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Original Research

Monitoring Training Loads in Judo Athletes: Different Time Courses of Physiological, Neuromuscular, and Perceptual Responses

BRUNO T. CAMPOS†[1], FÁBIO Y. NAKAMURA‡[2], EDUARDO M. PENNA‡[3], RENATO G. S. D. MORAES*[1], JOÃO GABRIEL DA S. RODRIGUES†[1], MAICON R. ALBUQUERQUE‡[1,4], and LUCIANO S. PRADO‡[1,4]

[1]Exercise Physiology Laboratory, School of Physical Education, Physiotherapy, and Occupational Therapy, Federal University of Minas Gerais, Belo Horizonte, Minas Gerais, BRAZIL; [2]Federal University of Paraíba, João Pessoa, Paraíba, BRAZIL; [3]Physical and Sports Training Study Group, Federal University of Pará, Castanhal, Pará, BRAZIL; [4]Sports Training Center (CTE), Federal University of Minas Gerais, Belo Horizonte (MG), BRAZIL

*Denotes undergraduate student author, †Denotes graduate student author, ‡Denotes professional author

ABSTRACT

International Journal of Exercise Science 16(6): 638-653, 2023. This study aims to elucidate the internal load, performance, physiological, and perceptual recovery responses during four weeks of traditional judo training. Ten cadet and junior judo athletes were evaluated daily for four weeks, in which their perception of recovery, heart rate variability, handgrip strength, and countermovement jump performance were assessed. A one-way repeated-measures ANOVA was performed to analyze the variables across the weeks. A significant time effect in internal load ($F = 6.51$; $p = 0.001$) has been observed. Handgrip test performance showed significantly higher values in the 3rd and 4th weeks ($p < 0.001$), while countermovement jump performance was significantly higher in the 4th week ($p = 0.0007$). The heart rate variability`s coefficient of variation was lower in both the 3rd and 4th weeks ($p = 0.02$). Regarding perceptual aspects, the Hooper Index showed a significant time effect ($p = 0.04$), but pairwise comparison did not reveal differences between weeks. The present study indicates that neuromuscular, physiological, and perceptual responses to training load alterations present different time courses. This must be considered for the adequate monitoring of training programs.

KEY WORDS: Recovery, heart rate variability, muscle power

INTRODUCTION

Judo athletes perform multiple high-intensity intermittent efforts to obtain a competitive advantage by throwing an opponent to the ground and demonstrating groundwork control through pin or submission (18). During a judo match, the athlete must establish contact by grip in *judogi*, disrupt the opponent's balance, and execute a throwing technique. Initially, the athlete performs strength-endurance actions of the upper limb to maintain grip in *judogi* (18). On the other hand, the throwing technique concomitantly demands the athlete's muscular power of upper and lower limbs (16). When the match extends to the ground, actions demanding maximal strength of upper and lower limbs are also performed (16). Due to its intermittent nature, athletes require aerobic metabolism to recover during and between matches (16).

In this context, the preparation of a judo athlete must consider a variety of physical abilities at a high level. However, the concurrent effect of training different physical abilities and different time courses of recovery variables may hinder or even inhibit some adaptations (23). Studies with judo athletes have described various ways of planning, training, and optimizing general adaptations of strength and aerobic fitness and specific performance (17,19). Although the most suitable path for adaptations of all abilities concurrently in judo athletes is not evident, it is known that recovery is a determinant in this process (29). Thus, load and recovery monitoring play an essential role in the sports training process, providing support to coaches in determining optimal (or more accurate) training loads and rest periods (25).

A single study has identified an optimal relationship between internal load monitoring and specific performance adaptation in judo athletes (2). Some authors have already demonstrated that high training loads can compromise cardiac parasympathetic activity (29) and the immune system (28). Still, when fine-tuned, optimized training loads may lead to positive hormonal (1) and metabolic (6) adaptations. There are numerous available tools to monitor training loads and their sub-acute effects. In most situations, non-invasive variables are preferred, such as the perceived exertion of a given training session and the heart rate variability (HRV), which can potentially identify poor or adequate physiological recovery and negative or positive training effects (7,8).

