Short-term low-volume high-intensity intermittent training improves judo-specific performance

Authors' Contribution:
A Study Design
B Data Collection
C Statistical Analysis
D Manuscript Preparation
E Funds Collection

Emerson Franchini[1ACDE], Ursula Ferreira Julio[1BCD], Valéria Leme Gonçalves Panissa[1BCD], Fábio Santos Lira[2BD], Marcus Fabio Agostinho[1BD], Braulio Henrique Magnani Branco[1BD]

[1] School of Physical Education and Sport, University of São Paulo (USP), São Paulo, Brazil
[2] Exercise and Immunometabolism Research Group, Department of Physical Education, Paulista State University (UNESP), Presidente Prudente, São Paulo, Brazil

Received: 24 March 2016; **Accepted:** 05 July 2016; **Published online:** 24 August 2016

AoBID: 11028

Abstract

Background & Study Aim: An important aspect concerning the specificity principle is related to the time structure of the sport. The aim of our study was the effects of short-term low-volume high-intensity intermittent training (HIIT) added to traditional judo training on physiological and performance responses to judo-specific tasks.

Material & Methods: Thirty-five judo athletes were randomly allocated to a control group (n = 8) and 3 HIIT groups: (1) lower-body cycle-ergometer (n = 9); (2) upper-body cycle-ergometer (n = 9); (3) *uchi-komi* (technique entrance) (n = 9). All protocols were constituted by 2 blocks of 10 sets of 20 s of all-out effort, with 10 s interval between sets and 5 min between blocks, executed twice per week for 4 weeks. Pre and post-training the athletes performed the Special Judo Fitness Test (SJFT) and a match simulation, with blood lactate, hormones (cortisol, C, and testosterone, T) and muscle damage marker (creatine kinase, CK, lactate dehydrogenase, LDH, aspartate aminotransferase, AST and alanine aminotransferase, ALT) measurements.

Results: There was an increase (p = 0.031) in the number of throws in the SJFT for the upper-body group, while decreasing the HR immediately after the SJFT and the number of sequences in standing position for the lower-body group (p < 0.001 and p = 0.034, respectively), the index in the SJFT for the *uchi-komi* group (p = 0.015) and the CK concentration (p = 0.014) in the match simulation for the upper-body group. T/C ratio increased (p = 0.028) after the match simulation in the post-training.

Conclusion: All training modes improved performance, biochemical and hormonal response to judo-specific performance, but each group adapted in a different way.

Key words: athletes • combat sport • training intensity • training load • uchi-komi

Conflict of interest: All authors declared did not have financial support of any institution

Ethical approval: This study was approved by the local Ethics and Research Committee

Provenance & peer review: Not commissioned; externally peer reviewed

Source of support: This work was supported by the FAPESP (Fundação de Amparo à Pesquisa do Estado de São Paulo) under Grant number 2012/00220-8; Ursula Ferreira Julios was supported by FAPESP (Fundação de Amparo à Pesquisa do Estado de São Paulo) under Grant number 2011/22105-3; Valéria Leme Gonçalves Panissa was supported by FAPESP (Fundação de Amparo à Pesquisa do Estado de São Paulo) under Grant number 2011/22862-9.

Author's address: Emerson Franchini; School of Physical Education and Sport, University of São Paulo; Av. Prof. Mello Morais, 65, Cidade Universitária, São Paulo 05508-030, Brazil; e-mail: efranchini@usp.br

Athletes – in the present text, this term was used to define state or national level judo competitors.

Judo – literally means "the way of gentleness". Nowadays is an Olympic sport involving throwing,grappling, strangles, and elbow-joint lock techniques.

Judo specific tests – refer to the tests that are structurally very similar to the structure of judo actions.

Martial arts – systems of codified practices and traditions of combat, initially created for warrior purposes,and nowadays practiced for a variety of reasons, including self-defense, competition,physical conditioning etc.

High-intensity intermittent training – refers to the interval training protocols used to improve athletic or physical performance. In the context of the present study the high-intensity intermittent exercises used followed the judo-specific time structure.

Training intensity – the effort of training. A number of methods are used to establish training intensities which give maximum benefits. These include the lactic acid method, minute ventilation method, and target heart-rate [41].

Introduction

Training prescription follows some basic principles to improve athletes' physical conditioning and competitive performance [1]. One of the most important training principles is the specificity of adaptation, which is defined as "the method whereby an athlete is trained in a specific manner to produce a specific adaptation or training response" [2]. Thus, the type of stimulus placed on the athlete dictates the adaptation that will occur [2].

An important aspect concerning the specificity principle is related to the time structure of the sport. Time-motion analysis were conducted to identify precisely what is performed during competition to help coaches to replicate this temporal structure during training sessions [3]. Combat sports are considered high-intensity intermittent sports, and recent studies described the time structure of judo matches [4-6]. Typically, judo matches are composed of ten to twelve 20 s action sequences interspersed by 10 s pauses [5].

In the last two decades high-intensity intermittent exercise has become recommended worldwide for different populations searching for improvement in physical fitness and for athletic groups looking for both aerobic and anaerobic fitness improvement in short periods of time [7]. In combat sports, specific high-intensity intermittent exercise protocols have been investigated [8, 9], but few longitudinal studies were conducted with athletes from combat sports [10-13], despite the intermittent nature of these sports (these and further remarks concern data from the scientific literature, to which we have limited access due to language barriers – see Barczyński et al. [14] and editorial note in article Vacher et al. [15]). Moreover, from all the investigations about high-intensity intermittent training (HIIT) involving athletes from combat sports, none included a sport-specific protocol, i.e., the studies investigated only running as an exercise mode. Although judo athletes frequently engage in non-specific training activities [16], it would be important to verify if a judo-specific high-intensity intermittent training protocol would result in better transference for judo-specific performance compared to more general approaches.

