BRIEF REVIEW

THE PHYSIOLOGY OF JUDO-SPECIFIC TRAINING MODALITIES

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ABSTRACT

Franchini, E, Brito, CJ, Fukuda, DH, and Artioli, GG. The physiology of judo-specific training modalities. *J Strength Cond Res* 28(5): 1474–1481, 2014—Understanding the physiological response to the most common judo training modalities may help to improve the prescription and monitoring of training programs. This review is based on search results using the following terms: "judo," "judo and training," "judo and physiology," "judo and specific exercises," and "judo and combat practice." Uchi-komi (repetitive technical training) is a specific judo exercise that can be used to improve aerobic and anaerobic fitness. Effort to pause ratio, total session duration, number and duration of individual sets, and the type of technique can be manipulated to emphasize specific components of metabolism. "Nage-komi" (repetitive throwing training) can also be used to improve aerobic and anaerobic fitness, depending on the format of the training session. "Randori" (combat or fight practice; sparring) is the training modality most closely related to actual judo matches. Despite the similarities, the physiological demands of randori practice are not as high as observed during real competitive matches. Heart rate has not shown to be an accurate measure of training intensity during any of the previously mentioned judo training modalities. High-volume, high-intensity training programs often lead judo athletes to experience overtraining-related symptoms, with immunosuppression being one of the most common. In conclusion, judo training and judo-specific exercise should be manipulated to maximize training response and competitive performance.

KEY WORDS martial arts, heart rate, lactate, muscle strength, athletic performance, immunosuppression

INTRODUCTION

Judo is a grappling combat sport in which athletes perform multiple high-intensity intermittent efforts to gain a competitive advantage by throwing an opponent to the ground or demonstrating control in groundwork through pin or submission (36). To achieve competitive success, athletes need highly developed technical and tactical skills (21) and high levels of physical fitness (17). Competitive matches can vary from a few seconds (when an "ippon," or "full point," is scored) to more than 8 minutes (when the 5-minute period ends tied and the extra time is used to establish the winner) (36). The physiological strain in judo matches is considerably high, because their duration is relatively long, and intense efforts are required to perform a great variety of complex motor actions in standing and groundwork positions (7,36). Physical fitness and technical and tactical knowledge are 2 of the most important aspects for performance in both male (31) and female judo athletes (32). Therefore, judo athletes dedicate long periods of training to improve physical fitness and technical-tactical skills through specific training modalities (8,30) or by combining general and specific modalities (35). However, little information is available concerning the physiological responses to judo-specific training, and no review has been conducted on this topic despite the widespread use of these modalities among athletes and coaches. In support of the need for this review, planning the training process and the development of technical-tactical skills are among the highest rated professional activities conducted by judo trainers and coaches (50). Indeed, knowledge on the physiological response to judo-specific modalities and training sessions can help coaches to improve their training prescription and, consequently, maximize their athlete's performance. In light of this, this review is directed to identify the physiological responses to the most commonly used judo-specific training modalities and the entire training session as a whole. To that end, the search terms "judo," "judo and training," "judo and physiology," "judo and specific exercises," and "judo and combat practice" were used in the following databases: PubMed, Scopus, SportDiscus, and Google Scholar. Articles published through May 2013 were selected based on the

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28(5)/1474–1481

Journal of Strength and Conditioning Research

following criteria: measurement of the physiological responses to judo-specific training modalities; full description of methods; and published in English, French, Japanese, Polish, Portuguese, or Spanish. Additional articles, books, and congress abstracts cited in these primary sources were only included when no other source of information was available. Because of the minimal number of well-controlled research studies available and the lack of uniformity regarding physiological variables measured and testing protocols used, a full-scale systematic review and meta-analysis could not be adequately performed.

