Carbohydrate intake and immunosuppression during judo training
Assunzione di carboidrati e immunosoppressione durante l’allenamento di judo

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SUMMARY
Aim. Hydro-energy replacement during exercise can act as an ergogenic aid and inhibit post-exercise immunosuppression. The aim of this paper was to test the hypothesis that carbohydrate (CHO) supplementation during judo training attenuates exercise-induced immunosuppression.

Methods. Fifteen male judo athletes (age: 22.1±2.1 years; body mass: 78.4±8.9 kg) completed two 120-min training sessions, 7 days apart, in a double-blind crossover study. In the first session, eight judo athletes, separated at random, were supplemented with a CHO solution (CHO group, 3 ml/kg body mass), while the others received a placebo solution (PLA group). The opposite was conducted on the second training session. The solution was taken every 20 min in both 120-min sessions. The concentrations of glucose, leukocytes, neutrophils, lymphocytes and monocytes of athletes were measured before and immediately after exercise.

Results. The concentrations of leukocytes and neutrophils increased (P<0.05) in both groups of athletes during the training session, but athletes in the CHO group exhibited lower concentrations of leukocytes and neutrophils at the end of the session vs. athletes in the PLA group (P<0.05). The blood glucose levels of the athletes in the CHO group increased (P<0.05) but the levels of the athletes in the PLA group decreased (P<0.05) during the training session.

Conclusion. The intake of CHO solutions by judo athletes can be beneficial for the maintenance of blood glucose levels and can diminish disturbances of the immune system during a typical training session.

KEY WORDS: Martial arts - Immunosuppression - Leukocytosis - Neutrophils - Carbohydrates.

RIASSUNTO

Metodi. Quindici atleti di judo maschi (età: 22.1±2.1 anni; massa corporea: 78.4±8.9 kg) hanno sostenuto due sessioni di allenamento di 120-min, a distanza di 7 giorni, in uno studio incrociato doppio-cieco. Nella prima sessione, otto atleti di judo, scelti casualmente, sono stati supplementati con una soluzione di CHO (gruppo CHO, 3 ml/kg per massa corporea), mentre gli altri hanno ricevuto una soluzione placebo (gruppo PLA). Nella seconda sessione di alle-
Judo is a combat sport characterized by high-intensity, complex intermittent actions performed to defeat the opponent by using specific techniques. As in other combat sports, judo athletes are categorized according to their body mass (BM). Thus, it is common for these athletes to avoid fluid ingestion during training sessions to achieve a lower weight category by dehydration. Such a practice can result in a decrease in performance during training sessions and, consequently, in a worse physical condition that could be achieved. On the other hand, nutritional support, when properly planned, can assist in the maintenance of quality training and can improve physical performance. Considering that the judogi (judo uniform) weighs ~2 kg and increases the risk of dehydration, it is important that athletes start a training session by being properly hydrated and with optimum levels of muscle and liver glycogen. In addition, the fluids and energy lost during the training session must be restored, reinforcing the need to plan for the replacement of hydro-energy.

In addition to being an ergogenic aid, hydro-energy replacement directly influences the immune system. The immune response to exercise depends on the intensity, duration and type of exercise, the concentration of plasma cytokines, body temperature and the athlete’s state of hydration and nutrition. Immunosuppression increases the likelihood that an athlete will acquire infections, especially of the upper respiratory tract. Several hours of intense exercise affect the activity of several components of the innate and adaptive immune systems, resulting in a general depression of their functions.

Performing exhausting and high-intensity exercises is closely associated with immunosuppression, especially when exercises are performed in hot environments or under conditions of dehydration and nutrition. Immunosuppression affects the activity of several components of the innate and adaptive immune systems, resulting in a general depression of their functions. Immunosuppression increases the likelihood that an athlete will acquire infections, especially of the upper respiratory tract. Several hours of intense exercise affect the activity of several components of the innate and adaptive immune systems, resulting in a general depression of their functions.

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L’immunosoppression e la reintegrazione idro-energetica influisce direttamente sul sistema immunitario. La risposta immunitaria all’esercizio dipende da intensità, durata e tipo di esercizio, e dalla concentrazione delle citocine ematiche, dalla temperatura corporea e dallo stato di idratazione e nutrizione dell’atleta. L’immunosoppression aumenta la probabilità che un atleta contragga infezioni, in particolare delle vie respiratorie superiori. Lunghe ore di intensi esercizi fisici si ripercuotono sull’attività di numerosi componenti del sistema immunitario innato e adattativo, determinando una depressione generale delle sue funzioni.

ditions of dehydration. Because judo training sessions last approximately 120 min per day and are performed indoors with the use of the judogi, immunosuppression in these athletes is commonly reported in the literature. However, it is not clear whether carbohydrate (CHO) consumption can reduce exercise-induced immunosuppression. Thus, this study aimed to evaluate the influence of CHO ingestion (6% CHO in the form of a drink) on the immune system during a typical judo training session. In addition, we also sought to determine how CHO intake affects the rating of perceived exertion (RPE) and the heart rate (HR) of judo athletes. We hypothesized that CHO attenuates immunosuppression and the RPE in judo athletes during their training session.

Materials and methods

This study was performed using a double-blind crossover design. We examined the influence of acute CHO consumption on the immune system, RPE and HR of judo athletes. The training regimen used in the present study was a typical judo training session, which is characterized by progressive and exhaustive exercises. The training sessions were held on two different days, with an interval of one week between sessions. All of the athletes were familiarized with the training regimen and the procedures used in the present study.

