Effects of recovery type after a judo combat on blood lactate removal and on performance in an intermittent anaerobic task

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The main characteristic of a judo combat is the intermittent, on account of interruptions and alterations of the intensity of the efforts during the combat. Studies about the time structure in a 5-min judo match demonstrated that the combat and rest periods have values around 15 with s and 10-s, respectively. These time characteristics have important physiological implications, since the short periods of high intensity efforts with the shorter rest intervals result in a great percentage of participation of the lactate anaerobic metabolism at the beginning of the combat, but towards the end, the aerobic metabolism prevails.

Therefore, the judo athlete needs to have appropriate lactate anaerobic and aerobic energetic systems to maintain the performance during the whole match period. The need of high energy production from glycogenolysis can be demonstrated by the high blood lactate concentrations presented by judo athletes after combat.

Some studies suggested that excessive lactate accumulation was associated with a decrease in athletic performance. The explanation for this association could be a high correlation between lactate and free H+ as the...
force-depressing agent is H+ and not lactate. However, the association between lactate, H+ and performance has been questioned, mainly because the studies which demonstrated a relationship between H+ and muscle contraction impairment were not conducted at physiological temperatures. If acidosis is involved in skeletal muscle fatigue, the effect may be indirect: extra-cellular acidosis may well activate group III-IV nerve afferents in muscle and hence be involved in the sensation of discomfort in fatigue. New findings point that a marked acidification implies that the energy demand exceeds the capacity of aerobic metabolism and that anaerobic pathways are used to generate ATP. Thus, some other consequence of anaerobic metabolism may be the actual cause of impaired muscle function, and increased Pi concentration in muscle is a possible explanation.

Judo athletes must frequently compete in several combats on the same day, sometimes with a very short interval time between them (approximately 15 min). So, it is possible to infer that, if lactate is implicated in the fatigue process, the athlete who is able to remove the lactate faster, will begin the next match with a smaller propensity to fatigue and, in this way, will have a greater chance to reach a high performance.

The lactate produced in the active muscles during exercise at supra-maximal intensity, is subsequently metabolized in the body during the rest phase. According to Saltin, there are evidences that the return to the rest values occur after 30 to 60 min after high intensity exercises with high lactate accumulation. As blood lactate accumulation after a judo match ranges from 10 to 17 mmol L−1, the interval time between matches, which is around 10 to 30-min in several championships, is insufficient to promote an adequate lactate removal. As a consequence, the athlete competes in the subsequent match in a situation where fatigue may be anticipated.

The lactate accumulation has been associated with a performance decrease and hence lactate removal after effort seems to be important to improve the subsequent performance, mainly when the exercise is performed at high intensity. Although it is known that active recovery results in faster lactate removal than passive recovery, there are doubts yet about how these recovery types influence the performance of the subsequent exercise, probably due to methodological differences of the various studies, specially in relation with the task that is used as performance criterion.

In fact, the recovery phase between matches has not been adequately analyzed yet as an important factor, which may influence the subsequent combat. However, the combat situation is a very complex activity, which makes difficult to know if the active recovery is the responsible by better performance in the next fight or there are other factors such as motivation, attention, technical or tactical aspects, etc. One possibility to know if the performance can be better after an active than passive recovery, is to utilize a less complex task, but with similar physiological solicitation that the judo combat, as the upper body Wingate test. The choice for this test is due to the fact that the Wingate test is able to discriminate wrestlers from different levels, besides its high reliability. Nevertheless, the Wingate test is shorter (30 s) than the judo combat (maximum time of 5 min), then the repetition of the Wingate tests seems more adequate to verify the effect of the recovery types, and to add the intermittent character to the task.

Therefore, this study intended to verify the effect of the type of recovery (active or passive) on blood lactate removal and performance in an intermittent anaerobic task, in judo athletes of different levels (Brazilian National/International level; State level and City level). Running was chosen as active recovery because it is generally the only activity possible during the recovery period of a real competition.

