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Food Restriction, Performance, Biochemical, Psychological, and Endocrine Changes in Judo Athletes

Abstract

In order to test the hypothesis that dietary restriction may have a negative influence on physiological and psychological adaptation to a judo competition, we examined the effects of weight loss induced by restricting energy and fluid intake on the physiology, psychology, and physical performance of judo athletes. Twenty male judoka were randomly assigned to one of two groups (Group A: called diet, n = 10; height 174.8 ± 1.9 cm, body weight 75.9 ± 3.1 kg; they were asked to lose ~ 5% of their body weight through self-determined means during the week before the competition; Group B: called control, n = 10; height 176.4 ± 1.1 cm, body weight 73.3 ± 6.3 kg maintained their body weight during the week before the competition). A battery of tests was performed during a baseline period (T_1), on the morning of a simulated competition (T_2) and 10 min after the end of the competition (T_3). The test battery included assessment for body composition, performance tests, evaluation of mood, determination of metabolic and hormonal responses. Dietary data were collected using a 7-day diet record. The nutrient analysis indicated that all the athletes followed a low carbohydrate diet whatever the period of the investigation. For the Group A, the food restriction (– 4 MJ per day) resulted in significant decreases of the body weight and altered the mood by increasing Fatigue, Tension and decreasing Vigour. Dietary restriction had also a significant influence on metabolic and endocrine parameters and was associated with poor performance. After the competition, significant decreases of the levels in testosterone, T/C ratio, alkali reserve, and free fatty acid were observed in both groups, whereas the plasma concentrations in insulin, ammonia, urea, and uric acid were increased. In conclusion, our results suggest that the combination of energy restriction and intense exercise training, which causes weight reduction before a competition, adversely affects the physiology and psychology of judo athletes and impairs physical performance before the competition. Our data are the first to demonstrate that a competition including five 5-min bouts induced the same changes of physiological and psychological variables and performance whatever the dietary intake (dietary restriction or not) during the seven days before the competition.

Key words
Weight loss · performance · hormonal status · metabolites · psychological state

Introduction

Competitions in wrestling or boxing, are contested in weight classes, and most athletes compete in a class 5 – 10% below their usual weight [11]. Dietary studies have indicated that there is an extreme variability in the dietary regimes looking for the optimum athletic diet. Little published scientific research is available on judo athletes. Nevertheless, anecdotal evidence suggests they

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typically lose weight rapidly by a reduction in food intake for 4–5 days prior to competition, sweating through intensive exercise in plastic suits to promote water loss, fluid restrictions, and even the use of diuretics [12,28]. However, such body weight reduction may affect plasma and blood volume [7], muscle glycogen stores [50], endocrine function [11], may induce a physiological and a psychological stress [24,54], and may have immediate effects on the aerobic endurance capacity and sports performance [19]. The influence on the anaerobic performance is more controversial [18,45,49]. Among sports classed by weight, judo is characteristic of short duration, high intensity, intermittent exercise lasting a total match of 7.18 ± 0.2 min for males. It has been shown that a single judo match is able to induce mobilization of both protein and lipid metabolism [13]. All significant judo events take place in a tournament setting (e.g., national championships), thereby requiring several matches to occur within a single day. Analysis of the 2004 Olympic Games in Athens shows that each Olympic Champion judo player fought for a total of four to six 5-min bouts, interspersed with a minimum 10-min seated recovery periods between each match. Consequently, the judo tournaments combine stressors beyond those already created by weight alone, including physiological and psychological stresses related to competition [15,16]. Because a judo match requires strength and power of both the upper and lower body musculature as well as isometric force for various judo techniques, it seems plausible that strength and power production could be further reduced over the course of multiple matches. Caloric restriction, dehydration, and/or physical exertion may also influence the endocrine environment [30,33,39].

Under the current rules of national and international judo competition, a judo competitor is allowed a period of 1–2 h after weigh-in and prior to the start of competition during which ad libitum food and fluid consumption is allowed [44]. In wrestling, the period after weigh-in prior the first fight lasts 14–18 h. Tarnopolsky et al. [52] reported that the muscle glycogen reduction induced by the weight loss methods is largely reversed during the 17-h repletion period between weigh-in and the start of the competition. However, even if there are data concerning the physiological responses to tournament wrestling, they cannot be transposed to judo, because of the short period after weigh-in and the start of the competition in this sport. Furthermore, compared to the duration of judo tournaments and matches (several 5-min matches during 1 day in judo), wrestling contests were longer (several two 3-minute bouts during 2 days). Thus, it is not clear whether two hours are sufficient not to affect the physiological processes of metabolism and tissue repair and are able to restore the potential for performance adjustments. In previous studies, acute weight reduction in judo athletes induces at rest proteolysis of muscle tissue, resulting in a decrease in fat-free mass and physical strength and in a change of the psychological capacities [16,32]. However, the effects of energy restriction on mood are still on debate: although Wells et al. [56] reported higher Profile of Mood States (POMS) scores for Anger/Hostility and Tension/Anxiety, there is also evidence for diminished depression and anxiety, and improved mood with dieting [20].