Subjects

The study included 15 adult male judo athletes (age: 22.1±2.1 years; BM: 78.4±8.9 kg; height: 177.5±5.2 cm; body fat: 17.2±3.3%; judo training experience: 10.4±5.7 years). The athletes were selected according to the following criteria: 1) more than 5 years of judo training experience; 2) participation in at least three competitions in the previous year. All the participants signed a written informed-consent form agreeing to the procedures and to the publication of the data. This study was approved by the Ethics Committee on Human Research of the Federal University of Viçosa.

Pre-exercise protocol

After assessment of eating habits, through questionnaires and recall of usual diet, we calculated the individualized diet for athletes ingest within three days prior to the start of the training regimen used in the present study.

Results

The study included 15 adult male judo athletes (age: 22.1±2.1 years; BM: 78.4±8.9 kg; height: 177.5±5.2 cm; body fat: 17.2±3.3%; judo training experience: 10.4±5.7 years). The athletes were selected according to the following criteria: 1) more than 5 years of judo training experience; 2) participation in at least three competitions in the previous year. All the participants signed a written informed-consent form agreeing to the procedures and to the publication of the data. This study was approved by the Ethics Committee on Human Research of the Federal University of Viçosa.
experiment. The energy content of the diet served from 90% to 110% of estimated need of energy (estimate energy requirement, EER). All of the athletes were instructed to avoid any intense physical exercise 24 h before both training sessions and to fast for 8 h prior to the collection of blood samples. The experimental procedures began at 8:00 am with an isocaloric breakfast (pre-exercise meal), which consisted of juice, biscuits and cereal. The amount of total calories consumed by the all athletes in this meal was 350 kcal, which represented 14% of a 2500 kcal diet and was comprised of 60 g CHO, 4 g protein, 3 g saturated fat and 9 g total fat. This pre-exercise meal provided the athletes with enough fluids to maintain a normohydration status, contained low levels of fat and fiber, was high in CHO to maintain high blood glucose levels and took into account the meal preferences of the athletes. One hour after breakfast, the athletes were weighed prior to beginning their training session. Immediately after the end of each session, the athletes were weighed again. The ambient temperature and relative humidity during each training period were monitored. These procedures were followed for both training sessions.

Hydration protocol

The hydroelectrolytic drink (CHO) used in this experiment contained 5% Glucose + 1% Fructose. The placebo solution (PLA), which did not contain CHO, was developed in the Department of Nutrition and Health of the Federal University of Viçosa using aspartame, water and sodium chloride. This solution had a similar taste, smell and color as the CHO-containing hydroelectrolytic drink. The amount of liquid consumed was calculated for each athlete individually and provided 3 mL/kg of BMI/20 min. The athletes consumed the drink at 0, 20, 40, 60, 80, 100 and 120 min of the training sessions.

Data collection

On the first day, eight athletes chosen at random consumed CHO, and the others consumed PLA. On the second day, the treatments were reversed. Each training session lasted 120 min and was structured as follows: 40 min of general exercises, 40 min of judo techniques and 40 min of fighting simulation (randori). The general exercises consisted of warm-up exercises, calisthenics and muscular endurance exercises. The

nuale, è stata calcolata una dieta personalizzata per gli atleti da seguire almeno nei tre giorni precedenti l’inizio della sperimentazione. Il contenuto energetico della dieta forniva dal 90 al 110% del fabbisogno calorico stimato (fabbisogno calorico stimato, EER). A tutti gli atleti è stato chiesto di evitare attività fisiche intense nelle 24 ore precedenti entrambe le sessioni di allenamento e di digiunare per 8 ore prima della raccolta dei campioni ematici. Le procedure della sperimentazione sono iniziate alle 8:00 con una colazione isocalorica (pasto pre-esercizio), composta da succo di frutta, biscotti e cereali. La quantità complessiva di calorie assunte da tutti gli atleti mediante questo pasto è stata di 350 kcal, che rappresentavano il 14% di una dieta da 2500 kcal e comprendeva 60 g di CHO, 4 g di proteine, 3 g di grassi saturi e 9 g di grassi totali. Questo pasto assunto nella fase che precedeva l’esercizio, ha fornito agli atleti liquidi sufficienti a mantenere uno stato di normoidratazione, aveva un basso contenuto di grassi e fibre, un alto contenuto di CHO per mantenere elevati tassi di glucosio nel sangue e tenere in considerazione le preferenze alimentari degli atleti. Un’ora dopo la colazione, prima di cominciare la loro sessione di allenamento, gli atleti sono stati pesati. Subito dopo la conclusione di ciascuna sessione, gli atleti sono stati pesati nuovamente. Durante ogni periodo di allenamento, sono state monitorate temperatura e umidità relative dell’ambiente. Queste procedure sono state seguite in entrambe le sessioni di allenamento.

Protocollo di idratazione

La bevanda idroelettrolitica (CHO) usata in questo esperimento conteneva il 5% Glucosio + l’1% di Fruttosio. La soluzione placebo (PLA), che non conteneva CHO, è stata sviluppata dal Dipartimento per la Nutrizione e la Salute dell’Università Federale di Viçosa utilizzando aspartame, acqua e cloruro di sodio. Questa soluzione aveva sapore, odore e colore simile alla bevanda idroelettrolitica contenente CHO. La quantità di liquido consumato è stata calcolata singolarmente per ciascun atleta e ha fornito 3 ml/kg di IMC/20 min. Gli atleti hanno consumato la bevanda a 0, 20, 40, 60, 80, 100 e 120 min delle sessioni di allenamento.