JUDO-SPECIFIC TRAINING MODALITIES

The most common modalities used during judo training sessions require 2 participants and include the following: "uchi-komi"–repetitive technical practice with a single partner executing the technique without throwing; "nage-komi"–repetitive throwing practice with a single partner executing the technique; "randori"–combat or fight practice, sparring with attempts by both the participants to execute techniques. Studies have examined the physiological responses to these specific training modalities and to whole judo training sessions, and the findings are discussed in the following sections.

Uchi-komi (Repetitive Technical Training)

One of the first studies investigating the physiological response to uchi-komi was undertaken by Sikorski (48). The junior Polish judo team was submitted to intermittent (ten 10-second sets at maximum speed for 5 minutes, with 20-second rest intervals) and continuous (self-selected steady rhythm of technique repetitions during 5 minutes 10 seconds) uchi-komi exercise sessions and had their blood lactate measured after each protocol. The intermittent protocol resulted in blood lactate concentrations of 14.4 ± 2.3 $\text{mmol}\cdot\text{L}^{-1}$, which is similar to the values measured after competitive matches (39,49), whereas the continuous protocol resulted in 4.6 ± 2.2 $\text{mmol}\cdot\text{L}^{-1}$, which is close to the value commonly associated with maximal lactate steady-state intensity in other exercise modes (6). In other investigations, judo athletes completed 5 minutes continuous all-out uchi-komi sessions and reported blood lactate values from 7.04 ± 1.07 $\text{mmol}\cdot\text{L}^{-1}$ (46) to 8.07 ± 3.22 $\text{mmol}\cdot\text{L}^{-1}$ (44). Both of these studies (44,46) indicated a low to moderate glycolytic demand when performing all-out continuous uchi-komi, whereas the all-out intermittent protocol used by Sikorski (48) resulted in high glycolytic demand.

An all-out uchi-komi approach was used to investigate the heart rate (HR) responses in 20 regional-level French judo athletes (10 men and 10 women) (27). The uchi-komi protocols adopted were the following: 30 repetitions (performed in 20–30 seconds), 60 repetitions (performed in 45–60 seconds), or 5 × 30 seconds interspersed by 30-second rest intervals. The authors found a lower HR response in the 30 repetitions protocol compared with the other 2 conditions, with no differences being found between men and women (Table 1). In the 60 repetitions and 5 × 30 seconds protocols, HR was similar to that observed during randori, suggesting that these uchi-komi protocols could be used to elicit similar cardiovascular demands to those observed in match simulations.

Heart rate responses to the combination of uchi-komi with running exercise have also been investigated (24). Eight Olympic-level and 8 Spanish national-level athletes performed 1 repetition every 3 seconds or 4 seconds, with a 4-m sprint between each repetition, for a total duration of 3 minutes. The authors found HR values of 165 ± 19 $\text{b}\cdot\text{min}^{-1}$ and 175 ± 15 $\text{b}\cdot\text{min}^{-1}$ for the 3-second and 4-second repetition schemes, respectively, suggesting that the increase in the displacement speed was directly related to the increase in HR. Additionally, Olympic-level athletes presented lower HR during exercise (4-second interval = 144 $\text{b}\cdot\text{min}^{-1}$ and 3-second interval = 154 $\text{b}\cdot\text{min}^{-1}$) and recovery (4-second interval = 119 $\text{b}\cdot\text{min}^{-1}$ and 3-second interval = 123 $\text{b}\cdot\text{min}^{-1}$) compared with national-level athletes (4-second interval = 176 $\text{b}\cdot\text{min}^{-1}$ and 148 $\text{b}\cdot\text{min}^{-1}$; 3-second interval = 184 $\text{b}\cdot\text{min}^{-1}$ and 160 $\text{b}\cdot\text{min}^{-1}$ for

TABLE 1. Heart rate (HR; $\text{b}\cdot\text{min}^{-1}$) and recovery heart rate (%) in 3 uchi-komi protocols.*