Therefore, the purpose of the present investigation was to mimic a typical major judo championship framework to examine the effects of restricted energy and fluid intake on the performance, physiological and psychological responses before and after a competition.

Methods

Subjects

Two groups of male judo competitors (n = 20) at national level served as subjects in this investigation. Subjects were only allowed to participate in the study if they had previously practiced rapid weight reduction of their own volition more than three times in a season. Their mean period of practicing this sport was 15 years. All participated in nine hours of training per week. For all of them, their technical level ranged between 1st and 4th Dan black belt. All sportsmen fought in a category less than 81 kg. Anti-doping controls required by the French Federation of Judo were regularly carried out. None of these sportsmen was taking any drugs or medication or any supplements. Medical screening indicated that none of the subjects had any endocrine or other medical problems that would confound their participation in the study. All subjects were informed about the possible risks of the investigation before giving their written informed consent to participate, and all procedures were approved by the local Ethical Committee.

Experimental design

The aim of our study was to examine the physiological and psychological effects of a one-day simulated judo competition after a 1-wk weight loss period.

- Subjects were randomly allocated into each of two groups (A, B: n = 10/group). All members of Group A (called diet) were asked to lose ~5% of their body weight through self-determined means during the week before the competition. The self-determined means were at the discretion of each individual; however, post hoc analysis revealed energy and fluid restriction (–33% and –22%, respectively).
- All members of Group B (called control) maintained their body weight. Assessments (weight, performance, psychological test, blood samples) were made during a period of weight maintenance (T_1), after a 7-d food restriction (this food restriction was only carried out by the Group A) on the morning of the competition (T_2), and at 10 min after the end of the simulated competition (T_3).

The period of weight maintenance (T_1) was considered a baseline phase and judo athletes performed their regular regimens of judo and interval, and resistance training. Judo training sessions normally lasted 2 h and consisted of judo specific skills and drills and randori (fighting practice) with varying intensity above and up to 90–95% of $\dot{V}O_{2max}$. Judoka were trained one specific training per day excepted Saturday and Sunday and practiced one conditioning session per week (4 hours of intensive workout, 4 hours of technical workout, and 1 hour of conditioning).

The experimental timeline is presented in Fig. **1**.

At T_2, the sportsmen all came to the gymnastic hall in the morning at 7:30, where they all had the same breakfast after the weigh-in and the blood sampling. For breakfast, they all had

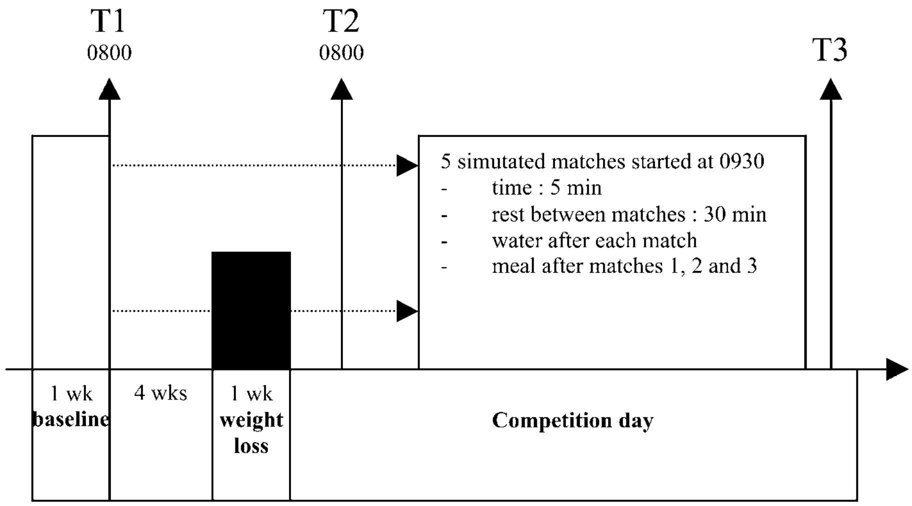

Fig. 1 Experimental timeline. The test battery was performed during a period of weight maintenance (T_1), after a 7-d food restriction (for the Group A) (T_2) the morning of the competition, and at the end of the simulated competition (T_3).

two pieces of bread and a glass of orange juice. We did not evaluate the change in weight gain from weigh-in to the match.

After a 20-min warm-up period followed by 10 min of rest, the subjects then participated in a simulated judo tournament with each subject wrestling for a total of five 5-min bouts, carried out under competition conditions, interspersed with 30-min seated recovery periods. Even if thrown the athletes continued until the end of the fiv-minute period. The first bout took place at 9.30 a.m. To create a demanding competitive environment, opponents with similar skills were matched. Each match was formally refereed and scored. The subjects were allowed to consume fluids and solids between bouts as is the usual practice of judo athletes. The liquids/solids that were consumed included on average 300 ml water and energy nutriments (Punch Power®, France). Energy nutriments included 1400 KJ. The proportion of total calories from carbohydrates, protein, and lipid was 55.9%, 4.9% and 6.7%, respectively. Pulse rate during all the matches was measured using a heart rate monitor (PE4000 Polar Electro, Oy, Finland).