Some fitness components play a role in determining success in judo. For instance, handgrip strength and vertical jump height may discriminate the performance of higher and lower-level athletes (4,27). However, the descriptive data regarding the time course of these performance variables and their association with physiological recovery and perceptual aspects during traditional training periods in judo is still embryonic. Furthermore, judo athletes constantly undergo protocols to reduce or control body weight, thus frequently training in a dehydrated state. The dehydrated state can hinder the recovery processes and, consequently, the achievement of optimal performance (38). Therefore, the simultaneous monitoring of external load, internal load, hydration status, recovery variables, and judo performance enables the prescription of well-adjusted training loads and the selection of “daily” tools supporting decision-making related to the training process.

In this sense, each physical training session provides athletes with physiological strain, leading to disturbances in physiological processes and biochemical pathways (39). It is noteworthy that available monitoring parameters usually reflect only one physiological aspect of fatigue and recovery (e.g., creatine kinase versus heart rate variability) (39). However, data that verified the time course response of internal load, perceptual, physiological, and performance recovery during a competitive period in young judo athletes are still lacking in the literature. Furthermore, it is necessary to discuss to which extent a monitoring model based on multiple selected variables responds to a period of typical training in judo, considering the different time courses of physiological adaptation and performance. In this respect, the literature still lacks information describing the external loads in judo in a detailed manner to enable its utilization in contextualizing training responses.

Among the specific exercises in judo training, *randori* is the most used drill (35). Also, 70% of the Olympic athletes performed the *randori* five to seven times a week in the final preparation phase for the Olympic Games (20). Indeed, according to experienced coaches, the *randori* is an essential practice during the preparatory and competitive phase, being present in almost all sessions (35). The manipulation of the *randori* duration and the inter-session recovery times could alter the predominant metabolic pathway in the session. For example, by reducing the inter-session recovery time and increasing the number of *randori* bouts, there will be an increase in the aerobic requirement and a reduction in the intensity of the match (11).

Thus, the primary purpose of the present study is providing a detailed description of the external load in a traditional training period in judo and the respective internal load responses, as well as the time course response of physiological, perceptual, and performance recovery variables. We hypothesize that physiological, perceptual, and performance variables may reflect fluctuations in judo training loads, like reducing weekly *randori* time. This could present temporal similarities and improve neuromuscular and physiological recovery.

METHODS

Participants

Ten cadet and junior judo athletes (6 males and 4 females; age: 19.0 ± 1.0 years; weight: 70.8 ± 20.5 kg; height: 170 ± 6 cm; body fat: 10 ± 2.2 %) took part in this study. Their age ranged between 16 and 19 years. The regular judo training experience was 5.5 ± 1.6 years. Moreover, the athletes were training regularly (11.26 ± 4.6 hours per week) and presented no musculoskeletal injuries in the 6 months preceding the study. Subjects did not take any medication or drugs or had no acute illness or infection during data collection. All procedures were approved by the Universidade Federal de Minas Gerais (protocol 12210219.7.0000.5149) and were conducted according to the regulations established in the Declaration of Helsinki (32). The subjects received written instructions describing all the procedures, risks, and benefits of participation in the study and signed an informed consent form. In the case of subjects younger than 18 years old (n = 4), the parents or guardians signed the written consent form.

Protocol

The athletes were evaluated daily (Monday to Friday) for 4 weeks (Figure 1). During in period, the athletes trained in technical-tactical sessions every day from approximately 2 pm to 4 pm. Additionally, they performed two weekly strength training sessions (Tuesday and Thursday) after the technical-tactical sessions. Before technical-tactical sessions, athletes were submitted to physiological and performance tests (hydration status, body mass, perception of recovery, heart rate variability, and strength tests). All trials were conducted in a laboratory (18 to 22 °C air temperature and 45 to 60% humidity controlled).

After training sessions, athletes answered the questionnaire about perceived exertion and session duration, and coaches recorded activities performed during the training sessions according to an activity catalog (34).

The present study was conducted between the 37th and 40th week of training of the annual macrocycle, characterized as the competitive period. Therefore, the data collection was performed 8 weeks before the subject´s main national competition. This period has been chosen because it occurred after a brief recovery phase in periodization and was temporally close to the season´s main competition. Thus, we could follow the evolution of athletes in a crucial period, in contrast to most studies that focused on initial training periods, such as pre-season, in which generally training loads of a different nature are utilized.