	Whole group (*n* = 20)	Women (*n* = 10)	Men (*n* = 10)
1 × 30 repetitions			
HR peak ($\text{b}\cdot\text{min}^{-1}$)	183 ± 9	180 ± 10	185 ± 7
HR recovery (%)			
30 s	10 ± 5.2	12.1 ± 5.5	7.88 ± 3.9
1 min	20.5 ± 9.3	23.4 ± 8.6	17.9 ± 9.0
1 × 60 repetitions			
HR peak ($\text{b}\cdot\text{min}^{-1}$)	192 ± 7	189 ± 8	195 ± 5
HR recovery (%)			
30 s	8.5 ± 3.1	9.8 ± 3.9	7.4 ± 2.0
1 min	17 ± 6.9	19.9 ± 8.0	14.0 ± 3.7
5 × 30 s			
HR peak ($\text{b}\cdot\text{min}^{-1}$)	191 ± 6	191 ± 7	191 ± 5
HR recovery (%)			
30 s	8.0 ± 3.0	8.7 ± 3.9	7.2 ± 1.1
1 min	13.3 ± 5.6	15.4 ± 5.1	10.9 ± 5.3

*Values are mean ± *SD*. Adapted from Houvenaeghel et al. (27).

exercise and recovery phases, respectively), indicating that Olympic athletes experience lower cardiovascular strain as compared with national-level athletes when submitted to the same type of uchi-komi protocol. Although it is not possible to understand to what extent this response was generated by the contribution of a higher technical ability/efficiency or higher physical fitness in the Olympic athletes, it seems clear that HR could be effectively used to detect improvements in this type of exercise and that an absolute rhythm increase should be necessary to create the same magnitude of cardiovascular stress in Olympic-level judo athletes.

The specific manipulation of effort to pause ratios has also been examined during uchi-komi protocols (5,20,53). Baudry and Roux (5) submitted 10 adolescent judo athletes to 3 uchi-komi protocols consisting of 6 × 40 seconds all-out repetitions and differing in the recovery period between the sets, as follows: 40 seconds (1:1 effort to pause ratio), 120 seconds (1:3 effort to pause ratio), and 200 seconds (1:5 effort to pause ratio). Higher values of HR were found in the 1:1 effort to pause ratio protocol in comparison with the 1:3 and 1:5 effort to pause ratio during the final bout of the protocols. Blood lactate concentration was also lower in the 1:5 effort-pause protocol compared with 1:1 and 1:3 effort-pause protocols from the third set to the end of the exercise. The number of repetitions also differed among conditions with lower values for the 1:1 effort-pause as compared with both 1:3 and 1:5 effort to pause ratio protocols. As expected, the longer rest intervals resulted in lower physiological stress, higher number of repetitions, and lower HR and blood lactate, when compared with the shorter interval periods.

Using the 1:1 effort to pause ratio and changing the duration of the effort (6 × 30 seconds:30 seconds, 9 × 20 seconds:20 seconds, and 18 × 10 seconds:10 seconds), Franchini et al. (20) investigated the performance, HR, blood lactate, oxygen consumption ($\dot{V}O_2$) and the fast component phase of oxygen consumption recovery responses to all-out uchi-komi with 3 different judo techniques ("o-uchi-gari" or major inner reapi, "harai-goshi" or sweeping hip throw, and "seoi-nage" or shoulder throw). Energy expenditure was also calculated for each protocol. Athletes were able to perform the greatest number of repetitions with o-uchi-gari, but no effect of uchi-komi duration was observed. There was no effect of technique on HR, blood lactate (pre, peak, and delta), $\dot{V}O_2$ during activity, or the amplitude and time constant of the fast phase of the excess postexercise oxygen consumption. Similarly, HR was not different between the time structure protocols. This suggests that the effort to pause ratio is the most important variable to be manipulated to elicit differential responses in these variables. However, average $\dot{V}O_2$ during the uchi-komi was higher in the 10 seconds protocols compared with the 30 seconds protocols, which indicates that average $\dot{V}O_2$ is also dependent on uchi-komi duration. Energy expenditure throughout the entire session did not differ between the techniques, but o-uchi-gari resulted in the lowest energy expenditure per repetition. According to these data, the shorter protocol can be used to improve aerobic power because it resulted in higher $\dot{V}O_2$ values. The all-out uchi-komi protocols resulted in similar $\dot{V}O_2$ and HR responses to those observed during simulated matches (1). Conversely, blood lactate concentration was lower as compared with that observed after matches (23,49), probably because of the absence of the grip disputes required to gain tactical advantage during competitive situations. Additionally, HR was similar among the techniques and time protocols used, whereas the energy expenditure and the number of techniques performed were not. This discrepancy suggests that HR is a poor indicator of the efficacy of the training modality and should not be used to monitor intensity during all-out intermittent uchi-komi protocols.