Materials and methods

Experimental design

All the athletes performed both situations: 1) combat—passive recovery (PR)—4 repetitions of the upper body Wingate test (4WT); 2) combat—active recovery (AR)—4WT (Figure 1). The situations were randomly determined. In a previous day, the subjects were submitted to a cardiological evaluation and a treadmill test to the determination of aerobic power (VO2 peak) and capacity (Anaerobic Threshold; AT). The tests were conducted with a minimal time interval of 24 hours and a maximum of 2 weeks between the 1st and the last test. The athletes were instructed not to perform any intense effort 16 hours before the tests and not to ingest any food during 3 hours before the test.

Subjects

Seventeen voluntary judo athletes participated in this study after having signed the informed consent. All the athletes participated in official championships, trained
3 times a week at least and were first kyu (1 belt before black belt) or first dan (black belt). They were either Junior or Senior and weighted less than 100 kg. The subjects were subdivided according to their competitive level: A) International and/or Brazilian National level; B) State level (São Paulo); C) City level (São Paulo).

**Body composition**

The anthropometric measures and the calculation of the percentage of fat and muscle masses were estimated according to the method proposed by Drinkwater and Ross.\textsuperscript{25}

**Determination of the anaerobic threshold velocity and VO\textsubscript{2peak}**

The protocol proposed by Heck et al.,\textsuperscript{26} (a progressive treadmill test) was used for determination of anaerobic threshold velocity (AT) and VO\textsubscript{2peak}. The initial load was at 6.0 km-h\textsuperscript{-1} with an increment of 1.2 km-h\textsuperscript{-1} at each 3-min with a interval of 30-s between stages. At the end of each stage, blood samples were collected from the earlobe for lactate concentration analysis. This procedure was repeated until the subject’s exhaustion. During all the test the subject was monitored by electrocardiogram and a heart rate monitor Polar\textsuperscript{TM} Vantage NV (Polar Electro Oy, Finland). The gases analysis were made through the instrument AeroSport TEEM 100, whose accuracy and reliability were estimated by comparison with the result of the SensorMedics system.\textsuperscript{27} (standard error of 3.95%). The AT was the velocity corresponding to the 3.5 mmol-l\textsuperscript{-1}.

**Intermittent anaerobic test**

The athletes were submitted to a 4WT with 3-min interval between them, that is similar to the test adopted by other authors.\textsuperscript{28, 29} During those intervals, the athletes recovered passively and stayed seated in front of the cycloergometer. This intermittent task was performed in 2 different situations: 1) 17 min after a judo match, from which 15 min were utilized for AR; 2) 17 min after a judo match, from which 15 min were utilized for PR. After the 15 min of recovery, the subjects walked (1 min) to the laboratory stretching the upper body segments. The cycloergometer load was adjusted to 0.05 kp-kg\textsuperscript{-1} of body weight. Power output was processed by a Wingate Test software (Skill Equipamentos Esportivos, Brazil) which computed power output on each second and mean power related to body weight during the test (MPr – arithmetic mean of power output during 30s) and peak power related to the body weight (PPr – the higher power that was developed during the 30-s test). Total work was related to body weight (J·kg\textsuperscript{-1}). Blood lactate was measured in the 1\textsuperscript{st}, 3\textsuperscript{rd}, 5\textsuperscript{th}, 10\textsuperscript{th} and 15\textsuperscript{th} min after the last Wingate test.

**Combat situation**

The combat duration was set at 5 min. Each athlete’s opponent was the same in both combats. Body weight dif-
TABLE I.—Characteristics and anthropometrical data of the 3 groups (mean±SD).