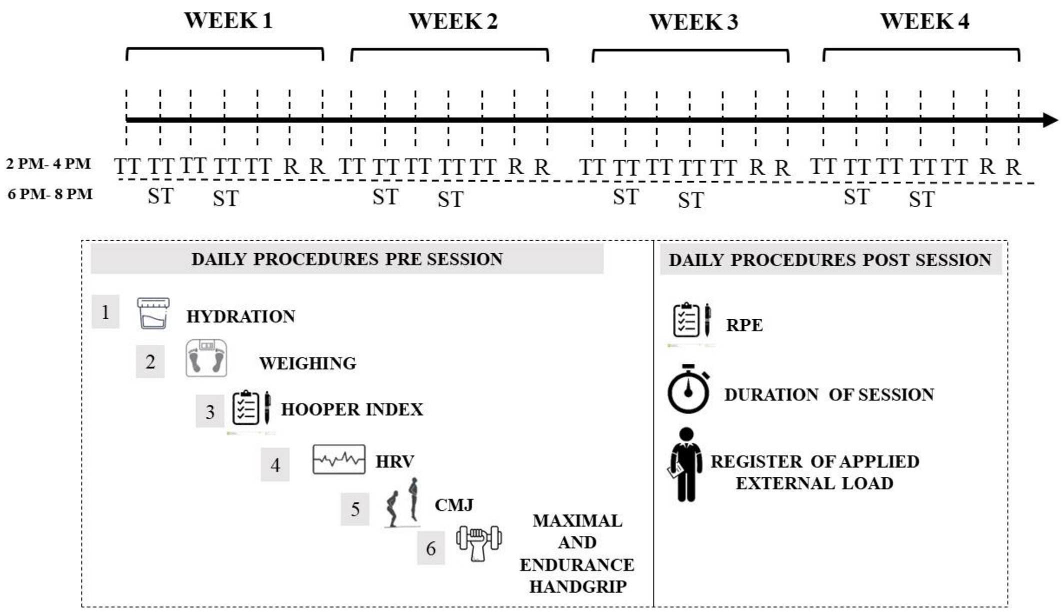

Figure 1 – Experimental approach. TT – Tactical Technical training session; ST – Strenght and Conditioning training Session; R – Passive Recovery; HRV – Heart rate variability; CMJ – Countermovement Jump; RPE – Rating of perceived of exertion.

Participants provided urine samples during the visit to the laboratory. Urine-specific gravity was used to assess the hydration status (3). This method measures the relative mass of solutes and solvents in a urine sample close to pure water using a refractometer (Uridens ®, Brazil). In dehydration, urine-specific gravity values exceed 1.030. When individuals are euhydrated, they range from 1.029 to 1.013; in hyperhydration, the urine-specific gravity ranges from 1.013 to 1.001 (3). Body mass (kg) was measured daily, with volunteers barefoot and wearing only shorts using a digital scale (Filizola ®, Brazil).

For the determination of HRV, athletes remained in a supine position and were instructed to stay calm, in silence, with spontaneous breathing and minimal body movements. They used a chest strap (Polar® H7, Finland) to collect the data. The raw data were exported to the Polar Precision Performance software (Polar Electro Oy). The R-R intervals were exported in ASCII format for posterior analysis in the Kubios HRV analysis software (version 2.0; University of Kuopio, Finland). All data were subjected to a "low" filter in the Kubios software to remove ectopic beats, which were replaced by interpolating the adjacent RR intervals (41). Data presented in the results section showed no more than 3% of the total beats removed.

The recordings lasted for 5 min, with the final 2 minutes of each recording used to calculate the HRV index (31). The HRV index analyzed in the time domain was the square root of the mean squared difference of successive R-R intervals (RMSSD). The RMSSD is assumed as an indicator of the activity of the parasympathetic nervous system (8). The RMSSD is considered the preferred index for athletic monitoring as it appears to be uninfluenced by the respiratory rate and is highly reliable at rest (8). The RMSSD was transformed into its natural logarithm before analysis [LnRMSSD; following standards already adopted in the literature (9)]. The weekly coefficient of variation LnRMSSD (LnRMSSDcv) for each athlete was also calculated from the ratio between the individual weekly standard deviation of LnRMSSD and the individual weekly average of LnRMSSD (9).