In fact, longitudinal studies investigating the adaptation of combat sport athletes to different HIIT protocols have also focused on non-specific indicators, such as VO_{2max}, time limit, performance in four sequential Wingate tests, performance in supramaximal tests at fixed intensity (e.g., 120% vVO_{2max}) and maximal accumulated oxygen deficit during running [10-12]. Thus, the type of performance tests used to verify the performance change are not sport-specific and the transference to actual combat performance may be questioned.

Only Bonato et al. [13] used a judo-specific test (the Special Judo Fitness Test, SJFT) to verify the effects of an aerobic training program (consisting of 2 sessions per week of 30 min continuous running at 60% of maximum aerobic speed – MAS – and one session per week of HIIT consisting of 15 x 1 min at 90% MAS with 1 min intervals of active recovery at 60% of MAS) on performance. The authors reported a 12% improvement in the SJFT index after 12 weeks of such a program. However, it is important to note that the interval training program was submaximal.

Another important characteristic of judo combat is the very high demand placed upon the upper-body due to the constant pushing and pulling actions executed during the grip dispute and technique entrance, while the lower-body segments perform low-intensity actions during feints and approximations interspersed by high-intensity explosive actions during technique entrance [9]. Thus, judo athletes frequently perform high-intensity training for both upper- and lower-body segments [16]. However, little is known about the effects of different modes of HIIT on judo-specific performance and on the physiological response to these tests.

The aim of our study was the effects of short-term low-volume high-intensity intermittent training added to traditional judo training on physiological and performance responses to judo-specific tasks.

The hypothesis of the present study was that judo athletes submitted to the more specific protocol would present better transference to judo-specific performance tests, while groups submitted to general stimulus would present smaller improvement in those tests.

Material and methods

Design

This study adopted an experimental design. Three groups of judo athletes were randomly formed and submitted to 4 week HIIT programs directed to the lower-body, upper-body or throwing technique entrance (*uchi-komi*) added to the regular judo training, while the fourth group (control) performed only the regular judo training. After familiarization with all test procedures, athletes were submitted to the SJFT and to a judo match simulation.

The tests were conducted on the same day, one week before the training protocol started and one week after the ending of the 4 week training. Eighty minute intervals were given between the SJFT and the match simulation. The same test sequence was adopted in the post-test, at the same time of day.

Participants

Thiryt-five male judo athletes were recruited to take part in the present study after giving their signed consent, as well as that of their guardians for the three athletes aged 17 (who turned 18 years old the year the project was conducted). Athletes were from eight different judo clubs and competed with each other at the state level. All procedures were approved by the Ethics and Research Committee.

To take part in this study the athletes were required to present the following characteristics: (1) to have taken part in official judo competitions during the current year; (2) to be training at least four times per week; (3) to be aged equal to or higher than 17 years old and less than 35 years old; (4) to be competing in the under 100 kg categories; (5) not to be involved with any process of weight loss; (6) not involved with any supplementation or medical treatment. At the time of the experiment athletes were engaged in four 1.5 to 2 h judo sessions per week and in three strength training sessions per week. Groups did not differ ($p > 0.05$) regarding age, body mass, height and time of judo practice, respectively: **lower-body** ($n = 9$) 22.3±5.2 years old, 76.9 ±10.9 kg, 173.5 ±10.9 cm and 12 ±7 years of practice; **upper-body** ($n = 9$) 23.6 ±6.7 years old, 84.2 ±13.4 kg, 174.0 ±5.7 cm, and 15 ±7 years of practice; *uchi-komi* ($n = 9$) 23.4 ±4.2 years old, 78.1 ±13.4 kg, 175.4 ±7.3 cm and 12 ±7 years of practice; **control group** ($n = 8$) 26.4 ±7.0 years old, 80.2 ±10.3 kg, 175.0 ±7.0 cm, 18 ±7 years of practice.

Training protocols

All experimental and control group performed the same judo training sessions. As in the studies of Ravier et al. [10] with karate athletes and Farzad et al. [11] with wrestlers, the experimental groups were submitted to complementary HIIT twice a week. The lower- and upper-body groups performed a 5 min warm-up at 40% of maximal aerobic power (MAP). For the lower-body group the warm-up was conducted at 70 rpm, while for the upper-body group cadence was set at 90 rpm, each on a specific ergometer. The warm-up of the *uchi-komi* group was 5 min in duration, with movements and entrances of the techniques without throwing the other athlete, who had a similar body mass to the executant (difference set at ± 10% of body mass). After the warm-up the athletes rested 3 min before starting the proposed protocol. The training session was a total of 22 min 40 s, considering the 5 min warm-up, 3 min rest after warm-up, one block of 4 min 50 s of high-intensity intermittent exercise (ten times 20 s effort followed by a 10 s pause), 5 min recovery and the 2nd block of high-intensity intermittent workout.

The only difference in the groups undergoing additional HIIT training was the way the high-intensity intermittent exercise was conducted: (1) the lower-body group performed the HIIT using a lower-body cycle-ergometer. Each effort was an all-out bout using 4.5% of body mass as resistance; (2) the upper-body group underwent exactly the same protocol as used by the lower-body group, except that the ergometer used was an upper-body cycle-ergometer and the load used was 3% of body mass; (3) the specific group was submitted to *uchi-komi* (technique entrance) with projection at the end of each series.

Similar to the other groups, the athletes in this group were also asked to perform each set in an all-out mode. The technique entrance was conducted on the tatami, and athletes were asked to perform either *te-waza* (arm techniques, such as *morote-seoi-nage, ippon seoi-nage*) or *koshi-waza* (hip techniques, such as *o-goshi, harai-goshi* and *koshi-guruma*). During the execution of *uchi-komi*, the athletes were also requested to execute the pulling action and the technique execution in its complete form and throw their partner at the end of each 20 s period.

The choice of this temporal structure was due to the following factors: (1) judo fights have an average duration of 3 min, with actions performed in about 10 sequences lasting around 20 s, with 10 s interval between them [4]; (2) these protocols can be executed in less than 15 min, including interval periods of rest between sets and between blocks of exercise; (3) in each session, the total exercise time does not exceed 7 min, resulting in only a small addition to the total weekly training volume.