Rilevazione dei dati

Il primo giorno, otto atleti scelti casualmente hanno consumato CHO e gli altri hanno consumato PLA. Il secondo giorno, le somministrazioni sono state invertite. Ogni sessione di allenamento ha avuto una durata di 120 min. ed è stata strutturata come segue: 40 min. di esercizi generali, 40 min. di tecniche del judo e 40 min. di simulazione
technical training was composed of judo-related falls (ukemi), judo techniques (uchi-komi) and throwing techniques (nage-komi). The randori was composed of 6 standing (tachi-waza) and 4 groundwork (ne-waza) combat repetitions, and each randori lasted 3 min, with a 1 min rest interval between each consecutive randori. The judo regimen used in the current study was similar to that previously reported to be carried out by Japanese judokas.13-15

Biochemical analysis of blood samples
We collected 10 mL of blood from each athlete. For each blood sample, a 5 ml aliquot was stored in a tube containing EDTA and was used for blood analysis; the remaining 5 mL were stored and was used for the determination of blood glucose levels. After centrifuging the samples at 3400 × g at room temperature, the levels of blood glucose in the plasma were quantified on a semi-automatic spectrophotometer (Abbott Laboratories, IL, USA) using an enzymatic-colorimetric method. Leukocytes, neutrophils, monocytes and lymphocytes were counted on an automatic microanalyzer (ABX Microanalysis©, Hematologie ABX, SP, Brazil). The immune measurement was performed by flow cytometry and automatic spectrophotometric absorption using hemoclean, hemolysis and hemotom solutions.

Anthropometric measurements
The BM of the athletes was measured at the beginning and end of each training session using a standard scale (Soehnle®; SP, Brazil) with a 200-kg capacity and a 100-g limit of precision. The height of the athletes was measured using the stadiometer that was attached to the scale (precision within 1 cm). To measure skinfolds, we used Lange® calipers (Lange, Maryland, USA). The height of the athletes was measured with a 200-kg capacity and a 100-g limit of precision using the stadiometer that was attached to the scale (precision within 1 cm). To measure skinfolds, we used Lange® calipers (Lange, Maryland, USA). Body density was estimated using the following equation developed by Thorland et al.17:

\[
D (g/mL) = 1.1030 - [0.000815(SD)] + [0.00000084(SD^2)]
\]

where: D = body density and SD = sum of subscapular and abdominal skinfold thickness. The percentage of body fat (% BF) was estimated by using the following equation developed by Brozek et al.18:

\[
%BF = 457/D - 414.2
\]

Absolute (total) and partial (observed) dehydration was calculated by measuring the
La disidratazione (totale) e parziale (osservata) è stata calcolata misurando la quantità di urina prodotta e la quantità di liquidi assunti durante lo svolgimento dell’esercizio. La perdita assoluta di BM è stata determinata calcolando la differenza tra BM iniziale e finale, come mostrato nella seguente equazione:

\[
\text{% disidratazione assoluta} = \left( \frac{\text{IBM} - \text{FBM} + \text{perdita di urina} + \text{consumo}}{\text{IBM}} \right) \times 100
\]

Dove IBM=BM iniziale e FBM=BM finale.

La disidratazione parziale è stata determinata calcolando la differenza tra BM iniziale e finale secondo la seguente equazione:

\[
\text{% disidratazione parziale} = \left( \frac{(\text{IBM} - \text{FBM})}{\text{IBM}} \right) \times 100
\]

Per la raccolta dei campioni di urina sono stati impiegati sacchetti monouso (Flexor®, RJ, Brasil). Dopo la raccolta, è stato registrato il volume dell’urina, successivamente eliminato. La temperatura e l’umidità relativa dell’aria durante le sessioni di allenamento sono state misurate utilizzando un termoigrometro (Micronta®, SP, Brasil); le registrazioni sono state eseguite all’inizio della sessione e successivamente ogni 40 min. La fc degli atleti è stata misurata prima di iniziare la sessione di allenamento (0 min) e ogni 10 min. Dopo la sessione. La RPE è stata monitorata durante il consumo di liquidi utilizzando la scala 6-20 proposta da Borg et al. La Figura 1 mostra lo schema di raccolta dei dati in base alla fase di allenamento.
Statistical analysis

Data are presented as the mean±standard deviation. After conducting the Shapiro-Wilk test for normality, a two-way (solution and time) analysis of variance (ANOVA) with repeated measurements of the factor time was employed. To validate the repeated measurements of the ANOVA test, we used Mauchly’s sphericity test and, when necessary, the Greenhouse-Geisser correction. When significant differences were found by ANOVA, the Scheffe’s post-hoc test was applied. P-values of <0.05 were considered statistically significant. All the tests were conducted using SPSS version 14.

Results

The temperature and relative humidity measured during the two training sessions are shown in Table I. The average temperature and relative humidity during the first and second training sessions were 29.6±2.8 ºC and 77.1±7.1% and 31.4±2.8 ºC and 75.8±4.9 %, respectively. In both sessions, there was an increase in the temperature and a decrease in the relative humidity. This change in temperature was expected because the training sessions began at 9:00 a.m. and ended at 11:00 a.m. No significant differences in the temperature and relative humidity were found between the two training sessions.

The main findings on the influence of judo training on the immune response of the athletes are shown in Table II. The duration of training and the consumption of the CHO solution had significant effects (P<0.05) on the number of leukocytes and neutrophils present in the blood of the athletes and on the neutrophil/leukocyte ratio. Although the numbers of leukocytes and neutrophils increased during the training session, CHO intake significantly (P<0.05) attenuated this increase when compared to PLA. In other words, a smaller percentage variation (P<0.05) was observed between the beginning and final leukocyte and neutrophil counts when compared to PLA. It is also observed that the consumption of CHO increased the level of neutrophils in the blood of the athletes, while the consumption of PLA decreased the level of neutrophils.

Table I.—Temperature and relative humidity at the training session.