Nage-komi (Repetitive Throwing Training)

Despite the fact that nage-komi is one of the most practiced judo training modalities, only a few studies have investigated the physiological responses to this activity (15,48,52). A standardized nage-komi test protocol has been incorporated into the Special Judo Fitness Test that is commonly used to evaluate and classify judo athletes. The physiological responses to this protocol, which includes one 15-second bout and two 30-second bouts of throwing with intermittent 6-m sprints separated by 10 seconds rest periods, have been previously reported (14,18,19,51). This review includes studies that focused on this specific modality related to training and not to testing.

Sikorski (48) examined blood lactate responses to 2 types of nage-komi (1 throw every 10 seconds during 5 minutes and 24 throws in 1 minute) in junior judo athletes and reported values of $6.3 \pm 3.6\ \text{mmol}\cdot\text{L}^{-1}$ for the 5-minute condition and $13.4 \pm 1.5\ \text{mmol}\cdot\text{L}^{-1}$ for the 1-minute condition. Also using nage-komi, international-level female athletes performed the maximal number of throws in 1 minute using their preferred technique (2 training partners were thrown in this protocol to minimize the interference of the partner on maximal throws) (44,45). It was observed that blood lactate increased from $1.87 \pm 0.66\ \text{mmol}\cdot\text{L}^{-1}$ in the resting condition to $7.92 \pm 1.47\ \text{mmol}\cdot\text{L}^{-1}$ after the exercise (44). In another similar study (45), athletes performed 33.8 ± 2.4 throws, with HR achieving very high values ($199 \pm 25.3\ \text{b}\cdot\text{min}^{-1}$) and blood lactate increasing from $2.39 \pm 0.41\ \text{mmol}\cdot\text{L}^{-1}$ at rest to $7.98 \pm 1.12\ \text{mmol}\cdot\text{L}^{-1}$ postexercise. The blood lactate concentration measured in these female judo athletes was approximately half of that measured in the male Polish judo athletes submitted to the same task, despite performing a lower number of throws (48). This suggests that energy transfer may be less reliant on glycolysis in female as compared with male judo athletes. These sex differences in training response may have important implications for training organization.

Only a few studies measuring $\dot{V}O_2$ during nage-komi were found (15,22,52). Sugiyama and Kajitani (52) observed that $\dot{V}O_2$ varied according to the technique used. The authors tested the following 5 different techniques: "seoi-nage" (shoulder throw, a "te-waza," i.e., arm technique), "o-uchi-gari" (major inner reap, an "ashi-waza," i.e., leg technique), "kata-guruma" (shoulder wheel, a "te-waza," i.e., arm technique), "sasae-tsuri-komi-ashi" (propping drawing ankle sweep, an "ashi-waza," i.e., leg technique), and "o-soto-gari" (major outer reap, an "ashi-waza," i.e., leg technique) during the "nage-komi" (1 throw every 5 seconds for 4 minutes). Seoi-nage resulted in the highest oxygen uptake (~85% of $\dot{V}O_2$max determined in a treadmill test) as compared with the other techniques (e.g., o-uchi-gari resulted in ~60% of $\dot{V}O_2$max determined in a treadmill test), suggesting that the arm techniques investigated were more physically demanding than the leg techniques analyzed. Based on these findings, the authors recommended that seoi-nage is an appropriate choice to improve the aerobic fitness of judo athletes in specific settings.