Anthropometric measurements

The weight and height of each subject was measured and the percentage of body fat mass was estimated from four measurements of skinfold thickness according to Durnin et Rahaman [14]. At T_1, T_2, and T_3, body mass was recorded to the nearest 0.1 kg using a portable digital scale with each athlete wearing light clothing and no footwear. Height was measured to the nearest 0.1 cm with an anthropometric plane only at T_1. A Harpenden caliper was used to measure the thicknesses, i.e., biceps, triceps, subscapular, and suprailiac on the right side of the body with the subject in a standing position. All skinfold measurements were collected by one of the authors, an experienced anthropometrist at T_1, T_2, and T_3. Each skinfold was estimated to 0.1 mm.

Dietary intake

Values for nutrient intakes were obtained from a 7-d food record kept during a period of weight maintenance for both groups and after a 7-d food restriction for group A. The diet for food restriction was self-selected. All participants received a detailed verbal explanation and written instructions. Subjects were asked to be as accurate as possible in recording the amount and type of food and fluid consumed. They were asked to record brand names of all commercial and ready-to-eat foods consumed and method of preparation. A list of common household measures, such as cups and tablespoons, and specific information about the quantity in each measurement (grams etc.) was given to each participant. Any questions, ambiguities, or omissions regarding the type and amount of food and beverages consumed were resolved individually with each judo athlete and controlled via direct interviews. A colour photo exhibit [50] of commonly consumed foods and their portion sizes was used during the interview to assist in estimating amounts consumed. Daily energy and nutrient intakes were calculated by a computer program developed by SCDA Nutrisoft (Bilnut.4 software package, France). This diet analysis program accesses French nutrient data base for standard reference [41].

Blood collection and biochemical analysis

Blood samples were drawn from the antecubital vein into plain vacutainer tubes in the morning at rest under fasting conditions at 7.30 a.m. at T_1 and T_2 and 10 min after the end of the tournament (T_3). To minimise discomfort, all subjects were provided with an anaesthetic cream (EMLA, Astra Pharmaceuticals) which was applied over the cubital region 1 h before each sample.

Triglycerides (TG), glucose concentrations, and alkali reserve were analysed by enzymatic techniques in HITACHI 911 (Roche Diagnostics) according to the manufacturer's protocol. The free fatty acids (FFA) were determined by a manual technique using Wako reagents. Measurements of blood glycerol and ammonia were conducted using a test kit (Boehringer Mannheim). The plasma for these measurements was immediately separated after puncture and conserved at – 20 °C.

Uric acid, urea, and creatinine were determined by a protocol edited for ROCHE in HITACHI 911.

All hormonal markers were determined in serum by direct chemiluminescence according to the manufacturer's protocol. Insulin, ACTH, cortisol, and testosterone were analyzed in Immunite 2000, and thyroid hormones concentrations in ACS 180 SE.

Table **1** Anthropometric data for diet (Group A) and control (Group B) groups at T_1 (weight maintenance), the morning of the competition (after a 7-d food restriction for the Group A) (T_2) and at T_3 (at the end of the simulated competition) (Mean ± SD)

	Group A (n = 10)			*Group B (n = 10)*		
Height (cm)	174.8 ± 1.9			176.4 ± 1.1		
Body weight (kg)	T_1	T_2	T_3	T_1	T_2	T_3
	75.9 ± 3.1	72.1 ± 1.4**	74.5 ± 3.4#	73.3 ± 6.3	74.7 ± 6.7	75.1 ± 1.6
BMI (kg/m²)	24.9 ± 0.8	24.1 ± 0.7	24.2 ± 0.9	23.0 ± 1.3	23.6 ± 1.5	23.9 ± 1.1
FFM (kg)	64.5 ± 1.1	62.2 ± 0.6**		61.7 ± 5.3	62.5 ± 5.3	
% body fat	15.8 ± 1.1	15.0 ± 1*		15.5 ± 3.3	14.9 ± 3	

* $p < 0.05$; ** $p < 0.01$ (T_2 vs. T_1); # $p < 0.05$ (T_3 vs. T_2)

Blood values obtained at T_2 and T_3 were corrected by using Van Beaumont formula [52], which includes hematocrit variations at each blood sample.

Psychological measurements

Mood was measured with the Profile of Mood States (POMS) questionnaire which assesses Tension, Depression, Anger, Vigour, Fatigue, and Confusion [34]. The POMS inventory was employed because it as been found to be a valid assessment tool for measuring alteration of mood states among weight class sport athletes [22] as well as to determining acute psychological responses following a single exercise or competition. French validation studies have reported internal consistency (alpha) coefficients for the Profile of Mood States subscales ranging from 0.82 to 0.92 [9]. Subjects completing the POMS are asked to reflect on the states of their emotion over the past week including today. Scores are then obtained for subjects on the states of tension, depression, anger, vigour, fatigue, and confusion. Morgan et al. [35] noted a tendency for those regularly involved in sport and exercise to report scores for Vigour above the 50th percentile of the published norms [34] and to report scores for Tension, Depression, Anger, Fatigue, and Confusion below the 50th percentile. Morgan and his associates referred to this pattern of scores as an iceberg profile and proposed that it reflected mental health. The standard "how are you feeling this week, including today" instructional set was used. The POMS was administered at T_1 and T_2, and T_3.

