Relationship between RPE and Blood Lactate after Fatiguing Handgrip Exercise in Taekwondo and Sedentary Subjects

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Purpose: To get information on the effort during vigorous exercise there are different ways and, the most popular, is the scale to measure subjective exertion or the rating of perceived exertion (RPE), such as the Borg scale. This scale is an effective methods to quantify and monitor the intensity of the exercise. The aims of this study were to investigate the association between RPE, blood lactate concentration and maximal voluntary handgrip (MVG) force, after fatiguing exercise in athletes and non-athletes.

Method: Twelve right-handed male taekwondo athletes (age: 27 ± 5 years) and 12 matched controls (age: 26 ± 5 years) were recruited. Peak force was measured and, after a subsequent rest, subjects were asked to reproduce 30% of their MVG for 4 s, then relax for 2 s, and then repeat this sequence for 10 minutes. Blood lactate was measured at rest (pre), at the end (0 min) as well as 3 and 10 min of the recovery. The RPE for the work performed were measured at the end of fatiguing handgrip exercise with Borg scale (range: 5-20).

Conclusion: The results of this study show significant correlation between RPE and blood lactate peak (p<0.01), RPE and MVG post exercise (p<0.01) and between RPE and Δ blood lactate (blood lactate post-blood lactate pre; p<0.01).

Keywords: Blood lactate; RPE; Fatigue

Introduction

The term fatigue, in healthy subjects, refers to any exercise induced loss of ability to exert force or power with a muscle or a muscle group [1,2]. Currently, the fatigue mechanism is generally considered a complex interaction between peripheral and central factors [3]. Nevertheless, following discovery of the monocarboxylate transporter [4], recent studies have suggested that lactate is an important fuel source during high-intensity exercise [5]. There is also evidence that reduction in pH [6] and blood flow [7] increases fatigue and that loss of homeostasis does not occur at the end of exercise [8].

Taekwondo is a martial art that had been growing in popularity even before its official inclusion in the Sydney 2000 Olympic Games. In the United States, approximately 1.5–2 million people practice martial arts [9], the most popular of which is. Athletes participate in full-sparring tournaments, in which points are awarded for punches and kicks to the head and torso [10,11].

Taekwondo is a popular organized activity, and recent studies have shown that related training activities, such as sparring and kicking drills, along with repetition can improve cardiovascular function, anaerobic power and strength [12–19]. In Taekwondo, competitors must be able to move at high speed and power, thus, taekwondo training may be a useful organized activity for improving essential elements of overall physical fitness [12,20]. In taekwondo competition the fatigue has large influence in performance [21–24]. When subject performed a maximal voluntary contraction, component fatigue is ascribed not only to peripheral factors but also to central factors that play role in the decline in force which results from a sub optimal output from the primary motor cortex, which ultimately leads to sub optimal firing rates of motor neurons [25]. When subject performed an incremental exhaustive exercise, rapidly decrease in muscle phosphocreatine and ATP, as well as an accumulation of metabolites like pyruvate and lactate [26].

To get information on the effort during vigorous exercise, there are different ways, such as the scale to measure subjective exertion, or the rating of perceived exertion (RPE), called the Borg scale [27]. This scale is an effective methods to quantify and monitor the intensity of the exercise [28]. This is primarily because of the strong association between RPE and such physiological variables such as heart rate, lactate, VO2max, ventilatory thresholds and respiratory rates [29–31].

Exhaustive exercise training especially in non-professional and untrained athletes cause oxidative stress associated with inflammatory response s, which is the cause for the muscle cell membrane damage observed in this sort of high-intensity and exhaustive activity and exercise. It is well known that exhaustive exercise result membrane cell damage to or inflammatory responses into the muscle cells [32–34]. The strenuous and exhaustive activity-induced muscular injury and damage has been related with oxidative stress, inflammation and an
increase in the pro-inflammatory mediators [35]. This increase in oxidative stress related with strenuous exercise increases inflammatory cytokines and marker include hs-CRP, IL-6, and TNF-alpha, among others [33].

Mechanical and metabolic stresses caused by vigorous training and competitive running may result to fatigue (increased lactate) and change in some biochemical indicators include enzymes (e.g., creatine kinase) to the serum [36].

Numerous studies involving resistance exercise [37–39] have demonstrated strong associations between the Borg scale RPE and intensity indices such as myoelectric activity, the total load and the percentages of the 1RM. These associations suggest an effective use of a perceived exertion scale in determining intensities of exercises using external resistance.

Handgrip strength is a general term used in clinical [40–42] and occupational [43–45] settings and by strength athletes [46–48]. It refers to the muscular strength and force that can be generated by the hands. The strength of a handgrip is the result of the maximum force that the subject is able to exert under normal biokinetic conditions through the voluntary flexion of all finger joints, thumbs, and wrists [49]. Factors that are considered during these activities include the absolute level of strength necessary to perform the tasks and the fatigue experienced by the muscles responsible for these movements [50]. Several sporting activities require the maintenance of adequate levels of handgrip strength to maximize control and task performance and decrease injury risk [50].

