<0.01, and P<0.001, respectively. SJ: Squat Jump; CMJ: Counter Movement Jump; MP: Mean Power; PP: Peak Power; FI: Fatigue Index.

Results

Muscle performances

Muscle performances recorded during the Wingate, SJ, and CMJ tests before and after the match are displayed in Table I. Statistical analysis showed that values of both PP and MP decreased significantly after the full contact match compared with rest values ($P<0.001$). Likewise, a significant decrease was observed in SJ ($P<0.01$), CMJ ($P<0.05$), and FI ($P<0.05$) after the match.

Rating of perceived exertion, blood lactate, and heart rate

BL, HR, and RPE in response to the kick boxing match are showed in Table II. BL concentrations and HR were found to be higher and increased significantly from pre combat to round 1 ($F_{(6.90)}=1195.94$; $P<0.001$ and $F_{(6.54)}=1152.43$; $P<0.001$, respectively) and remained significantly higher than pre combat throughout round 2 and 3 Likewise, values of BL and HR increased significantly after R2 and R3 when compared with values of R1 ($P<0.001$) and after R3 in comparison with after R2 ($P<0.001$). The BL measurements demonstrate the high metabolic demands of competing in the kick boxing sport. Similarly, the RPE scores rose significantly ($F_{(3.45)}=95.54$; $P<0.001$) throughout the fight in com-

TABLE II.—*Mean±SD of BL, HR, and RPE before and after the kick boxing match in youth division kick boxers (N.=18).*

	After R1	After R2	After R3
RPE	11.5±1.31	14.31±1.81***	16.37±2.47***, +
BL (mmol•L^{-1})	8.63±0.87	11.72±0.85***	14.93±0.71***, +
HR (beats.min^{-1})	141.11±3.02	166.23±3.13***	182.12±4.34***, +

***: Significant difference in comparison with R1 at the levels of P<0.001. +: Significant difference in comparison with R2 at the level of P<0.001. R: round; BL: blood lactate; HR: heart rate.

parison with value of round 1 (Table II) and from R2 to R3 (P<0.001).

Discussion

The principal aim of this work was to investigate the effects of a kick boxing (full contact) match on anaerobic power of the upper and lower body. The present study findings showed that the kick boxing match induces a significant decrease in the anaerobic power for both upper and lower body with a significant increase in BL, HR and RPE after each round.

Similarly to wrestling and boxing, in kick boxing power and explosiveness are of greater importance since the opponent must be beaten fast with technique used in a very short period of time.[13, 19] The findings of the present study showed that anaerobic performances of the lower body in SJ and CMJ decreased after the kick boxing match. This fall in performance could be explained by the fact that fighters are called to strike with full power to win the contest. These results could be explained by the fact that kick boxing competition needs special type of movements which are characterized by agility, velocity, and strength similarly to kung-fu competitions where combats consist in three 2 min rounds with a 1 min rest and are characterized by full-contact punches, kicks, and throwing technique.[3] Moreover, kick boxers generally use many jumping techniques to strike opponent and displacements can be characterized by plyometric phases. In this context, Allen *et al*.[1] showed that muscles that are used intensively show a progressive decline of performance which largely recovers after a period of rest.

Like Muay thai and boxing, kick boxing seems to be an intermittent physically demanding sport, with short phases of maximal or supramaximal intensity spaced by brief recoveries and multiple repeated high-intensity exercise domains.[9, 22] Therefore, fatigue development which reduces shortening velocity and slows time course of relaxation,[1] could explain the decline of performance during the match.

Concerning upper body power, the present study results indicate that the kick boxers show an above-average anaerobic power (PP: 5.89±0.69 W•kg^{-1}; MP: 4.51±0.53 W•kg^{-1}). Indeed, anaerobic power and capacity show high values in anaerobic types of sports such as volleyball, basketball, hockey, boxing, and wrestling.[17, 18] Data from Italian Olympic judokas showed relatively higher levels of muscle power (PP: 12.1±2.4 W•kg^{-1}; MP: 5.4 ±1.1W•kg^{-1}).[20] This may confirm the idea that athletes who strike opponents (*i.e*., karate and taekwondo players) have above-average anaerobic power.[14, 25, 27]

Concerning upper body power, the authors found that PP and MP marked a significant decrease and FI decreased after the match. It is difficult to determine which mechanisms were responsible to the fall of performance in the Wingate test. These findings could explain, at least in part, the great anaerobic solicitation of the upper body during the kick boxing match. In fact, it has been shown that exercise intensities during a Muay Thai match were slightly above the anaerobic threshold.[9] Moreover, types of movements and intensities in kick boxing match were ensured by recruitment of fast fibers. That is why we can suggest that it was impossible to perform at a high level in the Wingate test after the match. In this context, Allen *et al*.[1] showed that fatigue is more pronounced in fast versus slow fibers.

Furthermore, the authors found that BL levels increased significantly during the kick boxing match relative to rest values (*i.e*., an average of 14.93±0.71 mmol•l^{-1} after the match). Similarly, Bouhlel *et al*.[4] found that BL reached a value of about 10.2±1.2 mmol•l^{-1} after a taekwondo match. In addition, an average of 15.2±4 mmol•l^{-1} of BL values has been reported after two 4 min sparring rounds of mixed martial arts separated by a 1 min recovery.[2] This rise in BL concentrations confirmed that anaerobic glycolysis was significantly solicited during the combat.

The session RPE method has been shown to be a valid measure of internal training load in a variety of exercise modes.[12, 15] Moreover, previous studies have used RPE to monitor exercise intensity in martial arts.[14, 21] The present study' findings showed that the

RPE scores undergo a significant increase from one round to another of full contact match. The RPE fell into the range of 11-16. Same, Amtmann *et al*.[2] reported that the RPE in a match of MMA were in the range of 13-19. This difference may be related to the difference in match duration of each sport combat.

Finally, HR showed a variation during the whole time of kick boxing match with a significant increase from round to round and attains a value of 182.12±4.34 (beats·min^{-1}) at the end of the match. Likewise, Bouhlel *et al*.[4] demonstrated that HR increased significantly during a competition of taekwondo. Moreover, Iide *et al*.[14] showed that HR and percentage of maximum HR for a 3 min bout of sparring were significantly higher than for a 2 min bout of sparring. Therefore, we can suggest that HR could be viewed as a valid tool to monitor the exercise intensity during the match of kick boxing. Additionally, Kravitz *et al*.[16] showed that boxing speed is associated with increased of ventilation, HR responses, and RPE. Thus, we can conclude that the increase after a kick boxing match in both HR and RPE scores obtained in the present study is associated with the competition's specificities of that sport where fighters strike with speed to win the contest.

Conclusions

The main findings of this study suggest that kick boxing match causes a significant increase in perception of fatigue associated with a decrease in the anaerobic power of arms and legs measured during the Wingate and vertical jump tests (*i.e*., squat jump and counter movement jump). Therefore, coaches should focus on the development of these characteristics (*i.e*., muscle power) in lower-level athletes to attain a better performance. The competition simulations have shown that kick boxing seems to have a high anaerobic demand. Thus, during physical conditioning training sessions, coaches should place a specific emphasis on the anaerobic training to prepare them to be able to handle the metabolic and physiological demands of the kick boxing match (*i.e*., style full contact).

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