<table>
<thead>
<tr>
<th>Variables</th>
<th>Initial</th>
<th>40 min</th>
<th>80 min</th>
<th>Final</th>
<th>Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>First</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Temperature º C</td>
<td>26.3</td>
<td>28.4</td>
<td>31.5</td>
<td>32.3</td>
<td>22.8%</td>
</tr>
<tr>
<td>Humidity %</td>
<td>85</td>
<td>81</td>
<td>73</td>
<td>69.5</td>
<td>-18.2%</td>
</tr>
<tr>
<td>Second</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Temperature º C</td>
<td>28.2</td>
<td>30.4</td>
<td>32.1</td>
<td>34.8</td>
<td>23.4%</td>
</tr>
<tr>
<td>Humidity %</td>
<td>82</td>
<td>77</td>
<td>73</td>
<td>71</td>
<td>-13.4%</td>
</tr>
</tbody>
</table>

Table II.—Main findings on the influence of judo training on the immune response of the athletes.

<table>
<thead>
<tr>
<th>Variables</th>
<th>Initial</th>
<th>40 min</th>
<th>80 min</th>
<th>Final</th>
<th>Range</th>
</tr>
</thead>
<tbody>
<tr>
<td>Leukocytes</td>
<td>5000</td>
<td>5500</td>
<td>6000</td>
<td>6500</td>
<td>70%</td>
</tr>
<tr>
<td>Neutrophils</td>
<td>1000</td>
<td>1500</td>
<td>2000</td>
<td>2500</td>
<td>20%</td>
</tr>
<tr>
<td>Neutrophil/leukocyte ratio</td>
<td>0.5</td>
<td>0.6</td>
<td>0.7</td>
<td>0.8</td>
<td>15%</td>
</tr>
</tbody>
</table>

I dati sono presentati come la media±deviazione standard. Dopo aver eseguito il test di Shapiro-Wilk per la verifica della normalità, è stata impiegata una analisi delle varianze (ANOVA) a due vie (soluzione e tempo) con ripetute misurazioni del fattore tempo. Per la validazione delle ripetute misurazioni del test ANOVA, è stato impiegato il test della sfericità di Mauchly e, dove necessaria, la correzione di Greenhouse-Geisser. Quando il test ANOVA rilevava differenze significative, veniva applicato il test post-hoc di Scheffe. I valori P <0.05 sono stati considerati statisticamente significativi. Tutti i test sono stati eseguiti utilizzando la versione SPSS 14.

Risultati

La temperatura e l’umidità misurate durante le due sessioni di allenamento sono mostrate nella Tabella I. La temperatura e l’umidità relative durante la prima e la seconda sessione di allenamento corrispondevano rispettivamente a 29.6±2.8 ºC e 77.1±7.1% e 31.4±2.8 ºC e 75.8±4.9 %. In entrambe le sessioni si è verificato un aumento della temperatura e una diminuzione dell’umidità relativa. Questo cambiamento di temperatura era previsto in quanto le sessioni di allenamento iniziavano alle 9:00 e si concludevano alle 11:00. Non sono state rilevate differenze di temperatura e umidità relativa tra le due sessioni di allenamento.

I risultati principali relativi all’influenza dell’allenamento di judo sulla risposta immunitaria degli atleti sono mostrati in Tabella II. La durata dell’allenamento e il consumo di soluzione di CHO ha avuto effetti significativi (P<0.05) sul numero di leucociti e neutrofili presenti nel sangue degli atleti e sulla proporzione neutrofili/leucociti. Sebbene il numero di leucociti e neutrofili sia aumentato durante la sessione di allenamento, l’assunzione di CHO ha significativamente (P<0.05) attenuato questo incremento rispetto all’assunzione della soluzione PLA. In altre parole, è stata osservata una minore variazione percentuale (P<0.05) tra il conteggio iniziale e finale dei leucociti e dei neutrofili nel caso in cui gli atleti hanno assunto la soluzione di CHO.
the athletes consumed the CHO solution. The duration of training and the type of solution (P>0.05) had no significant effect on the numbers of lymphocytes and monocytes present in the blood.

Table III shows the results of the measurements of the initial and final BM, the amount of fluid intake and the level of partial and absolute dehydration. The duration of training had a significant (P<0.05) effect on the athletes’ BM in both training sessions, but the type of solution consumed had no influence on BM (P>0.05).

The athletes’ glucose levels, HR and RPE during both training sessions are shown in Figures 2-4, respectively. We found no statistically significant difference between the baseline and final blood glucose levels of the athletes (P>0.05), regardless of the type of fluid consumed. However, after 40 and 80 min of training, the CHO solution consumed by the athletes significantly increased their levels of blood glucose (P<0.05) when compared to the PLA condition.

The duration of training significantly affected the HR of the athletes (P<0.05), independent of the type of solution consumed (P>0.05). After 10 min of training, athletes’ HRs were significantly higher than at rest (P<0.05) and remained

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**Table II.**—Effect of carbohydrate consumption during judo training on leukocyte counts.