<table>
<thead>
<tr>
<th>Parameters</th>
<th>A (n=5)</th>
<th>B (n=7)</th>
<th>C (n=5)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (y)</td>
<td>22.3±3.6</td>
<td>19.9±2.1</td>
<td>22.6±3.7</td>
</tr>
<tr>
<td>Judo practice (y)</td>
<td>14.6±5.1</td>
<td>11.3±2.5</td>
<td>10.0±0.7</td>
</tr>
<tr>
<td>Body mass (kg)</td>
<td>74.4±18.0</td>
<td>73.2±14.8</td>
<td>70.5±3.8</td>
</tr>
<tr>
<td>Height (cm)</td>
<td>171.1±10.4</td>
<td>173.3±10.5</td>
<td>173.4±4.3</td>
</tr>
<tr>
<td>Body fat (%)</td>
<td>10.8±1.7</td>
<td>10.7±2.3</td>
<td>12.0±1.7</td>
</tr>
<tr>
<td>VO₂peak (ml·kg⁻¹·min⁻¹)</td>
<td>63.0±10.3</td>
<td>62.9±9.3</td>
<td>64.9±5.5</td>
</tr>
<tr>
<td>HR max (bpm)</td>
<td>191±10</td>
<td>203±7</td>
<td>199±9</td>
</tr>
<tr>
<td>Peak lactate (mmol·l⁻¹)</td>
<td>7.7±1.2</td>
<td>8.4±1.5</td>
<td>8.1±1.9</td>
</tr>
<tr>
<td>Velocity at AT (km·h⁻¹)</td>
<td>10.7±0.8</td>
<td>9.3±1.7</td>
<td>9.2±1.5</td>
</tr>
<tr>
<td>HR at AT (bpm)</td>
<td>166±13</td>
<td>168±16</td>
<td>166±18</td>
</tr>
<tr>
<td>VO₂ at AT (ml·kg⁻¹·min⁻¹)</td>
<td>47.7±4.9</td>
<td>46.9±10</td>
<td>44.4±7.5</td>
</tr>
<tr>
<td>AT (% of VO₂peak)</td>
<td>76.7±8.8</td>
<td>74.1±8.7</td>
<td>68.2±7.8</td>
</tr>
</tbody>
</table>


TABLE II.—Blood lactate concentration (mmol·l⁻¹) after fight for the 3 groups at different times of active (AR) and passive (PR) recovery (mean±SD).

<table>
<thead>
<tr>
<th>Time (min)</th>
<th>A-AR</th>
<th>A-PR</th>
<th>B-AR</th>
<th>B-PR</th>
<th>C-AR</th>
<th>C-PR</th>
</tr>
</thead>
<tbody>
<tr>
<td>Before</td>
<td>2.1±0.3</td>
<td>2.1±0.2</td>
<td>1.9±0.5</td>
<td>2.2±0.4</td>
<td>2.2±0.4</td>
<td>2.2±0.4</td>
</tr>
<tr>
<td>1</td>
<td>10.5±2.1</td>
<td>9.3±2.0</td>
<td>10.6±1.9</td>
<td>10.1±1.8</td>
<td>9.6±2.5</td>
<td>9.2±1.8</td>
</tr>
<tr>
<td>3</td>
<td>9.5±2.3</td>
<td>9.2±2.1</td>
<td>9.4±1.9</td>
<td>9.8±1.7</td>
<td>9.6±1.6</td>
<td>9.0±1.4</td>
</tr>
<tr>
<td>5</td>
<td>8.4±3.0</td>
<td>8.3±1.4</td>
<td>8.2±2.4</td>
<td>9.2±1.8</td>
<td>8.7±1.4</td>
<td>8.5±1.6</td>
</tr>
<tr>
<td>10</td>
<td>5.9±1.4</td>
<td>6.8±1.7</td>
<td>5.8±2.6</td>
<td>7.5±2.2</td>
<td>5.9±0.8</td>
<td>7.1±1.7</td>
</tr>
<tr>
<td>15</td>
<td>3.8±1.3</td>
<td>5.1±1.6</td>
<td>4.3±1.7</td>
<td>6.1±1.4</td>
<td>4.4±0.5</td>
<td>6.0±1.2</td>
</tr>
<tr>
<td>Peak</td>
<td>10.5±2.1</td>
<td>9.8±2.1</td>
<td>10.1±2.0</td>
<td>10.4±1.9</td>
<td>10.2±1.8</td>
<td>9.5±1.5</td>
</tr>
</tbody>
</table>