In a study by Franchini et al. (15), 12 judo athletes were submitted to 3 nage-komi sessions (1 throw every 15 seconds for 5 minutes) using o-uchi-gari (leg technique), morote-seoi-nage (arm technique), and harai-goshi (hip technique). $\dot{V}O_2$ and HR were measured at rest, throughout the 5-minute period of "nage-komi" and 6 minutes after the exercise, whereas blood lactate was measured at rest, 1, 3 and 5 minutes after exercise. The contribution of the energy systems and total energy expenditure were calculated. The authors reported higher $\dot{V}O_2$ values for "morote-seoi-nage" (33.71 ± 5.68 $ml \cdot kg^{-1} \cdot min^{-1}$) than for "o-uchi-gari" (29.97 ± 6.10 $ml \cdot kg^{-1} \cdot min^{-1}$), whereas harai-goshi (32.28 ± 5.10 $ml \cdot kg^{-1} \cdot min^{-1}$) did not differ from the other 2 techniques. Mean HR during nage-komi (morote-seoi-nage: 146 ± 14 $b \cdot min^{-1}$; harai-goshi: 140 ± 11 $b \cdot min^{-1}$; and o-uchi-gari: 139 ± 16 $b \cdot min^{-1}$) and blood lactate after nage-komi (morote-seoi-nage: 1.80 ± 0.56 $mmol \cdot L^{-1}$; harai-goshi: 2.02 ± 1.33 $mmol \cdot L^{-1}$; and o-uchi-gari: 1.73 ± 0.88 $mmol \cdot L^{-1}$) were somewhat low, probably because of the aerobic nature of the nage-komi session, and did not differ between the techniques. Morote-seoi-nage and harai-goshi resulted in higher absolute (46 ± 20 kJ and 43 ± 21 kJ, respectively) and relative (16.3 ± 2.7% and 16.1 ± 2.7% of total energy, respectively) anaerobic alactic contribution than o-uchi-gari (36 ± 22 kJ, or 14.6 ± 2.8%). As a consequence of the difference in the $\dot{V}O_2$ during nage-komi, the absolute aerobic contribution was also higher in morote-seoi-nage (223 ± 66 kJ) than in o-uchi-gari (196 ± 74 kJ), whereas harai-goshi (211 ± 66 kJ) did not differ from the others. However, no difference was observed in the relative aerobic contribution between techniques (morote-seoi-nage: 82.2 ± 2.9%; harai-goshi: 82.3 ± 3.8%; o-uchi-gari: 84.0 ± 3.8%). Because blood lactate responses did not differ between the techniques, relative and absolute anaerobic lactic contribution were also similar. However, total energy expenditure was higher during morote-seoi-nage (273 ± 86 kJ) compared with o-uchi-gari (237 ± 99 kJ), whereas harai-goshi (259 ± 91 kJ) did not differ from any of them. Thus, during nage-komi (1 throw every 15 seconds), the oxidative system provides most of the energy yield; morote-seoi-nage is more demanding and fits better with physical conditioning purposes (especially aerobic conditioning) in a specific setting. The biomechanical demands of each technique most likely impacted the discrepancies in energy expenditure with morote-seoi-nage (an arm technique) relying heavily on both trunk rotation and knee flexion, whereas o-uchi-gari (a leg technique) is completed primarily in the frontal plane. Although techniques differed in $\dot{V}O_2$ and anaerobic alactic contribution, HR was not different between them, indicating that changes in HR cannot accurately quantify the energy expenditure or intensity in this kind of exercise. Another important aspect to be considered is that, despite the modest increase in HR and blood lactate values elicited by this type of exercise (suggesting that it could be maintained for longer periods than those used in the study), nage-komi induced a very