Physical performance measures

In order to evaluate the performance of each subject, we have chosen specific tests of this sport which seemed to be adequate to represent aspects of physical fitness in judo, in order to assess forearms and hands maximal strength and anaerobic capacity of the upper limbs during 30 s [53]. Indeed, these muscular capacities were needed to grapple and maintain the judo costume and to control the opponent during successive short intensive bouts [44].

Muscular maximal strength measures included left-grip strength (Harpenden dynamometer, British Indicators, Ltd.). The strength score, recorded in kilograms, was the average of two trials. This performance was done at T_1, T_2 (10 min after the weighing), and T_3 (10 min after the end of the simulated competition).

Anaerobic capacity of the upper limbs was determined by using an isometric dynamometer (Globus Ergo Meter®) interfaced to a computer for data analysis and storage. The test consisted of 30-s horizontal isometric rowing: the subjects were seated to the chest on a vertical bench and performed this test with a 90-degree angle between arms and forearms. Thus, this test evaluated the maximal strength on 30-s isometric horizontal rowing (MS IR30). This test was done at T_2 and T_3.

Statistical analyses

Anthropometric data, physical performance and psychological parameters are expressed as a mean and standard deviation. Blood hormones and metabolic values are presented as mean ± SE. Data was analysed using a multivariate analysis of variance (MANOVA) with repeated measures. Where significant main effects were observed, Tukey post hoc procedures were performed to determine pairwise differences. Statistical power was determined to be from 0.80 to 0.85 for the samples sizes used at the 0.05 alpha level. Significance was defined at $p < 0.05$.

The SPSS/PC statistical package was used and the criterion for significance was set at $p < 0.05$.

Results

Values for the anthropometric parameters are shown in Table **1.**

Effect of dietary restriction

The anthropometric parameters at T_1 were not significantly different between the two groups. Group A lost a significant ($p < 0.01$) amount of weight from baseline to postweight loss (T_2) that was equivalent to 5% of their total body weight. Percentage of body fat and fat free mass also declined significantly ($p < 0.05$ and $p < 0.01$, respectively).

There were no differences in body composition parameters for Group B (Control) between T_1 and T_2.

From diet record analysis, the mean energy intake for Group A during weight loss period (T_2) was 7.0 ± 1.2 MJ·d^{-1} (– 33% compared to T_1; T_1 = 11.04 ± 1.9 MJ·d^{-1}). Intakes of protein, fat, and carbohydrate decreased significantly ($p < 0.01$) during this weight loss period. Carbohydrate intake for Group A was

Table **2** Psychological profiles for diet (Group A) and control groups (Group B) (Mean ± SD) during the investigation

	Group A (n = 10)			Group B (n = 10)		
	T_1	T_2	T_3	T_1	T_2	T_3
Tension	34.2 ± 1.1	38.9 ± 1.4*	45.6 ± 3.4#	36.2 ± 1.5	35.9 ± 0.7	39.8 ± 0.5#
Depression	35.3 ± 0.9	36.3 ± 0.5	35.7 ± 0.4	35.9 ± 1.3	38.6 ± 2.4	37.8 ± 1.2
Anger	43.3 ± 2.7	48.5 ± 1.7**	24.2 ± 0.9	45.3 ± 1.6	44.9 ± 3.5	45.7 ± 1.9
Vigour	60.9 ± 1.2	57.4 ± 0.6**	52.7 ± 2.4#	61.4 ± 0.8	60.9 ± 1.0	54.5 ± 3.1#
Fatigue	41.8 ± 0.9	46.8 ± 1.1**	51.3 ± 2.0#	42.5 ± 1.7	44.7 ± 2.4	51.3 ± 3.3#
Confusion	37.2 ± 1.2	41.8 ± 2.3	39.4 ± 2.5	39.6 ± 1.7	39.4 ± 1.9	38.8 ± 1.7

* $p < 0.05$; ** $p < 0.01$ (T_2 vs. T_1); # $p < 0.05$ (T_3 vs. T_2)

187.8 ± 60.5 g. The volume of fluid intake also decreased from 3873.2 ± 692.5 ml at T_1 to 3102 ± 448.3 ml at T_2. Carbohydrate intake for group B was 334.3 g ± 75.9 during this period.

Physical performance

In Group A, weight reduction induced a decrease in left Hand Grip values at T_2 compared to those observed at T_1 (T_1: 53.6 ± 2.7 kg; T_2: 50.4 ± 2.5 kg; $p < 0.01$, – 5 %). No significant change is observed in control group (Group B) between this period (T_1: 52.8 ± 3.1 kg; T_2: 53.9 ± 2.4 kg).