Peak: highest blood lactate concentration measured during the period. A) National/International level. B) State level. C) City level. AR = Active recovery. PR = Passive recovery. Effect of interaction between time and recovery type (F₄,106=8.11; p<0.001). For details see text.

ferences between athletes and opponents were less than 10%. In a previous study, this procedure showed a high reliability of the blood lactate concentration after the match (intraclass correlation coefficient = 0.92; p<0.05).30

Passive recovery

During the passive recovery the subject stayed seated at the natsume during 15-min with the heart rate monitor PolarTM Vantage NV (Polar Electro Oy, Finland). Blood samples were collected before and at the 1st, 3rd, 5th, 10th, 15th min after the combat.

Active recovery

During the active recovery the athlete ran (15 min) at the velocity corresponding to 70% of the anaerobic threshold velocity (VAT). The control of the running velocity was made by marks every 20-m and acoustical signal. Before the beginning of the matches the athlete made a warm up at the same velocity during 3-min to adapt to the running rhythm. In the 1st minute after the match, the subject wore tennis shoes and heart rate monitor (PolarTM Vantage NV - Polar Electro Oy, Finland). After the 1st blood sample collection the athlete started running (active recovery). Additional blood samples were collected during brief interruptions of the run at the 3rd, 5th, 10th and 15th min after the end of the match.

Blood lactate analysis

The blood samples collected at the earlobe after application of a vasodilator pomade (FilnalgonTM) were analyzed by mean of an AccusportTM device (Boehringer Mannheim), whose validity within the range of obtained blood lactate has been tested by comparison with usual laboratory methods.31

Data analysis

Results are expressed as means ± standard deviation. Groups and treatments were compared through a 3-way (group, type of recovery and time) analysis of variance (ANOVA) with repeated measures, followed by Newman-Keuls tests. Total work during 4WT were compared through a 2-way (group and recovery type) analysis of variance with repeated measures. The groups comparison of the treadmill test and body composition was made through an 1-way (group) analysis of variance. An α-level of 5% was used in all analyses. All statistical analyses were performed with Statistica for Windows.

Results

Table I presents the data related to age, years of judo practice, body mass, height and percentage of body fat and the main results of the treadmill test for each group. There was no significant difference between groups (p>0.05) for all variables presented in Table I.25

Table II presents blood lactate concentration in each group during passive and active recovery periods. Peak blood lactate concentration after fights was not different (p>0.05) between groups and recovery periods.
modes. There was no difference (p>0.05) between groups or interactions between groups and type of recovery at any time during the 2 types of recovery for all the lactate data. However, there was an effect of interaction between time and recovery type (p<0.01). The main result of this analysis was that there were no differences (p>0.05) in blood lactate concentration between the 2 types of recovery at 3 and 5 min, but blood lactate concentration was lower in AR compared to PR at 10 (AR=5.9±1.8 mmol·l⁻¹; PR=7.2±1.8 mmol·l⁻¹; p<0.01, n = 17) and 15 min (AR = 4.2±1.3 mmol·l⁻¹; PR = 5.8±1.4 mmol·l⁻¹; p<0.01; n = 17) after combat.

Table III presents the performance during the 4WT. Peak power did not differ (p>0.05) between types of recovery or groups, however there was a progressive decrease (F₁,₁₄=95.83; p<0.001) in peak power during the 4 Wingate tests. Peak power was different between all tests, independently of group or type of recovery.