<table>
<thead>
<tr>
<th>Immune Cell Type</th>
<th>Carbohydrate Drink</th>
<th>Placebo</th>
</tr>
</thead>
<tbody>
<tr>
<td>Leukocytes (1)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Initial</td>
<td>7.1±1.5</td>
<td>7.0±1.6</td>
</tr>
<tr>
<td>Final</td>
<td>9.7±2.2</td>
<td>11.7±2.9b</td>
</tr>
<tr>
<td>% Range</td>
<td>22.5±4.5%</td>
<td>67.1±10.2%c</td>
</tr>
<tr>
<td>Neutrophils (1)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Initial</td>
<td>4.0±0.9</td>
<td>3.8±0.7</td>
</tr>
<tr>
<td>Final</td>
<td>6.4±1.8</td>
<td>8.3±2.1b</td>
</tr>
<tr>
<td>% Range</td>
<td>60±5.8%</td>
<td>118.5±10.6%</td>
</tr>
<tr>
<td>Lymphocytes (1)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Initial</td>
<td>2.5±0.6</td>
<td>2.5±0.7</td>
</tr>
<tr>
<td>Final</td>
<td>2.3±0.8</td>
<td>2.4±0.7</td>
</tr>
<tr>
<td>% range</td>
<td>-8±1.9%</td>
<td>-4±1.1%</td>
</tr>
<tr>
<td>Monocytes (2)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Initial</td>
<td>458±65</td>
<td>485±75</td>
</tr>
<tr>
<td>Final</td>
<td>643±119</td>
<td>635±123</td>
</tr>
<tr>
<td>% Range</td>
<td>40.2±6.4%</td>
<td>40.9±7.2%</td>
</tr>
<tr>
<td>Neutrophils/leukocytes × 100 (%)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Initial</td>
<td>55.4±7.5</td>
<td>54.2±7.6</td>
</tr>
<tr>
<td>Final</td>
<td>66.0±8.3</td>
<td>70.9±7.6</td>
</tr>
<tr>
<td>% Range</td>
<td>19.1±2.5%</td>
<td>30.8±4.3%</td>
</tr>
</tbody>
</table>

(1)Number of cells × 10³/mm³. (2)Number of cells/mm³. aStatistical difference between baseline and final (P<0.05). bStatistical difference between carbohydrate and placebo (P<0.05). cDifference between the percentage of variation in the number of immune cells (P<0.05).
Table III. — Fluid consumption, body mass and dehydration level during two judo training sessions after consumption of a carbohydrate or placebo solution.

<table>
<thead>
<tr>
<th>Solution</th>
<th>IBM (kg)</th>
<th>FBM (kg)</th>
<th>Fluid Consumption (L)</th>
<th>Absolute Dehydration¹</th>
<th>Partial Dehydration²</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carbohydrate</td>
<td>78.6±8.7</td>
<td>76.9±8.5</td>
<td>1.6±0.2</td>
<td>4.4±0.5%</td>
<td>2.3±0.5%</td>
</tr>
<tr>
<td></td>
<td>(3.5±0.6 kg)</td>
<td>(1.8±0.4 kg)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Placebo</td>
<td>78.1±9.4</td>
<td>76.4±9.3</td>
<td>1.6±0.2</td>
<td>4.3±0.5%</td>
<td>2.2±0.5%</td>
</tr>
<tr>
<td></td>
<td>(3.4±0.4 kg)</td>
<td>(1.7±0.3 kg)</td>
<td></td>
<td></td>
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¹Difference between the initial (IBM) and final (FBM) body mass (P<0.05). ²Difference between IBM and FBM plus the amount of liquid consumed.

Figure 2.—Mean blood glucose levels in the judo athletes. a, b, c P<0.05 for 40 and 80 min vs. 0 and 120 min for the same solution. p<0.05 between solutions.

Figure 3.—Change in the RPE before and after the training session. a P<0.05 RPE at 0 min vs. RPE after 20, 40, 60, 80, 100 and 120 min; b P<0.05 RPE specific moment vs. RPE after 0 and 120 min.

Figure 4.—Mean HR of the athletes. a P<0.05 HR at 0 min vs. HR after 10, 20, 30, 40, 50, 60, 70, 80, 90, 100, 110 and 120 min; b P<0.05 HR after 10 min vs. HR after 0, 20, 30, 40, 50, 60, 70, 80, 90, 100, 110 and 120 min.
higher than at rest during all subsequent measurements (P<0.05). However, there was no statistically significant difference in athletes’ HRs beyond 20 min of training (P>0.05).

Athletes’ RPEs increased significantly at the end of the training session when compared to baseline (P<0.05), regardless of the type of solution consumed (P>0.05). As expected, athletes’ RPEs were lower at rest than at any other time point during the training session (P<0.05). After 20 to 100 min of exercise, the athletes’ RPEs were significantly lower than at the end of the training session (P<0.05).

**Discussion**

Overall, our results indicate that the consumption of CHO during a 120 min judo training session attenuates immunosuppression. Thermal conditions during exercise can influence an athlete’s physiological responses. During both of our experimental training sessions, the ambient temperature increased and the relative humidity decreased. According to the classification of the American College of Sports Medicine (ACSM),20 the judo athletes in this study were exposed to a moderate risk of heat exhaustion at the start of the two training sessions and to a high risk at the end of the training sessions. Besides decreasing sports performance, high temperatures can disturb the immune system.8, 20 Hyperthermia, either at rest or during exercise, is associated with an increased production of catecholamines, which promote the mobilization of immune cells.8 Therefore, it is possible that the increased ambient temperature observed during the training session contributed to the increase in leukocyte numbers in the blood (Table I). In agreement with our results, Umeda et al.13 also observed an increase in the neutrophil count of athletes in response to 120 min of judo training. However, it is important to note that they observed slightly lower average ambient temperature and relative humidity values than we did in the current study (28.2±0.4 °C and 61.2±1.9%).

Our hydration regimen followed the ACSM guidelines,21 which recommend that 150 to 350 ml of water should be consumed every 15 to 20 min to replace water loss that occurs during exercise. In this study, we adopted a single strategy for the replacement of fluids during the training sessions (3 ml/kg of BM/20 min, resulting in ~235 ml each 20 min, which is in (P<0.05) and is maintained higher than at rest, resulting in ~235 mL each 20 min, which is in (~235 mL each 20 min, which is in...
the range proposed by ACSM). However, the amount of fluid consumed by the athletes was not sufficient to maintain homeostasis, causing approximately 2% dehydration, regardless of the solution consumed (Table III). The few studies that have evaluated the influence of dehydration on immune function are controversial. For example, Mitchell et al.22 did not find differences in the numbers of leukocytes, lymphocytes, neutrophils and natural killer cells between athletes who performed exercise under hydrated or dehydrated conditions.