TABLE 2. Blood lactate concentration after randori training sessions.*

Authors	Sample characteristics	*Randori* characteristics	Lactate ($mmol \cdot L^{-1}$)
Sikorski (48)	Polish junior and Senior judo teams	15-minute *kakari-geiko* (successive attacks with light defense from the opponent)	9.4 ± 2.5
		25–30 minutes *randori* with "no strength" application (5–6 matches with 1-minute interval)	5.2 ± 2.3
Callister et al. (9)	Elite USA judo athletes	1-hour *randori*	8.9 ± 0.5
Callister et al. (10)	Elite USA judo athletes	3–7 *randori* (3-minute duration and 30-second intervals)	9.1 ± 1.1
Branco et al. (7)	State-level Brazilian judo athletes	4 × 5 minutes *randori* with 5-minute intervals	8.2 ± 2.6
			7.7 ± 2.6
			7.1 ± 2.3
			7.6 ± 2.2

*Values are mean ± *SD*.

high-caloric expenditure comparable with a full-body resistance training session (1 set each of 10 exercises at 10 repetition maximum) (26) and may be used as an adjunct to increase daily energy expenditure for body mass maintenance.

Randori (Combat or Fight Practice; Sparring)

During training sessions, randori is the exercise that most closely mimicks competitive matches (8) and, because it is comprised of multiple periods of high-intensity intermittent combat sessions, high post-exercise blood lactate concentrations have been observed (Table 2).

In studies carried out with North American athletes (9,10), blood lactate values measured after randori combat sessions were compared with those measured after a maximal treadmill test. The authors observed that randori elicited a ~14% higher lactate concentration than the maximal treadmill test. Moreover, blood lactate concentrations after randori and after continuous attack practice (kakari-geiko) are quite similar to those observed after match simulations, but slightly lower than lactate responses to real regional-level and markedly lower than international-level competitions (49). This suggests that these training methods do not properly simulate the physiological demands of high-level competitions. Thus, the inclusion supplementary exercise, such as all-out uchi-komi as previously described or chin-up exercise holding the judogi, in specific intervals of the randori session could help to increase the physiological demands of randori to the levels observed in a real competitive environment (7,20).

Some studies have also evaluated HR during and after randori combat sessions (7,9,10,27), with near maximal cardiovascular demands being reported in different forms of randori (Table 3). Interestingly, a study comparing HR responses between intermittent and continuous randori sessions observed that the HR in intermittent randori was 5–10 $b \cdot min^{-1}$ lower than the continuous randori (180–190 $b \cdot min^{-1}$) (28), suggesting a higher cardiovascular strain for the continuous format.

Only 2 studies have measured $\dot{V}O_2$ during randori (13,28). De Meersman and Ruhling (13) submitted 11 judo practioners to 1-minute uchi-komi followed by 2-minute randori combat sessions and measured $\dot{V}O_2$ immediately after this session. The authors repeated the same measurements after 7 weeks of judo training and found a decrease in the $\dot{V}O_2$ between the first (2.92 ± 1.44 $L \cdot min^{-1}$) and the seventh (2.30 ± 0.95 $L \cdot min^{-1}$) week, indicating that the practitioners likely became more metabolically efficient. Kaneko et al. (28) reported that the $\dot{V}O_2$ during the intermittent randori (28–31 $ml \cdot kg^{-1} \cdot min^{-1}$) was lower than that

Table 3. Heart rate ($b \cdot min^{-1}$) after different randori protocols.*

Authors	Sample characteristics	*Randori* characteristics	HR ($b \cdot min^{-1}$)
Callister et al. (9)	Elite USA judo athletes	1-hour *randori*	184 ± 3
Callister et al. (10)	Elite USA judo athletes	3–7 *randori* (3-minute duration and 30-second intervals)	185 ± 4
Houvenaeghel et al. (27)	Regional-level French judo athletes†	2 × 120 seconds (grip dispute)	
		G	187 ± 7
		M	189 ± 6
		F	185 ± 6
		2 × 120 seconds (performed without opposition)	
		G	188 ± 9
		M	189 ± 9
		F	188 ± 9
		2 × 120 seconds (displacement with light opposition)	
		G	189 ± 10
		M	189 ± 9
		F	188 ± 10
		1 × 120 seconds (free *randori*)	
		G	191 ± 9
		M	191 ± 9
		F	190 ± 9
Branco et al. (7)	State-level Brazilian judo athletes	4 × 5 minutes *randori* with 5-minute intervals	179 ± 10
			174 ± 15
			178 ± 14
			183 ± 9