Mean power was different among groups (F₂,₂₈= 9.21; p<0.001) and among tests (F₁,₈₄=196.5; p<0.001), but there was no effect of recovery type or interaction. As total work, groups A and B presented higher (p<0.05) mean power than group C. Mean power was different among all tests (W₁>W₂>W₃>W₄). As a consequence, total work performed in the Wingate tests was different between groups (F₂,₁₄=5.28; p<0.05). When compared to group C (504±45 J·kg⁻¹), groups A (570±37 J·kg⁻¹) and B (558±31 J·kg⁻¹) performed more total work (p=0.018 and 0.022, respectively).

Blood lactate concentration after the last Wingate bout (Table IV) did not differ (p>0.10) between groups and type of recovery at any time of measurement (1, 3, 5, 10 and 15 min). However, there was a time effect (F₄,₄₄=67.1; p<0.001): blood lactate was higher during 1, 3 and 5 min after the last Wingate bout than 10 and 15 min after 4WT.

Table IV——Blood lactate concentration (mmol·l⁻¹) after fight for the 3 groups at different times of active (AR) and passive (PR) recovery (mean±SD).

<table>
<thead>
<tr>
<th>Time (min)</th>
<th>A (n=5)</th>
<th>B (n=7)</th>
<th>C (n=5)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>AR</td>
<td>PR</td>
<td>AR</td>
</tr>
<tr>
<td>1*</td>
<td>11.7±0.8</td>
<td>13.4±5.2</td>
<td>12.1±1.8</td>
</tr>
<tr>
<td>3*</td>
<td>12.9±5.9</td>
<td>12.6±1.6</td>
<td>13.0±2.3</td>
</tr>
<tr>
<td>5</td>
<td>11.7±5.7</td>
<td>11.5±2.1</td>
<td>11.8±1.6</td>
</tr>
<tr>
<td>10</td>
<td>11.3±2.6</td>
<td>10.5±2.8</td>
<td>9.8±2.8</td>
</tr>
<tr>
<td>15</td>
<td>10.8±2.0</td>
<td>11.3±2.7</td>
<td>10.4±1.7</td>
</tr>
</tbody>
</table>

A) National/International level. B) State level. C) City level. AR: active recovery; PR: passive recovery. * Time effect-blood lactate 1, 3 and 5 after 4WT were higher than 10 and 15 min after 4WT.
Table V.—Correlation between the anaerobic threshold running velocity and the blood lactate concentrations at various recovery times and mean power during upper body Wingate test.

<table>
<thead>
<tr>
<th>Concentrations</th>
<th>Anaerobic threshold running velocity</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>R</td>
</tr>
<tr>
<td>Lactate 1st min AR</td>
<td>-0.7165</td>
</tr>
<tr>
<td>Lactate 3rd min AR</td>
<td>-0.8020</td>
</tr>
<tr>
<td>Lactate 5th min AR</td>
<td>-0.8715</td>
</tr>
<tr>
<td>Lactate 10th min AR</td>
<td>-0.6895</td>
</tr>
<tr>
<td>Lactate 15th min AR</td>
<td>-0.7172</td>
</tr>
<tr>
<td>Peak lactate after the combat AR</td>
<td>-0.7819</td>
</tr>
<tr>
<td>Mean power W1 AR</td>
<td>+0.8349</td>
</tr>
<tr>
<td>Mean power W1 PR</td>
<td>+0.6059</td>
</tr>
<tr>
<td>Mean power W2 AR</td>
<td>+0.6757</td>
</tr>
</tbody>
</table>

Discussion

The lack of significant differences between groups concerning anthropometrical data and years of judo practice indicates morphological similarities in judoists, practicing this activity for the same numbers of years.