It is important to note that dehydration may cause large immune disturbances in judo athletes. Using a longer duration of randori (70 min) than used here, Umeda et al.13 and Yamamoto et al.23 reported that judo athletes exhibited less leukocytosis and neutrophilia and a smaller decrease in BM after exercise than before exercise (0.8±0.1 kg and 1±0.1 kg, respectively, vs. 1.8±0.4 kg in the current study). However, neither study monitored the amount of liquid consumed by the athletes. In the present study, if the judo athletes had not consumed liquid during the training sessions, their levels of dehydration would have exceeded 4%. This level of dehydration decreases the number of T lymphocytes in judo athletes24 and can affect the health and performance of athletes involved in combat sports.25

In the training regimen used here, we began each session with low intensity and general exercises and progressed to higher intensity and specific exercises. This progression in exercise intensity is reflected in the RPE and HR measurements over time (Figures 3, 4), which show that the baseline values were statistically lower than the final values. Several studies have reported that intense exercise disturbs the immune system9,26. In the latter part of training (randori), the high intensity effort endured by the athletes was possibly the largest contributor to the observed leukocytosis because intense activities increase the number of circulating immune cells.27

All the values obtained before the beginning of exercise and after 120 min were not statistically different, regardless of the type of solution consumed by the athletes. However, the levels of blood glucose remained higher during the training session when the athletes consumed CHO than when they consumed PLA. In agreement with these results, several studies have shown that consumption of CHO during exercise is beneficial for the immune system9. Con-
assumption of CHO maintains higher blood glucose levels during exercise, resulting in a lower endogenous catabolism of muscle and liver glycogen\textsuperscript{28}. Reducing the catabolism of endogenous sources of CHO decreases the secretion of catabolic hormones, including cortisol and epinephrine.\textsuperscript{29} Because increased production of these hormones is associated with immunosuppression,\textsuperscript{26} CHO consumption can reduce the immunosuppression associated with intense exercise in athletes. In addition, longitudinal studies have found that, despite adjustments to training regimens, the immune systems of judo athletes are disturbed on a daily basis.\textsuperscript{15, 23} Thus, the consumption of CHO during exercise is essential to preserve the functions of the immune system and to maintain high performance during training.

The normal leukocyte count for adults is between 3500 and 10000 cells/mm\textsuperscript{3} \textsuperscript{30}. In this study, at the start of the training session, all athletes had normal levels of leukocytes. However, at the end of the session, 11 (73\%) athletes who consumed PLA had leukocytosis, while only six who consumed CHO (40\%) had leukocytosis (white blood cell counts above 10000 cells/mm\textsuperscript{3}). In athletes, leukocytosis is associated with an increased susceptibility to infections, which, in turn, is highly associated with overtraining.\textsuperscript{11} Our results are consistent with those of Nemet et al.,\textsuperscript{31} who reported that acute exercise significantly increases the number of white blood cells in adolescent wrestlers. This immunosuppression may be associated with increases in the levels of stress hormones, such as cortisol and adrenaline, especially as the production of these catabolic hormones is more commonly increased in athletes who train or compete under conditions of CHO deprivation.\textsuperscript{22} With respect to judo, the regimens and fighting techniques used during training have been shown to significantly increase the secretion of cortisol by approximately 47 and 54\%, respectively.\textsuperscript{32}

Previous studies have reported that intense exercise causes leukocytosis.\textsuperscript{9} This increase in the number of circulating immune cells during exercise has been associated with post-activity immunosuppression, which increases susceptibility to infection.\textsuperscript{33} Bøyum et al.\textsuperscript{6} reported that the energy deprivation associated with strenuous exercise also disrupts the immune system, indicating that a lack of CHO consumption during exercise likely contributes to changes in the number of leukocytes. The magnitude of leukocytosis induced by exercise is less than those found in this study,\textsuperscript{9} yet it is evident that exercise exacerbates the immunosuppression associated with CHO deprivation.\textsuperscript{22} With respect to judo, the regimens and fighting techniques used during training have been shown to significantly increase the secretion of cortisol by approximately 47 and 54\%, respectively.\textsuperscript{32}

**BRIT**

**CARBOHYDRATE INTAKE AND IMMUNOSUPPRESSION DURING JUDO TRAINING**

CHO during the exercise has an effect beneficio sul sistema immunitario\textsuperscript{9}. L’assunzione di CHO mantiene elevati i livelli di glucosio nel sangue durante l’esercizio, determinando un più basso catabolismo endogeno del glicogeno epatico e muscolare\textsuperscript{28}. Riducendo il catabolismo delle fonti endogene di CHO, diminuisce la secrezione di ormoni catabolici, compresi il cortisolo ed l’epinefrina\textsuperscript{29}. Dato che l’aumento della produzione di questi ormoni è associata all’immunosoppressione\textsuperscript{26}, l’assunzione di CHO è in grado di ridurre negli atleti l’immunosoppressione associata all’attività fisica intensa. Inoltre, studi longitudinali hanno provato che, nonostante le variazioni dei regimi di allenamento, i sistemi immunitari degli atleti di judo vengono quotidiana mente alterati.\textsuperscript{15, 23} Pertanto, durante l’esercizio è fondamentale il consumo di CHO al fine di preservare le funzioni del sistema immunitario e mantenere elevati livelli di prestazione durante l’allenamento.