Recent reports have described how lactate released from ischemic muscle may contribute to ischemic pain by acting on sensory neurons innervating muscles [51,52], while lactate was also shown to cause an increase in blood pressure through activation of groups III and IV afferent muscles (i.e., muscle metaboreflex) [53, 54].

The aim of this study was to investigated the relationship concerning RPE and increase in blood lactate level after fatiguing handgrip exercise, and the decrease in maximal voluntary grip (MVG) between taekwondo athletes and sedentary subjects. Moreover we investigated if the relationship between RPE and blood lactate is different between athletes and non-athletes.

Methods

Participants

Twelve right-handed [55] male taekwondo athletes (age: 26.5 ± 5.0 years) and 12 matched controls (age: 25.5 ± 4.8 years) were recruited (Table 1). A preliminary analysis was conducted to ascertain that there were no differences for age and anthropometric characteristics between the groups. The athletes were enrolled in a taekwondo club of Foggia (Italy). They were regularly competing at the national and international levels and undergoing a training regimen of at least five 2-hr sessions week-1 for the previous 10 years.

The controls declared to be not engaged in amateur or competitive sports. The local Institutional Ethics Committee approved the study. Participants were provided both written and oral information regarding the possible risks and discomforts and were ensured that they were free to withdraw from the study at any time.

Protocol

Subjects sat in an armchair with their left hand relaxed in the prone position and their right hand holding a hand dynamometer. Subjects were asked to grip the dynamometer with their right hand, producing a isometric contraction.

|              | Athletes | Non-athletes | P-value |
|--------------|----------|--------------|---------|
| Age          | 26.5 ± 5.0 | 25.5 ± 4.8   | >0.05   |
| Height       | 176.5 ± 6.6 | 181.4 ± 8.0  | >0.05   |
| Body mass    | 72.4 ± 3.6  | 78.9 ± 3.1   | >0.05   |

Table 1: Anthropometric characteristics: Values are in mean (M) ± standard deviation (SD).

Maximal voluntary grip (MVG) was recorded as the highest of the 3 values of maximal isometric force generated from the dominant hand using hand grip dynamometer (Biopac systems, MP 100). Peak force was measured on the oscilloscope screen and, after a subsequent rest, subjects were asked to reproduce 30% of their MVG for 4 s, then relax for 2 s, and then repeat this sequence for 10 minutes. The force trace on the oscilloscope allowed the subject to visually control the force exerted and keep it at the requested level. During all the exercises, the experimenters encouraged the subject and assured that the requested level of force was maintained. Data were acquired at 500 Hz via a Biopac MP 100 system. Biopac Acqknowledge 4.1 software was used to determine the peak force amplitude for each trial [56]. Capillary blood lactate was measured at rest (pre-test), at the end (0 min) as well as 3 and 10 min of the recovery by using a "Lactate Pro" portable lactate analyser [57–59].

The RPE, subjective perception of effort (RPE), for the work performed were measured at the end of fatiguing handgrip exercise with Borg scale (range:6-20) [60,61]. Written instructions on the use of the Borg scale were read to the participants prior to the test and participants were used to the method on a daily basis for at least one month before starting the study.

Statistical Analysis

The R Project for Statistical Computing software (version 3.1.0) was used for statistical analyses. Means and SDs were calculated for each of the analyzed variables and statistical significance was set at p ≤ 0.05. The Shapiro-Wilk test was used to verify the normal distribution of variables. T-test was used to compare the differences in RPE between groups. Blood lactate data collected from the participants were compared by means of two-way repeated measure ANOVA, followed by Tukey’s multiple comparison post hoc test. Pearson product-moment correlation was performed to ascertain the relationship between RPE and blood lactate measured at the end of fatiguing exercise (peak), and between RPE and maximal voluntary grip measured at the end of fatiguing exercise. Furthermore Pearson product-moment correlation was performed to ascertain the relationship between RPE and the increase in blood lactate (Δ) (blood lactate peak-blood lactate rest). Linear regression was performed to investigate the relationship between RPE and Δ peak force (peak force pre-peak force post).
Results

No discomfort or adverse effects during fatiguing handgrip exercise were noticed or reported. The MVG measured by hand-grip transducer before fatiguing exercise, as expected was higher in athletes than in non-athletes, but there are no differences between groups. However significant differences in MVG between groups emerged after exercise (p<0.05) (Figure 1).

**Figure 1**: Changes in maximal voluntary grip between groups. A) Differences in MVG before fatiguing exercise. B) Differences in MVG after fatiguing exercise. **p<0.01

Compared to pre-exercise values blood lactate strongly increased at the end of exercise in athletes group (pre: 2.1 mmol/l ± 0.4; post: 4.2 mmol/l ± 0.2; p<0.001; +50%) and in non-athletes (pre: 1.9 mmol/l ± 0.2; post: 6.2 mmol/l ± 1.8; p<0.001; +69%), decline after 3' min (athletes: 3.5 mmol/l ± 0.5; non-athletes: 4.0 mmol/l ± 0.6), and recovered to the pre-exercise value within 10 min (athletes: 2.1 mmol/l ± 0.4; non-athletes 2.0 mmol/l ± 0.6). Blood lactate values showed differences between two groups. In particular at the end of the exercise non athletes showed higher value of blood lactate compared to athletes (6.2 mmol/l ± 1.8 vs 4.2 mmol/l ± 0.2; p<0.001). However after 3 minute of the end of the exercise, no differences emerged between two groups (p>0.05) (Figure 2).