Psychological variables

During the first testing time with the POMS, the "iceberg profile" (high score on Vigour, low scores on Depression, Tension, Fatigue, Confusion, and Anger) was noted for both groups (Table **2**). The POMS inventory at T_2 reflected changes in specific mood states in the weight reduction group (Group A). Tension, Fatigue, and Anger scores increased significantly, while Vigour scores decreased significantly compared to T_1. No significant changes were noted in overall mood for Group B between T_1 and T_2.

Hormonal and chemistry parameters

The results of the blood hormonal and chemistry parameters are shown in Tables **3** and **4**.

The standard laboratory values for all parameters are given.

All hormonal parameters were in the normal range within the study for both groups. There was no significant difference between Group A and B for all the hormonal parameters at T_1. We observed at T_2 for the Group A a significant decrease in testosterone and insulin concentrations ($p < 0.05$), T/C ratio ($p < 0.01$; – 45 %), and T3/T4 ratio ($p < 0.05$; – 7 %) compared to those observed at T_1. ACTH, cortisol, and DHEA-S were significantly higher at T_2 ($p < 0.05$). We also noted a significant decrease ($p < 0.01$) in DHEA-S/C ratio.

Concerning the blood chemistry tests, all parameters did not differ from the normal range at T_1 and T_2 for both groups. After the competition, concentrations of ammonia and uric acid were higher than the normal range.

Dietary restriction induced a significant increase in blood urea, uric acid, glycerol, and Free Fat Acid (FFA) concentrations ($p < 0.05$) (Table **4**; Group A). In the same time, blood concentrations of triglycerides decreased significantly ($p < 0.05$).

No significant changes were noted in all hormonal and chemistry parameters for Group B between T_1 and T_2.

Effect of the judo tournament

Each subject participated in a simulated judo tournament wrestling for a total of five 5-min bouts, carried out under competition conditions, interspersed with 30-min seated recovery periods. Participants were allowed to consume fluids and solids between bouts as is the usual practice of judo athletes. No fluid other than water was available.

At the end of the competition, Group A had a significant increase in body mass ($p < 0.05$: T_3 versus T_2), whereas no significant difference in body mass was seen in Group B (Table **1**).

Physical performance

Compared with T_2, physical performance decreased in Group A (T_2: 50.4 ± 2.5 kg; T_3: 47.4 ± 2.9 kg; $p < 0.01$; – 7 %).

Grip strength values reported at T_3 in Group B were significantly lower than those at baseline testing (T_1; $p < 0.01$) or T_2 ($p < 0.01$; – 8 %) (T_2: 53.9 ± 2.4 kg; T_3: 48.6 ± 1.9 kg).

The same changes were observed concerning the maximal strength on 30-s isometric horizontal rowing.

Psychological variables

Significant decrease in vigour and increase in fatigue and tension scores were observed in both groups at the end of the tournament ($p < 0.05$) compared with T_2.

Hormonal and biochemical parameters

The judo competition induced a significant decrease in testosterone concentrations ($p < 0.05$; – 22 % and – 24 % in Group A and B, respectively) and a significant increase in insulin concentrations ($p < 0.01$) in both groups (T_3 vs T_2) (+ 90 % and + 80 % in Group A and B, respectively. T/C ratio also decreased significantly in both groups (– 25 % and – 40 % in Group A and B, respectively).

Table 3 Mean values (SE) for hormonal parameters for diet (Group A) and control groups (Group B) at T_1 (weight maintenance), the morning of the competition (after a 7-d food restriction for the Group A) (T_2) and at T_3 (at the end of the simulated competition)

	T_1	T_2	T_3	Standards
ACTH (pg·ml⁻¹)				
– *Group A*	21.4 ± 3.35	30.18 ± 4.2*	31.63 ± 7.24	< 46
– *Group B*	27.75 ± 3.53	27.22 ± 2.5	22.49 ± 2.72	
Cortisol (mmol·l⁻¹)				
– *Group A*	438.3 ± 33.69	545.0 ± 38.9*	505.86 ± 41.87	138 – 690
– *Group B*	496.37 ± 37.96	472.56 ± 19.90	510.11 ± 44.44	
Testosterone (nmol·l⁻¹)				
– *Group A*	18.37 ± 2.10	12.17 ± 0.72*	9.52 ± 0.73#	9.9 – 52.4
– *Group B*	19.89 ± 0.70	18.6 ± 1.09	14.03 ± 1.57#	
Testosterone/cortisol				
– *Group A*	40.07 ± 3.95	25.88 ± 2.13**	19.89 ± 2.90#	
– *Group B*	44.11 ± 3.86	41.48 ± 4.52	22.89 ± 2.22##	
DHEA-S (µmol·l⁻¹)				
– *Group A*	6.1 ± 0.26	6.3 ± 0.3*	6.67 ± 0.30	2.2 – 15.2
– *Group B*	6.55 ± 0.38	7.97 ± 0.59	9.10 ± 0.67	
DHEA-S/C				
– *Group A*	1.43 ± 0.09	1.16 ± 0.08**	1.24 ± 0.09	
– *Group B*	1.4 ± 0.1	1.7 ± 0.1	1.8 ± 0.1	
Insulin (mUI·l⁻¹)				
– *Group A*	7.85 ± 1.05	4.53 ± 0.58*	8.92 ± 1.2##	0.5 – 15
– *Group B*	6.48 ± 0.73	6.44 ± 1.86	11.6 ± 1.52##	
T3/T4				
– *Group A*	0.35 ± 0.01	0.32 ± 0.01*	0.35 ± 0.01#	
– *Group B*	0.35 ± 0.01	0.34 ± 0.01	0.35 ± 0.01	