*Values are mean ± *SD*.
†G = whole group; M = males; F = females.

measured during the continuous randori (39 $ml \cdot kg^{-1} \cdot min^{-1}$), confirming the suggestion (based on HR analysis) that intermittent randori may result in higher anaerobic and lower oxidative participation. Furthermore, the authors reported that the values represented 55–60% of $\dot{V}O_2max$ determined in a treadmill test, suggesting that this method of practice assimilates quite well with the moderate-intensity recommendations for improvements in aerobic fitness (25).

Only 1 study investigated the hormonal responses to randori (43). Athletes were submitted to a 5-minute randori combat session, and testosterone and cortisol concentrations were measured. They reported an increase in the testosterone concentration from rest (4.2 ± 0.4 $ng \cdot ml^{-1}$) to postrandori (4.6 ± 0.4 $ng \cdot ml^{-1}$) and that this change in testosterone concentration was significantly correlated ($r = 0.61$) with the number of attacks performed during randori. Furthermore, the pre and postrandori testosterone levels were lower in the winners when compared with the defeated athletes. The authors suggested that the lower concentration presented by the winners could be a consequence of the better emotional control displayed by these athletes, although no measurement associated to emotional control was conducted. An increase in cortisol concentration (prerandori = 129.3 ± 14.5 $ng \cdot ml^{-1}$; postrandori = 199.0 ± 13.3 $ng \cdot ml^{-1}$) was also found.

Training Session

Contrary to the true competition environment, where matches can be finished in a few seconds (17), training sessions commonly last more than 2 hours (38). A single judo training session may consist of any combination of the previously described judo-specific training modalities and additional components of general strength and conditioning programs. Previous studies (8,12,34,37,38,54) have investigated judo training sessions composed of approximately 40 minutes of general exercise, 40 minutes of judo-specific exercises such as "ukemi" (falling techniques), uchi-komi, and nage-komi, plus 40 minutes of randori. Thus, training stimuli and recovery processes need to be well planned to allow athletes to reach their peak physical and technical-tactical abilities during competition. In intense training sessions, judo athletes might present impaired performance associated with overtraining (41). Immune response is one of the best indicators of overtraining (55), and several studies have monitored the acute (8,12,33,34,38,54) and chronic immune responses to judo training (11,30,37,38,42,55,56). Innate immunity seems to be the most affected by judo training, especially neutrophil function (38,54–56). Yaegaki et al. (55) observed a decreased neutrophil phagocytic activity after a 7-day training camp (−6.3 to −15.8 fluorescence intensity [FI] in men post-training) and reduced oxidative burst and reactive oxygen species (ROS) production (9.8 to −13.1 FI) in neutrophils. Yamamoto et al. (56) observed an initial decrease in neutrophil phagocytic activity in the first 2 months of judo training, which was followed by a gradual recovery throughout the next 6 months.

Despite the initial decrease in neutrophil function, an acute 2.5-hour judo training session seems to have no impact on overall neutrophil function (54) because any decrease in phagocytic activity would be adequately compensated by an increase in opsonization and ROS production. Similar results were also reported after 64 days of 2.5 hours per day judo training (38). Koga et al. (30) observed that judo athletes displayed good adaptation to post-training immunosuppression (to −11.2 from 8.2 FI in ROS production and −26.1 from −2.6 FI in phagocytic activity) after 3 months of training, whereas untrained individuals present abnormal neutrophil function in response to training, indicating that neutrophil responses seem to be dependent on physical fitness. Yaegaki et al. (55) recommended that neutrophil phagocytic activity and oxidative burst should be monitored as a preventive measure to detect and prevent overtraining in judo athletes submitted to long-term training periods. Finally, caution is needed with judo athletes reducing weight before competition, as weight loss may have a negative impact on the immune system, probably because of the combination of food deprivation, increased training volume and intensity, and increased thermal stress associated with rapid weight loss methods (12,40,55).