Groups did not differ in aerobic power (VO2peak). However, the aerobic power of these 3 groups were above those found in other studies with judo players.\(^5\)\(^,\)\(^8\)\(^,\)\(^32-34\) Results of VO2max for male judo players reported in other studies range from 53.2±1.4 ml·kg·min\(^{-1}\) (mean standard deviation) in judo players from USA 7 to 59.2±5.18 ml·kg·min\(^{-1}\) in Canadian Judo Team members.\(^5\) Several studies with male judo players reported intermediate values.\(^8\)\(^,\)\(^33-34\)

The variability (high standard deviations) of VO2peak found in judo players in our study may be related to the fact that the subjects were from different weight categories, which according to Thomas et al.\(^5\) present distinct characteristics of aerobic power (expressed relative to body mass). There is an inverse correlation between VO2max or VO2peak (expressed relative to body mass) and body mass in judo (r = -0.69; p<0.0005).\(^5\)

One point that seems to justify the high aerobic power of judo athletes is the positive influence of the aerobic metabolism on high intensity intermittent anaerobic exercise.\(^3\)\(^,\)\(^4\)\(^,\)\(^35\) This suggestion is made from the observation that, despite the reduction of glycolytic contribution (=45%) in the subsequent supramaximal exercise lasting 30-s, there is no proportional reduction in power output (=18%).\(^35\) Thus, in intermittent anaerobic activities like judo, the improvement of aerobic fitness can contribute to improve performance provided there is no reduction of anaerobic fitness. Tabata et al.\(^36\) and MacDougall et al.\(^29\) demonstrated that it is possible to improve both aerobic and anaerobic performances through a high intensity anaerobic exercise protocol training. The positive influence of aerobic fitness on blood lactate removal and subsequent performance was indirectly demonstrated by the significant negative correlation between anaerobic threshold running velocity and blood lactate after combat during AR and by the positive correlation with mean power during Wingate bouts 1 and 2 after AR and bout 1 after PR.

Blood lactate after combat did not differ between groups, suggesting that the glycolysis is solicited in a similar way in judo players of different levels. This values were similar to those reported by other studies,\(^16\)\(^,\)\(^8\) but lower than observed during international competitions,\(^2\) probably because athletes tend to increase their efforts during high level competitions.

Blood lactate decreases after fights were similar for the 3 groups and AR resulted in higher blood lactate removal than PR, as verified in minutes 10 and 15. Higher blood lactate removal after AR when compared with PR has been reported in several studies.\(^37-41\) and, the lactate oxidation in active muscles seems to be the main cause of this difference.\(^16\)

There is some disagreement about the effects of AR on subsequent performance, because, in general, studies that adopted more than 15-min recovery found no difference in performance between AR or PR,\(^37,38\) while studies with lower recovery time (6 min or less) found improvement of performance with AR compared to PR.\(^39,40\) In the present study, there was no difference between AR and PR concerning performance. However, athletes with higher competitive levels (groups A and B) performed better in the high-intensity intermittent exercise compared to athletes with lower competitive level (group C), indicating that the capacity to maintain the intensity of anaerobic exercise can discriminate properly judo players of different levels. Another important finding is that if groups had been evaluated using only one Wingate bout, there would not be any difference between them. Thus, the high intensity intermittent exercise model can be an important mean to evaluate and study the performance of sports like judo. On the other hand, peak power did not differ between groups, indicating that the ability to recover high-power production was similar in these groups. However, the ability to
maintain power for a time superior to 10-s was higher in groups A and B. The blood lactate after Wingate bouts did not differ between groups and recovery types, indicating that metabolic response to intermittent exercise was similar for the groups studied, despite different performance and that there was no more effect of recovery type after the Wingate bouts.

Conclusions

From the results observed in this study it can be concluded that blood lactate removal is faster during AR than during PR and this response is similar in judoists of different competitive levels, but there is no difference in performance between these procedures. Performance in high intensity intermittent exercise differed between groups of different competitive levels, suggesting that the use of this kind of test can be a convenient mean to evaluate athletes involved in intermittent sports.

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References