T_2 vs. T_1; * $p < 0.05$; ** $p < 0.01$; T_3 vs. T_2; # $p < 0.05$; ## $p < 0.01$

The value for the ratio T3/T4 noted at T_3 in Group A was the same as those reported at T_1. In group B, this ratio remained unchanged throughout the study.

For the Group A, the competition did not induce any additional increase in ACTH, cortisol, and DHEA-S concentrations, nor in DHEA-S/C ratio compared with the restriction alone. No significant changes were seen in these parameters in group B compared with T_2.

A significant decrease in alkali reserve (Group A: $p < 0.05$; Group B: $p < 0.01$), FFA ($p < 0.05$ in both groups), and triglycerides concentrations ($p < 0.05$ in both groups) were observed between T_2 and T_3.

A trend to an increase in glycerol concentrations was observed in Group A.

Glycerol concentrations were significantly higher after the competition (T_3 in Group B compared to those noted at T_2 ($p < 0.01$, + 45 %).

The competition also induced a significant increase in ammonia, urea, and uric acid concentrations (Group A: $P < 0.05$; Group B: $p < 0.01$). Glycemia increased significantly in Group A ($p < 0.05$). This parameter tended to increase in Group B.

Discussion

The objective of this investigation was to determine the effects of a rapid weight loss on physical performance, physiological and psychological responses before and after a simulated judo competition.

Two main results emerged from this study:

First, rapid weight loss adversely affects the physiology and psychology of judo athletes and impairs physical performance. Secondly, our data showed that a competition including five 5-min bouts induced the same changes of physiological and psychological variables and performance whatever the dietary intake during the seven days before the competition.

Effect of the dietary restriction

Food records, as used in this study, are considered the standard for dietary assessment and provide a quantitative account of an individual's diet during a specific period. Although the judo athletes in this study were highly motivated, underreporting errors

Table **4** Mean values (SE) for chemistry parameters for diet (Group A) and control groups (Group B) at T_1 (weight maintenance), the morning of the competition (after a 7-d food restriction for the Group A) (T_2) and at T_3 (at the end of the simulated competition)

	T_1	T_2	T_3	*Standards*
Triglycerides ($mmol \cdot l^{-1}$)				
– *Group A*	0.77 ± 0.06	0.58 ± 0.05*	0.54 ± 0.11#	0.5 – 1.6
– *Group B*	0.78 ± 0.07	0.86 ± 0.11	0.26 ± 0.05#	
Free fat acid ($mmol \cdot l^{-1}$)				
– *Group A*	0.33 ± 0.08	0.74 ± 0.80*	0.54 ± 0.11#	0.1 – 0.5
– *Group B*	0.33 ± 0.05	0.40 ± 0.05	0.26 ± 0.05#	
Glycerol ($\mu mol \cdot l^{-1}$)				
– *Group A*	83.00 ± 14.88	144.22 ± 16.34*	194.87 ± 32.00	50 – 200
– *Group B*	83.22 ± 7.04	126.2 ± 14.29	183.50 ± 18.28##	
Ammonia ($\mu mol \cdot l^{-1}$)				
– *Group A*	44.22 ± 7.48	36.56 ± 5.86	84.12 ± 10.65#	10 – 46
– *Group B*	37.59 ± 7.06	26.70 ± 2.24	57.18 ± 6.01##	
Uric acid ($\mu mol \cdot l^{-1}$)				
– *Group A*	346.62 ± 36.78	382.22 ± 33.63*	580.12 ± 46.53#	200 – 360
– *Group B*	365.33 ± 17.28	369.60 ± 20.35	613.00 ± 49.97##	
Urea ($mmol \cdot l^{-1}$)				
– *Group A*	5.70 ± 0.48	6.3 ± 0.4*	7.26 ± 0.63#	3 – 7.5
– *Group B*	5.52 ± 0.33	5.18 ± 0.18	5.88 ± 0.23##	
Glucose ($mmol \cdot l^{-1}$)				
– *Group A*	4.84 ± 0.19	4.92 ± 0.12	5.71 ± 0.33#	4 – 6
– *Group B*	4.96 ± 0.14	5.27 ± 0.10	5.63 ± 0.42	
Alkali reserve ($mmol \cdot l^{-1}$)				
– *Group A*		25.00 ± 0.67	18.56 ± 4.34#	25 – 27
– *Group B*		24.40 ± 0.75	18.65 ± 0.91##	