Il valore normale dei leucociti per gli adulti è compreso tra 3500 e 10000 globuli/mm\textsuperscript{3}. In questo studio, all’inizio della sessione di allenamento, tutti gli atleti presentavano nodi normali di leucociti. Tuttavia, al termine della sessione, 11 (73\%) atleti che avevano assunto la soluzione di CHO22. Per quanto riguarda l’assunzione di CHO durante l’esercizio ha un effetto benefico sul sistema immunitario\textsuperscript{9}. L’assunzione di CHO mantenere i livelli di glucosio nel sangue durante l’esercizio, determinando un più basso catabolismo endogeno del glicogeno epatico e muscolare\textsuperscript{28}. Riducendo il catabolismo delle fonti endogene di CHO, diminuisce la secrezione di ormoni catabolici, compresi il cortisolo ed l’epinefrina\textsuperscript{29}. Dato che l’aumento della produzione di questi ormoni è associata all’immunosoppressione\textsuperscript{26}, l’assunzione di CHO è in grado di ridurre negli atleti l’immunosoppressione associata all’attività fisica intensa. Inoltre, studi longitudinali hanno provato che, nonostante le variazioni dei regimi di allenamento, i sistemi immunitari degli atleti di judo vengono quotidianamente alterati.\textsuperscript{15, 23} Pertanto, durante l’esercizio è fondamentale il consumo di CHO al fine di preservare le funzioni del sistema immunitario e mantenere elevati livelli di prestazione durante l’allenamento.

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Precedenti studi riportano che l’attività fisica intensa provoca leucocitosi\textsuperscript{9}. Questo aumento del numero di cellule immunitarie circolanti durante l’esercizio fisico è stato associato all’immunosoppressione post-attività che porta all’aumento della sensibilità alle infezioni\textsuperscript{33}. Bøyum et al.\textsuperscript{6} riferiscono che l’insufficienza di energia associata all’attività fisica intensa, altera il sistema immunitario, sottolineando che la mancata assunzione di CHO durante l’attività fisica contribuisce a modifica-
Leukocytosis is related to the intensity of exercise. The numbers of leukocytes quantified in the athletes who participated in this study were similar to those seen in runners after 180 min of exercise, although the total duration of activity in the current study was only 120 min. Because judo training is predominantly aerobic with bouts of both alactic and lactic anaerobic contribution, it is likely that anaerobic energy systems contributions the latter promoted the observed leukocytosis even though the activity performed in this study was of shorter duration.

Neutrophils are the first line of defense against infections. These cells have high phagocytic capacity and produce reactive oxygen species that function as microbicides. In healthy adults, the normal range of neutrophils is between 1800 and 8000 cells/mm$^3$. At baseline, all of the judo athletes exhibited normal levels of neutrophils. At the end of the training session, 13 (87%) athletes who consumed PLA had neutrophilia, while only 6 (40%) who consumed CHO did so (neutrophil values above 8000 cells/mm$^3$) (Table II). In addition, the variation in the neutrophil/leukocyte ratio was also higher in athletes who consumed PLA (30.8±4.3%) than in those who consumed CHO (19.1±2.5%). Given these results, it appears that CHO consumption is essential to prevent post-exercise neutrophilia.

The results of this study are consistent with those obtained by Nemet et al. and Rysøy et al. In addition, Scharhag et al. observed that after 4 h of moderate intensity cycling, there was a pronounced increase in the numbers of circulating neutrophils. However, in another study of shorter duration (1 hour) and more intense activity (resistance exercise), Rysøy et al. observed a significant increase in the number of neutrophils. This increase in neutrophils is likely related to muscle wasting induced by strenuous exercise because neutrophils are the first cells to respond to muscle microdamage and start the repair process.

The variation in the neutrophil counts in this study was higher than previously observed in Japanese judo athletes. Mochida et al. reported that athletes who participated in a judo training camp (6.5 h of daily training) exhibited a 25% increase in the number of neutrophils, while Umeda et al. reported an increase of 19.6%. It should be noted that the athletes who took part in these studies were from a higher competitive level than the athletes who participated in this study.

I neutrofili sono la prima linea di difesa contro le infezioni. Queste cellule hanno capacità fagocitica elevata e producono specie reattive di ossigeno che funzionano come microbicidi. Negli adulti sani, il normale intervallo di neutrofili varia tra 1800 e 8000 globuli/mm$^3$. In questo studio, 13 (87%) atleti che avevano assunto PLA mostravano neutrofilia, mentre solo 6 (40%) degli atleti che avevano assunto CHO (valori dei neutrofili oltre 8000 globuli/mm$^3$) (Tabella II). Inoltre, la variazione del rapporto neutrofili/leucociti era maggiore negli atleti che avevano assunto PLA (30.8±4.3%) rispetto a quelli che avevano assunto CHO (19.1±2.5%). Sulla base di questi risultati, appare evidente che l’assunzione di CHO è fondamentale per prevenire la neutrofilia post-attività fisica.

I risultati di questa ricerca sono in linea con quelli ottenuti da Nemet et al. e Rysøy et al. Inoltre, Scharhag et al. osservarono che dopo 4 ore di ciclismo con intensità moderata, si verificava uno spiccato incremento del numero di neutrofili circolanti. Tuttavia, in un altro studio basato su una minore durata (un’ora) e un’attività più intensa (esercizio di resistenza), Rysøy et al. hanno osservato una diminuzione significativa del numero di neutrofili. Questo aumento di neutrofili è probabilmente correlato alla perdita di massa muscolare indotta dall’esercizio intenso dato che i neutrofili sono i primi globuli che reagiscono ai microdanni della muscolatura e avviano il processo di riparazione.