Alterations in markers of muscle damage (e.g., creatine-phosphokinase, (CPK) (30,37,38,54,56), lactate dehydrogenase, [LDH], aspartate aminotransferase, [AST] (37,38,54,56), and alanine aminotransferase, [ALT]) (37,38,54) have also been reported after judo training sessions. After a 64-day training camp, Mochida et al. (38) reported increases ranging from 16.5% to 21.9% in CPK, LDH, AST, and ALT. Similar results were observed in male and female judo athletes after a 7-day training camp and after an acute 2-hour training session (54). However, Koga et al. (30) observed a remarkable attenuation in exercise-induced increase in serum CPK after a 3-month training camp both immediately after exercise (30.9–7.4% after the 3-month training) and 24-hour after exercise (79.3 to −6.8% after training). Aminoacidemia is another variable that should be monitored throughout the season, especially plasma levels of glutamine and branched-chain amino acids, which may decrease during intensive training periods, resulting in increased probability of infection and fatigue (29).

Although numerous concerns regarding rapid weight loss before competition, primarily through dehydration, have been addressed in the literature (2,3,16), this topic during judo training sessions requires further investigation. Weight loss after 90–150 minutes of judo training has shown to decrease between 1 and 3% with some variation because of environmental conditions and pre-exercise dehydration (4,12,47,55). In favorable environmental conditions, Chishaki et al. (12) reported significant relationships between the changes in plasma volume after a 2% body weight reduction from training and markers of muscle damage and immunosuppression. Concerns regarding alterations in sweat rate, sweat sodium concentration, and other symptoms of dehydration during judo training sessions in high heat stress environments have also been observed (4,47).

Perspectives

Judo is a highly complex sport in which the organization of specific training is a challenging task. Gaining an understanding of the physiological responses to training and competitive situations is critical for designing appropriate training methods. Although the physiological responses to judo competition and to the most used judo-specific training modalities are fairly well known, improvements in training methods will depend on further well-controlled prospective research studies. Because the Olympic sport of judo has been through constant changes over the past decades (mostly because of improvements in athletes' technical, tactical, and physical levels and because of changes in official competition rules), future research investigations must provide an understanding of how these changes impact combat dynamics and, as a consequence, how they impact the physiological and metabolic demands of judo combat. Judo coaches must be aware of these changes as their impact on combat dynamics may require adjustments in training methods.

PRACTICAL APPLICATIONS

In this review, we discussed the physiological responses to some of the most commonly used judo-specific training modalities; the information presented herein can be useful for the prescription and monitoring of training programs. Uchi-komi and nage-komi exercises can be used for metabolic training, with continuous steady-state or technique repetition every 10–15 seconds being useful for aerobic fitness development, whereas all-out intermittent protocols are useful especially for anaerobic development, but may elicit aerobic improvements as well. Techniques involving trunk rotation and accentuated knee flexion (e.g., seoi-nage) are more physically demanding than frontal attacks (e.g., o-uchi-gari). Longer randori sessions with lower intensity combat sessions and shorter rest intervals are more appropriate for improving aerobic fitness. However, to improve anaerobic capacity, combat sessions should be more intense, shorter in duration, and interspersed by longer intervals. Changes in immune function and selected blood amino acids and markers of muscle damage are also important to be monitored throughout the season as they may provide early evidence of overtraining.

ACKNOWLEDGMENTS

The first author thanks the CNPq support (236768/2012-3). The last author is supported by FAPESP (grant 2011/17059-2).

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