The mean training load for the 8 HIIT sessions, assessed via the method proposed by Foster et al. [17], did not differ ($p>0.05$) between the experimental groups: lower-body group = 171.7 ± 51.5 a.u.; upper-body training group = 168.6 ± 55.8 a.u.; *uchi-komi* training group = 190.8 ± 45.0 a.u.

Special Judo Fitness Test

This test was developed by Sterkowicz [18]. Briefly, this test is divided into three periods (A = 15 s; B and C = 30 s) with 10 s intervals between them. Each partner was positioned 6 m apart and the athlete being tested was required to run to each partner and then throw them as many times as possible using the *ippon-seoi-nage* technique. Both partners had a similar height and body mass as the athlete performing the test. Just after and 1 min after the test, heart rate was measured by a Polar T-31 device (Polar, Finland). The throws were summed and the following index was calculated:

$$Index\ (beats.min^{-1}.throw^{-1}) = \frac{final\ HR\ (beats.min^{-1}) + HR\ 1\,\text{min}\ after\ the\ test\ (beats.min^{-1})}{\text{number of throws}}$$

The ICC for the SJFT variables in our laboratory, using a similar sample, was as follows: throws (0.73), heart rate (HR) after the test (0.93), HR 1 min after the test (0.89), and index (0.89) [19].

Blood samples (25 μl) from the ear lobe were taken before, 1-, 3- and 5 min after the SJFT to determine blood lactate concentration using an automated device (YSI 1500, Yellow Springs, OH, USA). The highest value measured after the SJFT was used as a peak blood lactate, and delta of lactate was calculated (peak lactate concentration after the test minus the lactate concentration at rest).

Judo match simulation and technical-tactical analysis

Each athlete performed one 5 min match simulation. Opponents were from the same weight category and technical level and were not involved in any other physical exertion during the experimental conditions. Combat was mediated according to official rules.

All matches were video-recorded (Sony DCR-DVD508) in order to provide information on technical actions and time-motion analysis. Match analysis followed the procedures validated by Miarka et al. [20], using the FRAMI software, to determine the following time structure and technical action variables: (a) time structure: Time-motion measures were composed of combat time, standing combat time, preparation time without contact, gripping time, groundwork combat time and pause time. The frequency of each time-motion indicator was collected per match and expressed by s of fighting time and per sequence (defined as the time between *hajime* – beginning command – and *matte* – stop command), following preceding recommendations [4, 6]; (b) technical actions – all techniques were classified and accounted following the Kodokan technical classification, as suggested by previous studies [4, 6]: *ashi-waza* – leg-technique; *te-waza* – arm technique; *koshi-waza* – hip technique; *sutemi-waza* – sacrifice technique; *kansetsu-waza* – elbow joint-lock technique; *shime-waza* – strangle technique; *osae-waza* – immobilization technique.

During the match simulation the following variables were measured: (a) rating of perceived exertion – registered immediately after the match using the Borg 6-20 scale [21]; (b) blood lactate 25 μl blood ear samples were taken before 1-, 3- and 5 min after the match (blood lactate was measured by using an automated device (YSI 1500, Yellow Springs, OH, USA). The highest value measured after the match was used as the peak blood lactate concentration, and delta of lactate was calculated (peak lactate concentration after the test minus the lactate concentration at rest); (c) heart rate (HR) – measured via a HR monitor (Polar T-31, Polar, Finland).

Venous blood sampling and analyses

Venous blood samples were collected by venous puncture from an antecubital vein (15 mL) pre- and post-training period before and after the lower and upper-body high-intensity intermittent tests. Athletes always performed the tests in the same schedule (afternoon and evening). They reported an adequate hydration status and sleep before the day of each testing protocol. Blood samples were collected at rest in a lying position and room temperature (~20° C) on all days for all athletes to eliminate fluctuations in circulating analyte concentration because of circadian rhythm.

The blood samples (15 mL) were immediately allocated into two 5 mL vacutainer tubes (Becton Dickinson, BD, Juiz de Fora, MG, Brazil) containing EDTA for plasma separation and into one 5 mL dry vacutainer tube for serum separation. The tubes were centrifuged at 3,500 g for 12 min at 4° C, and plasma and serum samples were stored at –80° C until analysis. To eliminate inter-assay variance, all samples were analysed in identical runs, resulting in an intra-assay variance of < 5%. Testosterone and cortisol were assessed using ELISA commercial kits (Monobind Inc. 100 North Point Drive, Lake Forest, CA 92630 USA). Creatine kinase (CK) lactate dehydrogenase (LDH), aspartate aminotransferase (AST), and alanine aminotransferase (ALT) were assessed using commercial kits (Labtest®, São Paulo, Brazil). The testosterone and cortisol levels were assessed using plasma, and CK, LDH, AST and ALT levels were assessed using serum. As there was evidence [10, 11] that no change would ocurr in the control group, the venous blood samples were not taken and, thus, the muscle damage markers and hormonal responses were not measured for this group.

Statistics analyses

All analyses were performed using the Statistica software (version 12). Data was reported as means and standard deviation (±). A Mauchly's test of sphericity was used to test this assumption, and a Greenhouse-Geisser correction was applied when necessary. A two-way (group and period of training) and three-way (group, period of training and moment of measurement) analysis of variance with repeated measures were applied to compare performance in the variables derived from the physical test and match simulation. Bonferroni's multiple comparisons test was used when a significant difference was found in the analysis of variance. When only the period of training factor was found, paired Student t tests was conducted for each group to verify the effect of each training protocol. The 95% confidence intervals (CIs) and effect sizes using Cohen'd were calculated and classified as proposed by Rhea [22] following the scale for highly trained individuals for interpretation: < 0.25 [trivial]; 0.25 to < 0.5 [small]; 0.5 to < 1.00 [moderate]; > 1.0 [large]. Statistical significance was set at p < 0.05.