La variazione del valore dei neutrofili nella presente ricerca è stata maggiore rispetto a quanto precedentemente osservato negli atleti di judo giapponesi. Mochida et al. riportano che gli atleti che partecipavano a un allenamento college di judo (6,5 ore di allenamento quotidiano) mostravano il 25% di aumento del numero di neutrofili, mentre Umeda et al. riportavano un
pated in the present study. Highly trained judo athletes probably have adaptations that have been acquired through practice. As such, they may produce lower concentrations of enzymes, such as creatine kinase and lactate dehydrogenase, resulting in less muscle damage during training. However, Wolack et al. found that judo athletes and sedentary individuals exhibited a similar reduction in neutrophil activity after strenuous exercise.

The normal range for lymphocytes is between 900 and 2900 cells/mm$^3$. At baseline, all the judo athletes had normal lymphocyte levels. However, at the end of the training session, only two athletes had lymphocytosis (lymphocyte counts above normal values) half on each condition. Lymphocytes are the main cells responsible for adaptive immunity, and a decrease in the number of these cells affects the body's ability to respond to complex pathogens. In this study, we did not observe a pronounced increase in the number of lymphocytes in the athletes. In contrast, Sureda et al. reported that one hour of football practice significantly increased the numbers of circulating lymphocytes.

The normal range for monocytes is between 300 and 900 cells/mm$^3$. At baseline and after training, all the judo athletes had normal monocyte levels. Monocytes play an important role in the phagocytosis of pathogens. Thus, a decrease in these cells can affect the innate immune system and the communication between innate and adaptive immune cells. The studies on the influence of exercise on monocytes are controversial. Unlike in the present study, Green et al. found that, in well-trained cyclists who could cover a distance of 40 km in 60 min, the numbers of monocytes in the blood increased over the course of one year, and CHO supplementation did not attenuate this increase. In contrast, Lancaster et al. reported a significant increase in monocytes after 150 min of cycling, which was prevented by consumption of a solution of 6.4% or 12.8% CHO during the activity.

The results described here need to be confirmed by additional studies. In addition, it is important to consider some of the limitations of the present study. One such limitation is the absence of monitoring variables that directly affect the immune response (e.g., epinephrine and cortisol). Another limitation involves the inherent characteristics of judo, a sport where it is difficult to quantify the effort of the athletes. In aumiento del 19.6%. Va considerado che gli atleti che parteciparono a queste ricerche apparteneva-no ad un livello competitivo più elevato rispetto agli atleti che hanno partecipato al presente studio. Atleti di judo molto allenati probabilmente sono soggetti ad adattamenti che sono stati acquisiti attraverso la pratica. Sono pertanto in grado di produrre minori concentrazioni di enzimi, quali la creatina chinasi e il lattato deidrogenasi, e di conseguenza sono soggetti a un danno muscolare minore durante l’allenamento. Ciononostante, Wolack et al. hanno scoperto che gli atleti di judo e gli individui sedentari mostrano una riduzione simile dell’attività dei neutrofili dopo un’attività fisica intensa.

L’intervallo normale per i linfociti varia tra 900 e 2900 globuli/mm$^3$. All’inizio, tutti gli atleti di judo mostravano valori normali dei linfociti. Tuttavia, al termine della sessione di allenamento solo due atleti avevano linfocitosi (valore dei linfociti superiore al normale) in ogni condizione. I linfociti sono i principali cellule responsabili dell’immunità adattativa; una diminuzione del numero di questi globuli influenza sull’abilità del corpo a reagire a patogeni complessi. In questo studio non è stato osservato uno spiccato aumento del numero di linfociti negli atleti. Al contrario, Sureda et al. riferiscono che un’ora di allenamento di calcio ha portato all’aumento significativo del numero di linfociti circolanti.

L’intervallo normale per quanto riguarda i mononucleati varia tra 300 e 900 globuli/mm$^3$. All’inizio e dopo l’allenamento, tutti gli atleti di judo avevano valori dei mononucleati normali. I mononucleati svolgono un ruolo importante nella fagocitosi dei patogeni. Pertanto, una diminuzione di queste cellule può influire sul sistema immunitario congenito e sulla comunicazione tra cellule immunitarie innate e adattative. Gli studi sull’influenza dell’esercizio fisico sui mononucleati sono controversi. Discostandosi dal presente studio, Green et al. hanno scoperto che, nei ciclisti ben allenati in grado di coprire distanza di 40 km in 60 min, il numero di mononucleati nel sangue aumentava nel corso di un anno, e la supplementazione di CHO non attenuava questo incremento. Al contrario, Lancaster et al. riferiscono un sensibile incremento di mononucleati dopo 150 min di pedalata, che tentava evitato assumendo una soluzione al di CHO 6,4 o 12,8% durante l’attività fisica.

I risultati descritti in questo lavoro devono essere confermati da ulteriori studi. È inoltre importante considerare la presenza di alcuni limiti in questa ricerca. Un limite è rappresentato dall’assenza di monitoraggio di variabili che influiscono direttamente sulla risposta immunitaria (ad es., epinefrina e cortisol). Un altro limite riguarda le
addition, several factors, such as temperature, the intensity of training and dehydration, may have contributed to the immunosuppression observed.

The present study examined the acute influence of judo training on the immune system. Given our results, we suggest that the consumption of CHO during exercise is beneficial to judo athletes because CHO helps to maintain adequate blood glucose levels and lower concentrations of neutrophils and leukocytes after training.

Conclusions

These results can be used by coaches and judo athletes to establish strategies to improve athletic performance during training. We recommended that a liquid CHO be consumed during and after training (1-1.5 g/kg BM) to quickly restore hydro-energy homeostasis. To do this, the judokas must be weighed before and after training so that athletes can drink an amount of CHO equivalent to the net difference between their initial and final BM. Following these recommendations, judokas can reduce the adverse effects of intense exercise on their immune systems and can compete at a higher fitness level.

Carbohydrate intake and immunosuppression during judo training

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