T_2 vs. T_1; * $p < 0.05$; T_3 vs. T_2; # $p < 0.05$; ## $p < 0.01$

may have occurred. Therefore, it is important to view the report data as the mean intake for these athletes. Baseline energy intake (11.04 ± 1.9 $MJ \cdot d^{-1}$ at T_1) was within the average range for athletes practicing high-intensity weight loss sports but low when compared with 12.5 – 20 $MJ \cdot d^{-1}$ reported for male endurance athletes [17,47]. The average caloric intake during the food restriction period for the Group A was 7.0 ± 1.2 $MJ \cdot d^{-1}$ inducing a decrease in body weight (4.9 ± 0.06%), which was in accordance with other athletes in weight loss sports [16,43]. The loss of body weight represented an average of 3.8 kg in absolute (Table **1**). The deficit in energy intake represented about 4 MJ per day, i.e., 28 MJ for a week. This deficit corresponded to less than 1% of body fat (approximately 600 g of fat) and less than 3.5% of fat free mass (approximately 2.6 kg of fat free mass; Table **1**). Moreover, no difference exists between the body weight reported at T_1 and that noted at T_3. One can then put forward the hypothesis that the main part of the body weight loss observed during the dietary restriction is due to a body water loss. We reported that the proportion of total calories from carbohydrates was low compared to French Recommendations [41] whatever the period of the investigation. Regarding carbohydrates, an intake < 500 $g \cdot d^{-1}$ may be too small to ensure rapid glycogen resynthesis after training sessions [25].

The ability to produce appropriate emotional feeling before major competitions is recognized by coaches and athletes as one of the most important factors contributing to athletic performance. It is proposed through Morgan's Mental Health Model that positive emotional health and successful athletic performance are correlated [15]. In fact, athletes who are less anxious, angry, depressed, confused, and fatigued, and more vigorous will be more successful than those who exhibit the opposite profile, as assessed by the Profile of Mood States. Our results of the mood states showed that both groups were characterised by the "iceberg" profile at T_1 confirming Filaire et al. [17]. This specific and positive profile is identified in sport research as a successful mood profile [44]. However, several studies have provided contrasting views on the predictive effectiveness of mood [3,46] and despite the vast amount of research, findings are unclear. Recent research has suggested that mood is an effective predictor of performance only when certain conditions are met [3]. In fact these authors found that mood was a poor predictor of performance for level of achievement. However, they showed that precompetition mood was an effective predictor of a single performance. Weight loss removed this "iceberg" profile by lowering the positive mood state of vigour and increasing the negative mood states of tension, anger, and fatigue (Table **2**). Our data are in agreement with those of Newton et al. [36] in competitive bodybuilders. However, the effects of energy restriction on mood in the literature are still debatable: energy restriction reportedly may lead to increased fatigue, with higher Profile of Mood States scores for Anger and Tension [56]. However, other reports prove that Tension and Depression are diminished while mood is improved with dieting [10]. The conflicting findings may be attributed to differences in the testing methodological protocol. One can also put forward the hypothesis that the pre competitive status of the athlete could just produce the mood state profile. For example, judo athletes who were assured to perform a good performance were not likely to be overly stressed during competition and as result they should demonstrate positive precompetitive mood states. In contrast, borderline athletes may be more likely to perceive pressure because they were less likely to obtain a good performance.

In this study, performance, as assessed by muscular maximal strength was altered with energy restriction. Studies have used high intensity arm cranking, upper body strength, sprinting, cycle ergometry, and vertical jumping test to measure the effects of rapid weight loss on performance in these activities that are assumed to be representative of wrestling or judo. In particular, grip strength, as we used in our study, is a vital performance capability in the sport of judo as various take-down and defensive counter maneuvers rely on a strong grip. Some studies have reported decreased performance after a rapid weight loss, while another did not demonstrate any impairment of performance after a rapid 5% weight loss [24]. The conflicting findings may be related to differences in the testing protocol [19] and to the dietary intake. In fact, Horswill et al. [24] did not find that performance was impaired after weight loss if a relatively high percentage of energy was consumed from carbohydrates. The low carbohydrate intake for the Group A may be one of the causes of the impaired performance, as suggested by Greenhaff et al. [21]. In fact, these authors hypothesized that a low carbohydrate diet may diminish the buffering capacity of blood. Acidosis from the combination of weight loss and a low carbohydrate intake would decrease the muscle hydrogen ion efflux, which is known to accelerate fatigue during intense muscular contractions. In the present study, energy intake had decreased by 33% mainly from a reduction of carbohydrate diet lower than the French recommendations [41]. Elevated plasma free fatty acids observed at T_2 (Table **4**) and the subsequent inhibition of glycolysis are also a possible explanation for the decrease in performance after a 7-d food restriction [4]. In fact, a decreasing rate of glycolysis linked to elevated free fatty acids would limit the anaerobic metabolism required to sustain the high intensity of arm cranking.