Simultaneously blood lactate, from pre-exercise condition to post-exercise condition, increased 2.1 ± 0.4 mmol/l in taekwondo group and 4.3 ± 1.0 mmol/l in non-athlete group (p<0.01).

**Figure 2**: Changes in blood lactate level at rest (pre), at the end (0 min) as well as 3 and 10 min of the recovery, between two groups.

The RPE value, collected at the end of the fatiguing handgrip exercise, show significant differences between athletes and non athletes respectively (14.1 ± 1.2 vs 16.7 ± 1.0; p<0.01).

Pearson product-moment show significant positive correlation between RPE and blood lactate peak (r= 0.652; p<0.001), significant negative correlation between RPE and MVG post fatiguing exercise (r= -0.534; p<0.001), and positive correlation between RPE and blood lactate increase (Δ= blood lactate pre-blood lactate post) (r= 0.673; p<0.001).

Furthermore significant negative correlation emerged between blood lactate peak and MVG post (r= -0437; p<0.05). Linear regression (Figure 3) show significant relationship between RPE and Δ peak force (R2=0.40; F=14.38; p<0.01).

**Figure 3**: Linear regression analysis between REP (Borg Scale) and Δ Peak force.
Discussion

The aim of this study was to analyze the differences in physiological aspect, in particular the differences in RPE, peak force and blood lactate between taekwondo athletes and non-athletes. The major findings of the present study were that: a) after fatiguing exercise significant differences emerged between athletes and non-athletes in RPE, MVG and blood lactate values; b) significant overall correlation emerged between RPE and blood lactate collected after fatiguing test exercise, and between RPE and Δ peak force. The major conclusion drawn from this study was that handgrip strength was significantly different between athletes and non-athletes.

The present study shows that a voluntary sub-maximal tonic contraction is associated with a small but significant increase in blood lactate in each group. According with literature, the small increase in blood lactate found in our subject is a consequence of the relatively small muscle mass involved in the exercise coupled to the low-level work done during grip [62–65]. As we expected blood lactate increase (peak) was significantly higher in non-athletes than athletes. Furthermore athletes show also higher MVG than non-athletes before and after fatiguing exercise (p<0.001).

During and following a sustained maximal effort there is a reduction in the ability of the muscles to generate force. A contribution of central mechanisms to this fatigue is indicated by a progressive increase in superimposed twitch size during the sustained effort and a reduced voluntary activation in the recovery period afterward. Strength exercises are usually characterized by high energy demand and restricted blood flow during time under tension. Thus, due to the hypoxic environment experienced by the exercising muscle, anaerobic energy metabolism plays an important role during exercise. As a result, lactate production is increased in the working muscles, especially in type II muscle fibers, and consequently blood lactate concentration increases. Numerous studies evidence has led to the suggestion that there is no single mechanism but multiple mechanism of fatigue, of which the most significant include depletion of ATP (adenosine triphosphate) and overproduction of reactive oxygen species [66, 67]. Other cause include local inflammatory reactions, altered calcium levels, modified bioenergetic pathways, or impaired endocrine function of muscle cell [68].

Pearson product-moment analysis show significant positive overall correlation between RPE and blood lactate peak (p<0.01). This results show that the increase in blood lactate seems to influence the RPE. The subjects who perceived greater effort show also greater blood lactate values. This results was confirmed by the significant positive correlation between RPE and blood lactate Δ (p<0.01). Higher RPE values are associated with higher blood lactate values. Our data are in line with literature. In fact After 3 fight simulations, Franchini et al [69] only verified a strong correlation between the RPE (RPE 6-20 scale) and blood lactate peak (r = 0.81) in the first fight. In other study, Serrano et al [70] while investigating the perception of effort in relation to the competition, inferred a significant correlation between the RPE (RPE 6-20 scale, mean =14.6; variation between 11 and 18) and the Lactate peak (r =0.63, p<0.01) and between the RPE and the variation (Δ) of blood lactate (r=0.64, P<0.05). Based on those findings, the current study hypothesized the existence of a relation between RPE, blood lactate and MVG after fatiguing exercise. In fact our results are in line with previously published article, were is reported that RPE can be affected by physiological factors that can diminish the sense of exertion [16].

Conclusion

In conclusion, given that RPE is a non-invasive method to investigate the perceived exertion, and given that our results indicate that there are correlation between RPE and blood lactate level, and that this condition is reflected on MVG performance, it can be used for the evaluation of the workload, both in training and in particular during competitions in taekwondo athletes.

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