Results

Judo-specific tests

Table 1 presents the judo-specific tests' performances and delta of lactate in the special judo fitness test.

For the total number of throws in the SJFT there was a period of training and group interaction effect, with higher values post- compared to pre-training for the upper-body group (p = 0.031, CI —0.84 to —2.93, d = 1.00).

For HR imediatelly after the SJFT, there was a period of training effect, with higher values pre- than post-training (p = 0.034, CI 0.32 to

Table 1. Athletes' performance in the judo-specific tests pre- and post- three different high-intensity training protocols (values are mean ± standard deviation).

Variable	Lower-body training group (n = 9)		Upper-body training group (n = 9)		Uchi-komi training group (n = 9)		Control group (n = 8)	
	Pre	Post	Pre	Post	Pre	Post	Pre	Post
Number of throws in the SJFT (rep)	27±3	27±3	25±2*	27±2	25±3	26±2	25±3	24±2
HR after the SJFT (bpm)	**181±9***	174±9	175±11	177±13	180±8	175±9	176±2	173±11
HR 1 min after the SJFT (bpm)	152±10	150±13	142±22	144±13	152±14	140±12	146±16	150±11
SJFT index (beats.min^{-1}.throw^{-1})	12.68±1.99	12.04±1.75	12.84±2.55	12.08±1.35	**12.84±1.47***	12.07±1.36	13.11±1.49	13.80±1.14
Delta blood lactate SJFT (mmol.L^{-1})#	**8.60±0.79**	**7.24±2.40**	**9.62±2.20**	**9.73±2.26**	**10.27±1.47**	**10.42±1.61**	**8.23±2.11**	**7.51±1.46**

Note: **SJFT** Special Judo Fitness Test; **HR** heart rate; * different from post-training (p < 0.05); # lower-body training group different from control group (p < 0.05).

Table 2. Time structure of judo combat pre- and post- three different high-intensity intermittent training protocols (values are mean ± standard deviation).

Variable	Lower-body training group (n = 9)		Upper-body training group (n = 9)		Uchi-komi training group (n = 9)		Control group (n = 8)	
	Pre	Post	Pre	Post	Pre	Post	Pre	Post
Standing sequences (n)	**13±2***	10±3	11±3	11±3	10±2	10±2	9±2	9±1
Groundwork sequences (n)	4±3	3±3	5±3	3±2	6±1	5±2	6±2	6±3
Preparation time per sequence (s)	7±8	5±2	5±2	6±2	4±1	5±2	7±2	7±2
Gripping time per sequence (s)	15±5	16±6	16±6	17±6	19±4	20±4	18±5	17±6
Standing combat time per sequence (s)	24±7	26±4	23±5	26±7	25±3	26±5	27±4	26±5
Groundwork time per sequence (s)	6±4	9±6	8±5	7±6	9±6	7±4	11±4	10±5
Pause time per sequence (s)	11±10	9±2	7±2	8±2	8±2	8±2	8±1	8±1

Note: **Sequence** time between beginning (*hajime*) and interruption (*mate*) commands; * different from post-training ($p < 0.05$).

Table 3. Type and quantity of techniques used during the judo combat pre- and post- three different high-intensity intermittent training protocols (values are mean ± standard deviation).

Variable	Lower-body training group (n = 9)		Upper-body training group (n = 9)		Uchi-komi training group (n = 9)		Control group (n = 8)	
	Pre	Post	Pre	Post	Pre	Post	Pre	Post
Attacks performed in standing position (n)	10±6	10±5	12±3	13±4	10±5	11±4	7±3	7±2
Different attacks used (n)	8±3	7±3	5±3	6±1	7±3	7±3	5±2	5±2
Leg techniques per match (n)	6±4	6±4	7±4	9±4	5±4	6±4	3±3	3±2
Hip techniques per match (n)	1±2	1±1	0±1	1±1	1±1	1±1	1±1	1±2
Arm techniques per match (n)	1±1	2±2	3±3	3±3	3±3	3±2	2±1	2±1
Sacrifice techniques per match (n)	2±2	1±1	1±1	0±1	2±2	2±1	1±1	1±1
Immobilizations per match (n)	0±1	1±1	0±1	0±1	0±1	0±0	1±1	1±1
Strangles per match (n)	0±0	0±0	0±0	0±0	0±0	0±0	0±0	0±0
Joint-locks per match (n)	0±0	0±0	0±0	0±0	0±0	0±0	0±0	0±0

6.82, d = 0.34). Isolated t tests for each group revealed lower values in post- than pre-training only in the lower-body group (p = 0.006, CI 2.84 to 12.04, d = 0.87).

For the SJFT index, there was a period of training effect, with higher values pre- than post-training (p = 0.029, CI 0.10 to 0.93, d = 0.27). Isolated t tests indicated lower values post- than pre-training in the *uchi-komi* group only (p = 0.015, CI 0.29 to 1.93, d = 0.84).

For delta of lactate, only a tendency to lower values in the lower-body group compared to *uchi-komi* group (p = 0.051, CI 0.49 to 5.36, d = 1.35).

Time-motion and judo match analysis

Table 2 presents the time-motion analysis of the judo matches before and after three different high-intensity intermittent training protocols.

For the number of standing sequences there was a training period and group interaction effect, but only in lower-body group the values in post- were lower compared to pre-training (p = 0.034, CI 0.19 to 1.67, d = 1.17). For the other variables related to time-motion there were no effects (p > 0.05).

Table 3 presents the technical analysis of the judo matches before and after three different high-intensity intermittent training protocols.

Table 4. Rating of perceived exertion, delta blood lactate, and heart rate responses to the judo matches pre- and post- three different high-intensity intermittent training (values are mean ± standard deviation).