It has also been shown that weight reduction may lead to alterations in lipid profile with a reduction of TG [29], as it is the case in our study (Table **4**). This triglycerides decrease and the increase in FFA and glycerol concentrations may be the consequence of the increased lipolysis in adipose tissue and circulating triglycerides [27] and of hormonal adaptations induced by training, i.e., low testosterone, increase in the sensitivity to cortisol, increase in cortisol secretion, which improves lipid utilisation [8,26]. Moreover, during exercise training combined with food restriction, metabolism is directed towards the energy mobilization from fat and proteins [37]. The significant elevation of urea and uric acid levels observed in our study at T_2 confirms these data and shows an activation of the protein catabolism [43].

The results of the present study also showed that the ratio T3/T4 declined after the dietary restriction (T_2 vs. T_1: $p < 0.05$) in Group A. Reports in the literature indicate that athletes with excessive weight loss may exhibit a "low T3 syndrome" accompanied by other alterations in pituitary function [31]. This reduction may be due to blockade of the transformation of T4 (thyroxine) to T3 (triiothyronine) and by the conversion of T4 to rT3 (reverse T3) and would reflect the reduced activity of the process of deiodination in the peripheral cells [40].

We also noted that restrained eating may be a stressor, which induced elevated levels of ACTH and cortisol (Table **3**). These data are in accordance with the results of Kraemer et al. [30] and Anderson et al. [2]. The low carbohydrate intake may affect the cortisol levels [1]. Meanwhile, for the Group A, DHEA-S significatively increased, but the DHEA-S/Cortisol ratio decreased ($p < 0.01$). Thus, adrenocortical adaptation to dietary intake included an increase in DHEA-S production concurrent with increased cortisol secretion. Insulin secretion is thought to lower serum DHEA-S [38]. In our study, blood insulin levels fell by approximatively 37% in Group A at T_2. Decreased insulin along with increased ACTH would be expected to increase DHEA-S [6]. By contrast, measurements of testosterone showed decreases with dietary and fluid restriction (Table **3**) similar to those reported in several studies [29,47]. Strauss et al. [51] reported significant relationships between testosterone values, weight loss, body fat percentage, and body fat loss. It may be possible that the dehydration-induced weight loss and caloric restriction experienced by the judo athletes in the present study combined with the high-intensity nature of the training judo contributed to the reduced testosterone concentrations.

Effect of the judo competition

To our knowledge, this study is the first to report that a competition including five 5-min bouts induced the same changes of physiological and psychological variables and performance whatever the dietary intake during the seven days before the competition.

We measured a significant decrease in alkali reserve in both groups (– 25% on average) after the competition demonstrating the dramatic anaerobic nature of judo that has been observed in prior studies [13] and the disruption in the acid-base balance in the body with each subsequent match occurs [30]. Such stress has been shown to affect contractile capabilities [24].

Increases in urea, ammoniac, and uric acid (as we noted in our study) are thought to reflect imbalances in protein metabolic homeostasis, an increased protein catabolism that is associated with tissue damage, and fatigue from exercise and a delayed recovery. Moreover, it is well accepted that the rise in ammonia after short-term intensive exercise derives from the first branch of the purine nucleotide cycle catalysed by adenylate deaminase [23]. These reactions take place in all muscle fibres, in relation to the intensity of the metabolic stress and glycogen availability. Sahlin et al. [48] suggested that reductions in muscle glycogen availability impair ATP resynthesis, lead to AMP accumulation, and induce ammonia production. The rise in ammonia levels observed in our study in both groups after the competition may be the consequence of several factors including the activation of type II fibres, peripheral fatigue, and increased activity in the purine nucleotide cycle, as we previously noted [13].

The competition induces no changes in T3/T4 ratio in Group B. On the other hand, we noted a return to basal values of this ratio in Group A (Table **3**) induced by a significant increase in T3 values and a decrease in T4 concentrations. According to Bernet and Wartofsky [5] maximal exercise is associated with a decrease in T4, a rise in T3 without changes in rT3 concentrations. We hypothesized that this effect is due to a re-balancing of the synthesis of T3 which is the most functional thyroid hormone [5]. Moreover, the carbohydrates intake between each fight included a proportion of total calories from 55.9% of carbohydrates, 4.9% of protein, and 6.7% of lipid which also could blunt the drop in T3 concentrations.

In conclusion, our results suggest that the combination of energy restriction and intense exercise training, which causes weight reduction before a competition, adversely affects the physiology and psychology of judo athletes and impairs physical performance before the start of the competition. Our data are the first to demonstrate that a competition including five 5-min bouts induced the same changes of physiological and psychological variables and performance whatever the dietary intake during the seven days before the competition. This similar pattern of responses may be linked to the food containing a large proportion of carbohydrates and fluid intake after each fight. Thus, the consideration of a correct diet schedule (food and fluid intake) during a judo competition must be taken into account.

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