Variable	Lower-body training group (n = 9)		Upper-body training group (n = 9)		Uchi-komi training group (n = 9)		Control group (n = 8)	
	Pre	Post	Pre	Post	Pre	Post	Pre	Post
Rating of perceived exertion (a.u.)	15±2	16±2	16±2	16±3	16±2	15±2	15±3	16±3
Delta blood lactate (mmol.L^{-1})	6.20±2.50	5.70±2.00	5.70±1.80	5.50±2.70	8.10±2.30	8.60±3.50	6.70±2.10	7.70±2.00
Heart rate (bpm)	169±11	156±23	175±5	169±13	170±13	172±11	166±11	174±12

Table 5. Muscle damage markers and hormonal responses to the judo matches pre- and post- three different high-intensity intermittent training (values are mean ± standard deviation).

Indicator	Circumstances	Lower-body training group (n = 9)		Upper-body training group (n = 9)		Uchi-komi training group (n = 9)	
		Pre	Post	Pre	Post	Pre	Post
CK (U.L^{-1})$^{\#}$	**before the match***	**303.3±262.1**	**303.0±198.2**	**505.6±210.2**	**219.8±105.8**	**606.5±654.4**	**210.6±98.6**
	after the match	370.6±256.8	368.3±229.8	592.4±248.9	291.8±170.5	763.7±780.9	238.7±103.2
LDH (U.L^{-1})	before the match	73.1±25.7	74.1±31.4	71.1±23.4	76.6±19.8	87.0±9.8	91.2±13.3
	after the match*	**81.8±27.3**	**89.1±11.4**	**83.6±14.5**	**96.8±32.0**	**102.4±17.2**	**115.2±12.2**
ST (U.L^{-1})	before the match	5.0±0.9	4.7±1.8	4.6±2.8	5.8±2.1	5.2±1.7	5.9±2.7
	after the match*	**5.3±0.9**	**6.4±1.9**	**6.2±3.2**	**6.4±2.6**	**6.2±1.9**	**6.5±1.9**
ALT (U.L^{-1})	before the match	2.95±1.19	3.40±0.78	4.11±2.17	5.29±2.84	4.17±1.73	4.64±1.78
	after the match*	**4.57±0.67**	**4.92±1.34**	**5.58±3.27**	**6.48±3.13**	**5.04±1.11**	**6.46±1.68**
Cortisol (ng.mL^{-1})	before the match	12.22±6.20	11.68±6.42	11.89±6.70	9.26±5.01	11.25±6.79	7.09±4.39
	after the match	12.96±5.62	13.62±7.64	10.83±6.45	9.64±6.74	12.13±6.47	9.08±7.08
Testosterone (ng.mL^{-1})	**before the match***	**4.53±1.42**	**4.18±1.47**	**4.55±1.54**	**5.07±0.15**	**4.93±0.27**	**4.53±1.22**
	after the match	4.56±1.41	4.62±1.18	4.61±1.56	5.20±0.15	5.09±0.16	5.09±0.25
T/C (ng.mL^{-1})	before the match	0.56±0.48	0.48±0.31	0.63±0.54	0.68±0.31	0.69±0.53	0.79±0.34
	after the match§	**0.48±0.36**	**0.49±0.32**	**0.68±0.50**	**0.86±0.60**	**0.63±0.49**	**1.00±0.71**

Note: **CK** creatine kinase; **LDH** lactate dehydrogenase; **AST** aspartato transaminase; **ALT** alanine transaminase; *different from after the match ($p < 0.05$); $^{\#}$ pre-different from post-training in upper-body training group ($p < 0.05$); § after the match pre-training different from after the match post-training ($p < 0.05$).

For the technical variables, there were no effects ($p > 0.05$). For the delta blood lactate, HR, and RPE in response to the judo match there were no effects of group, training period or interaction ($p > 0.05$, Table 4).

Table 5 presents the muscle damage markers and hormonal responses to the judo matches before and after three different HIIT protocols.

For the creatine kinase concentration response to the judo match an effect of moment of measurement was observed, with higher values after combat compared to before ($p < 0.001$, CI –106.07 to –55.52, d = 0.24). An effect of training period was detected, with lower values post-training compared to pre-training ($p = 0.029$, CI 21.55 to 476.91, d = 0.72). When each group was analysed isolated this difference was confirmed only for the upper-body training group ($p = 0.014$, CI 114.41 to 487.16, d = 1.39).

For LDH ($p < 0.001$, CI –36.60 to –9.01, d = 0.63), AST ($p < 0.001$, CI –1.36 to –0.66, d = 0.52) and ALT ($p < 0.001$, CI –1.73 to –0.92, d = 0.67) only an effect of moment was found, with higher values after compared to before the match simulation. For cortisol response to the judo match simulation there were no effects ($p > 0.05$) of group, moment of measurement, training period or interaction.

Testosterone concentration response to the judo match simulation was affected only by moment of measurement, with higher values after the match compared to before the match simulation (p = 0.010, CI –0.36 to –0.03, d = 0.196). For the testosterone-cortisol ratio response to the match a training period and moment of measurement interaction was detected. Values after the match at pre-training were lower than after the match at post-training (p = 0.028, CI –0.32 to –0.02, d = 0.334).

Discussion

The main findings of the present study were that the addition of a short-term, low-volume, HIIT program to the typical judo training program increased the number of throws in the SJFT for the upper-body training group, while decreasing the HR immediately after the SJFT and the number of sequences in standing position for the lower-body training group, the index in the SJFT for the *uchi-komi* training group, and the CK concentration the match simulation for the upper-body training group. Moreover, the T/C ratio increased after the match simulation in the post-training period. LDH, AST and ALT and testosterone concentrations were increased only by the execution of the match simulation, with no differences between groups or training periods. Additionally, no changes in delta blood lactate in the SJFT and match simulation, HR and RPE in response to match simulation. Thus, the hypothesis that judo athletes submitted to the more specific protocol would present better transference to judo-specific performance tests was not confirmed, as all training modes were able to improve performance, biochemical and hormonal response to judo-specific performance.

Both aerobic and anaerobic energy systems contributed to the SJFT performance [23] and HIIT has been reported to improve both aerobic and anaerobic fitness [7]. Thus, it is probable that the improvement in energy release through these pathways have contributed to an increased number of throws in the SJFT for the upper-body training group, decreased HR immediately the SJFT for the lower-body training group and improved index for the *uchi-komi* training group. These results suggest that each group adapted in a different way to the SJFT due to the different HIIT protocols. Furthermore, although the SJFT includes displacements using running as exercise mode, the *ippon-seoi-nage* is classified as an arm technique [9] and a higher transference may have occurred for the upper-body training group.

The decreased HR immediately the SJFT for the lower-body training group seems to indicated that the adaptations for this groups were mainly related to an improved aerobic fitness, which can be a consequence of the higher muscle mass involvement in this exercise mode, resulting in lower cardiovascular demand during the test execution. The *uchi-komi* training group had the most desirable improvement in this test, as a lower index is considered a mixture of aerobic and anaerobic improvements [24], and was probably generated due to both high muscle mass engagement in the technique entrance and to a positive transference of the technique execution to the *ippon-seoi-nage* performance during the test. A recent study [25] demonstrated that both undulating and linear strength 8 week training programs were able to increase the numbers of throws in the B and C sets of the SJFT and decreased the SJFT index without changing the HR response to this test. These results suggest that HIIT should be applied when SJFT aerobic-related adaptation is desired, while the SJFT anaerobic-related variables can be improved using either strength training or HIIT.

The lower-body HIIT protocol used in the present study decreased standing combat time per sequence during the match simulation. Most of the combat time in judo is spent in the standing position [4], more scores are obtained in this combat phase and judo matches are considered to have a high physiological demand [5]. Thus, the decrease in the standing combat time can be associated to the improved aerobic and anaerobic fitness generated by the HIIT protocols, which probably allowed the athletes to peform techniques in higher intensity despite spending less time in this preferrable condition where more scores are achieved. No change was observed concerning technical actions. Another study [25] investigating 8 weeks of linear and undulating strength training protocols also did not result in changes in technical actions during a simulated combat, despite changes in strength-related and in the SJFT performances. Thus, it seems that changes in physical fitness generated by short-term training protocols (4 to 8 weeks) do not affect technical-tactical actions during simulated judo combats.

Increased values of blood lactate were observed both in the SJFT and in the match simulation. Blood lactate is a common biochemical marker used to infer glycolytic activation during judo combat and a recent review [5] reported similar values as found in the present study. Farzad et al. [11] also did not find any changes in peak blood lactate after a high-intensity intermittent test (four Wingate bouts) after a 4 week HIIT protocol in wrestlers. Conversely, Ravier et al. [10] reported increased blood lactate after a supramaximal test to determine MAOD in karate athletes submitted to 7 week HIIT protocols. A possible explanation for this difference can be associated to the training period applied. Studies reporting higher blood lactate after supramaximal tests following HIIT protocols were typically longer than 6 weeks [26]. RPE, as expected, increased when the match simulation was conducted, but no change was found with HIIT protocols, probably because the athletes regulated themselves to perform a similar effort during the match, which was elevated after the match both pre- and post-training.

CK, LDH, AST and ALT increased after match simulations. Recent studies using grappling combat sports match simulations (e.g., judo and jiu-jitsu) also reported increased values post- compared to pre-match [27-31], although in some of these studies the increased concentration was significant only after 2 or 3 matches [30, 31]. Among the muscle damage markers used in the present study, only the CK response to the match simulation was decreased after the HIIT and only for the upper-body training group, which can be a consequence of the lower total muscle mass involved in this protocol compared to the others.

When HIIT studies using combat sports athletes are considered, only Farzad et al. [11] measured CK after a 4 week training protocol in wrestlers and observed increased values after the training period. However, as wrestlers were submitted to HIIT using running as an exercise mode, these athletes were submitted to a higher eccentric overload than the judo athletes from the present study, who executed 2 cycle-ergometer-type exercises and *uchi-komi* protocols. The cycle-ergometer protocols have minimal eccentric actions, while the *uchi-komi* is a very common judo exercise to which judo athletes are adapted. Taken together, these aspects may explain the difference observed between our study (mantainance of CK concentrations for the lower-body and *uchi-komi* training groups and decreased CK values for the upper-body training group) and the results reported by Farzad et al. [11]. No HIIT studies using combat sport athletes measured other muscle injury markers. In the present study, no evidence of changes in LDH, AST and ALT in response to the match simulation were found, suggesting that the HIIT protocols did not induce extra muscle damage.

Cortisol was not changed in the match simulation, while testosterone increased in response to match simulation execution. However, no training period or group effects were found for these variables. The T/C ratio increased in response to the match simulation, suggesting that this condition induced a more anabolic state in these judo athletes. The increase in T to the match and T/C ratio in response to the match simulation can be explained by a behavioural adaptation to the confrontation and by the high-intensity generated by the combat, as observed in studies investigating the hormonal response to match simulation [32, 33] and *randori* [34]. Additionally, a testosterone increase was reported to be positively correlated to offensive actions (e.g., grip disputes and attacks) during the judo match simulation [32], and to the motivation to win the match [33].

Accordingly, there was an increase in the T/C response to the match simulation post-training compared to pre-training, suggesting that the HIIT protocols induced a more anabolic response to the judo-specific action. Only one study investigated the T/C ratio response to HIIT in grappling combat sport athletes [11]. Wrestlers submitted to a 4 week HIIT presented a significant increase in resting T/C ratio post-training compared to pre-training [11], but no measurement was conducted in response to a wrestling-specific test or match simulation.

Conclusions

In conclusion, short-term, low-volume HIIT added to regular judo training was able to increase the number of throws in the SJFT for the upper-body training group, while decreasing the HR immediately after the SJFT and the number of sequences in standing position for the lower-body training group, the index in the SJFT for the *uchi-komi* training group and the CK concentration in the match simulation for the upper-body training group. Moreover, the T/C ratio increased after the match simulation in the post-training period. Thus, all training modes improved performance, biochemical and hormonal response to judo-specific performance, but each group adapted in a different way.

Highlights

High-intensity intermittent training (HIIT) was able to improve performance in SJFT for upper, lower-body and *uchi-komi* groups. HIIT was able to decrease number of sequences in standing position for the lower-body training group. HIIT was able to decrease CK in a match simulation for the upper-body group. HIIT increased T/C in all training groups in a match simulation.

References

1. Issurin VB. New horizons for the methodology and physiology of training periodization. Sports Med 2010; 40: 189-206
2. Baechle TR, Earle ER, Wathen MS. Resistance training. In: Baechle TR, Earle RW, editors. Essentials of Strength Training and Conditioning. National Strength and Conditioning Association. Champaign: Human Kinetics; 2008: 381-412
3. Spencer M, Bishop D, Dawson B et al. Physiological and metabolic responses to repeated-sprint activities: specific to field-based team sports. Sports Med 2005; 35: 1025-1044
4. Miarka B, Panissa VLG, Julio UF et al. A comparison of time-motion performance between age groups in judo matches. J Sports Sci 2012; 30: 899-905
5. Franchini E, Artioli GG, Brito CJ. Judo combat: time-motion analysis and physiology. Int J Perform Anal Sport 2013; 13: 624-641
6. Miarka B, Cury R, Julianetti R et al. A comparison of time-motion and technical–tactical variables between age groups of female judo matches. J Sports Sci 2014; 32: 1529-1538
7. Buchheit M, Laursen PB. High-intensity interval training, solutions to the programming puzzle. Sports Med 2013; 43: 313-338
8. Baudry S, Roux P. Specific circuit training in young judokas: effects of rest duration. Res Q Exerc Sport 2009; 80: 146-152
9. Franchini E, Panissa VLG, Julio UF. Physiological and performance responses to intermittent uchi-komi in judo. J Strength Cond Res 2013; 27: 1147-1155
10. Ravier G, Dugué B, Grappe F. Impressive anaerobic adaptations in elite karate athletes due to few intensive intermittent sessions added to regular karate training. Scandinavian J Med Sci Sports 2009; 19: 687-694
11. Farzad B, Gharakhanlou R, Agha-Alinejad H et al. Physiological and performance changes from the addition of a sprint interval program to wrestling training. J Strength Cond Res 2011; 25: 2392-2399
12. Kim J, Lee N, Trilk J et al. Effects of sprint interval training on elite Judoists. Int J Sports Med 2011; 32: 929-934
13. Bonato M, Rampichini S, Ferrara M et al. Aerobic training program for the enhancements of HR and VO_2 off-kinetics in elite judo athletes. J Sports Med Phys Fitness 2014: 55: 1277-1284
14. Barczyński BJ, Graczynski M, Kalina RM. Barriers Restricting the Free Dissemination of Scientific Achievements: Own Experiences in Crossing Walls and Bridges. J Hum Kinet 2009; 22(22): 7-14
15. Vacher P, Nicolas M, Mourot L. Monitoring training response with heart rate variability in elite adolescent athletes: is there a difference between judoka and swimmers? Arch Budo 2016; 12: 35-42
16. Franchini E, Takito MY. Olympic preparation in Brazilian judo athletes: description and perceived relevance of training practices. J Strength Cond Res 2014; 28: 1606-1612
17. Foster C, Florhaug JA, Franklin J et al. A new approach to monitoring exercise training. J Strength Cond Res 2001; 15: 109-115
18. Sterkowicz S. Test specjalnej sprawnosci ruchowej w judo [Special fitness test in judo athletes]. Antropomotoryka 1995; 12-13: 29-44 [in Polish]
19. Agostinho MF, Philippe AG, Marcolino GS et al. Perceived training intensity and performance changes quantification in judo. J Strength Cond Res 2015; 29: 1570-1577
20. Miarka B, Hayashida CR, Julio et al. Objectivity of FRAMI-software for judo match analysis. Int J Perform Anal Sport 2011; 11: 254-266
21. Borg GAV. Psychophysical bases of perceived exertion. Med Sci Sports Exerc 1982; 14: 377-381
22. Rhea MR. Determining the magnitude of treatment effects in strength training research through the use of the effect size. J Strength Cond Res 2004; 18: 918-920
23. Franchini E, Sterkowicz S, Szmatlan-Gabrys U et al. Energy system cotntributions to the special judo fitness test. Int J Sports Physiol Perform 2011; 6: 334-343
24. Franchini E, Vecchio FBD, Sterkowicz S. A special judo fitness test classificatory table. Arch Budo 2009; 5: 127-129
25. Franchini E, Branco BM, Agostinho MF et al. Influence of linear and undulating strength periodization on physical fitness, physiological, and performance responses to simulated judo matches. J Strength Cond Res 2015; 29: 358-367
26. Ross A, Leveritt M. Long-term metabolic and skeletal muscle adaptations to short-sprint training: Implications for sprint training and tapering. Sports Med 2001; 31: 1063-1081
27. Ribeiro SR, Tierra-Criollo CJ, Martins RÁBL. Effects of different strengths in the judo fights, muscular electrical activity and biomechanical parameters in elite athletes. Revista Brasileira de Medicina do Esporte 2006; 12: 27-32
28. Andreato LV, de Moraes FSM, Del Conti Esteves JV et al. Physiological responses and rate of perceived exertion in Brazilian jiu-jitsu athletes. Kinesiol 2012; 44: 173-181
29. Andreato LV, de Moraes SMF, Del Conti Esteves JV et al. Psychological, physiological, performance and perceptive responses to Brazilian jiu-jitsu combats. Kinesiol 2014; 46: 44-52
30. Andreato LV, Julio UF, Panissa VLG et al. Brazilian jiu-jitsu simulated competition, Part II: physical performance, time-motion, technical-tactical analyses and perceptual responses. J Strength Cond Res 2015; 29: 2015-2025
31. Detanico D, Dal Pupo, J, Franchini E et al. Effects of successive judo matches on fatigue and muscle damage markers. J Strength Cond Res 2015; 29: 1010-1016
32. Salvador A, Suay F, Martinez–Sanchis S et al. Correlating testosterone and fighting in male participants in judo contests. Physiol Behav 1999; 68: 205-209
33. Suay F, Salvador A, González-Bono et al. Effects of competition and its outcome on serum testosterone, cortisol and prolactin. Psychoneuroendocrinology 1999; 24: 551-566
34. Parmigiani S, Bartolomucci A, Palanza P et al. In judo, randori (free fight) and kata (highly ritualized fight) differentially change plasma cortisol, testosterone, and interleukin levels in male participants. Aggressive Behav 2006; 32: 481-489

Cite this article as: Franchini E, Julio UF, Gonçalves Panissa VL et al. Short-term low-volume high-intensity intermittent training improves judo-specific performance. Arch Budo 2016; 12: 219-229

Editorial note

Apart from the standard review procedure Scientific Editors had to make two interventions in this article, similarly to *Vacher P et al.* [15] – in agreement with corresponding author. We have included references 35-42 to the content of this *Editorial Note*.

Monitoring exercises intensity (regardless of applied indicators) not only during the judo training but any physical activity in sport and during health-related training [35] is only one of the elements of training load. Literature review concerning especially a sports training is confirming that the large number of publications is concerning effects, however few papers the causes, that is just precise evaluation of training load. Therefore very valuable publications announcing among others that it is possible to get identical or higher training effects in the short time at the lower number of repetitions of specific exercises [36], at lower body exploitation. Very important are articles concerning the evaluation of means (exercises) [36, 37]. Since the concept of training load is not limited to the physical sphere (energy) [35], therefore it is important also to analyse training means (causes) in psychological and pedagogical terms [38, 39]. Without accurate knowledge of the reasons for the effects of adaptation (verified by a sports score) is hard to modify the structure and content of the next training.

The specificity of judo and other combat sports consists of the fact that the same exercise performed at the same time by athletes representing extreme weight categories (but with similar motivation to exercise) results very often in different neurophysiological responses in the body. Therefore, accurate estimation of stimuli during training is a methodological necessity. Over 40 years ago, Russian scientists (Andriejev et al., 1974), followed by Polish scientists (Jaskólski et al., 1978, 1979) developed effective methods for assessment of the training load in judo (more in [35]).

Because many essential terms to the training theory and science of martial arts are differently defined by researchers from different countries, therefore Editors of Archives of Budo in glossary are trying to bring the reader to this diversity (in this article references to the dictionaries [40, 41] and to the glossary in the Japanese monograph dedicated to budo [42]).

This is an example showing that one of the most important missions of the journals is being accomplished – both readers of papers published in Archives of Budo and potential authors become closer to scientific achievements which for many years were almost exclusively available in Polish or Russian. Many of these articles were created in the period when the world was divided by the Iron Curtain. This situation is widely discussed in the paper of Barczyński BJ et al. [14].

Recommended References

35. Kalina RM. Methodology of measurement, documentation and programming optimal workload continuous with variable intensity – applications in sports medicine, physiotherapy, geriatrics, health-related training, sport for all. Arch Budo 2012; 8(4): 235-249
36. Iermakov SS, Arziutov GN, Jagiełło W. Quick training of students to judo techniques. Arch Budo 2016; 12: 15-24
37. Pedrosa GF, Soares YM, Gonçalves R et al. Elaboration and evaluation of judo training means. Arch Budo 2015; 11: 7-16
38. Pedrosa GF, Soares YM, Gonçalves R et al. Content validation of a catalog of exercises for judo. Percept Mot Skills 2016; 122(3): 933-2955
39. Bliznevsky AA, Kudryavtsev MD, Iermakov SS et al. Formation of active-effective attitude of 12-13 years' judo athletes to sports functioning in competition period. Arch Budo 2016; 12: 101-115
40. Dictionary of Sport and Exercise Science. Over 5,000 Terms Clearly Defined. A & B Black, London 2006
41. Kent M. The Oxford Dictionary of Sports Science and Medicine. Oxford-New York- Tokyo: Oxford University Press; 1994
42. Budō. The Martial Ways of Japan. Nippon Budokan Foundation; 2009

Athlete – *noun* **1.** someone who has the abilities necessary for participating in physical exercise, especially in competitive games and races **2.** a competitor in track or field events [40].

Condition – *noun* 1. the particular state of someone or something 2. a particular illness, injury or disorder; *verb* to undertake a fitness plan to improve general health, appearance or physical performance [40].

Hajime (jap.) – begin.

Mate (jap.) – stop (wait).

Uchi-komi (uchikomi) – repetition of basic technique in kendo and judo training [42].

Randori – sparring in judo in which both participants practice attacking and defending [42].

Training load – "A simple mathematical model of training load can be defined as the product of qualitative and quantitative factor. This reasoning may became unclear whenever the quantitative factor is called 'workload volume' or 'training volume' interchangeably with 'volume of physical activity'. Various units have been adopted as measures i.e. the number of repetitions, kilometres, tons, kilocalories, etc. as well as various units of time (seconds, minutes, hours) (...) As in the real world nothing happens beyond the time, the basic procedure of improvement of workload measurement should logically start with separation of the time factor from the set of phenomena so far classified together as '*workload volume*'. (...) Due to the fact that the heart rate (HR) is commonly accepted as the universal measure of workload intensity, the product of effort duration and HR seems to be the general indicator of *training load* defined as the amount of workload. It is useful in analyses with a high level of generality. (...) In current research and training practice the product of effort duration and HR was referred to as conventional units' or further calculations have been made to convert it into points." [35, p. 238].