Athletes performed the countermovement jump (CMJ) on a contact mat of a 0.1 cm precision (Hidrofit® Ltda, Brazil) connected to a Multisprint software (Hidrofit® Ltda, Brazil). The athlete was positioned with his or her feet at a parallel position on the mat, hands resting on the height of the iliac crest, head up, and looking forward. They were instructed to maintain their hands in the iliac crest and extend their knees during the flight phase. On hearing the "jump" command, the individual immediately flexed their knee to the extension that felt more comfortable and jumped vertically as high as possible. Athletes performed five jumps, and the mean value was used (12). $ICC_{(2,1)} = 0.95$ (CI 95% = 0.94 – 0.96; $F_{(217,868)} = 98.880$; $p < 0.0001$; SEM = 1.39 cm).

The maximal strength handgrip test (MSH) was conducted with the judo athletes standing upright, the shoulder placed at 90º of flexion, and the elbow completely extended (4). The athletes pressed the dynamometer (Kratos Ltda®, Brazil) during three attempts of maximum effort for five seconds with the dominant hand and a 1-minute pause between tests (4). The value was expressed in its absolute terms (kgf). The highest value of the three attempts was assumed as the maximum isometric handgrip strength. $ICC_{(2,1)} = 0.91$ (CI 95% = 0.89 – 0.93; $F_{(217,434)} = 33.576$; $p < 0.0001$; SEM = 0.36 kgf).

The endurance strength handgrip test (ESH) was performed five minutes after the MSH. The test comprised eight maximum isometric contractions of 10s, alternating with 10s of passive rest (4). The execution, position, and instruments used were the same as described in the test above. Each athlete was told to perform the highest contraction force possible in each sustained contraction. The isometric strength of each contraction was determined in absolute terms (kgf). We analyzed the delta change (%) between the average of the first 3 attempts and the last 3 attempts. Thus, the endurance strength was expressed as a percentage of strength reduction at the end of the effort. $ICC_{(2,1)} = 0.87$ (CI 95% = 0.75 – 0.92; $F_{(217,434)} = 31.006$; $p < 0.0001$; SEM = 0.37 kgf).

We evaluated subjective self-reported wellness measures using a customized questionnaire comprising perceived sleep quality and quantities of stress, muscle fatigue, and muscle soreness. Each question was scored on a 7-point scale on which "1" and "7" represented "very, very good" and "very, very poor" wellness ratings, respectively. As an overall wellness measure, the Hooper-Index is the sum of its four subsets (37).

At the end of each training session, the athlete reported the perceived exertion of the session (RPE session) on a scale ranging from 0-10, where 0 represents rest and 10 means maximal (15). Thus, the internal training load is the product between the subjective value of the RPE session and the duration of training in minutes and expressed in arbitrary units (15). We recorded the internal load of each training session and the weekly sum of internal loads. The Monotony is the ratio between the average internal weekly load by its weekly standard deviation. At the same time, the Strain is the product between the weekly internal load and the Monotony (15).

According to an activity catalog, staff members registered the training means used in the training sessions (34), for example, the preparatory exercises used, the type of *randori* used in the technical-tactical session, and its respective duration and pause. In the strength training session, all activities and their loads were recorded (Table 2). Therefore, we used the total weekly *randori* time as the primary external load measure of technical-tactical sessions.

Statistical Analysis

The individual daily data (LnRMSSD; LnRMSSDcv; CMJ; MSH; ESH; Hooper Index) were averaged to present the weekly group mean (± standard deviation). The internal load was presented as an average (± standard deviation) of the weekly sum of daily internal loads. Monotony and Strain data are expressed in a single weekly indicator representing the group as a whole.

Before the inferential analysis, data normality and homoscedasticity were tested with the Shapiro-Wilk and Levene tests. Then, a one-way repeated-measures ANOVA was performed to analyze the variables across the weeks. If necessary, Bonferroni's *post-hoc* was used. We performed analyzes of statistical power, with all tests presenting power above 0.80 and effect size above 0.50. A significance level set at $\alpha \leq 0.05$ was used in all inferential analyzes. All data were analyzed and plotted using the statistical package Graph Pad Prism™ (version 5.0, GraphPad Software, San Diego, CA, USA).

RESULTS

Table 1. Descriptive data on hydration status and body weight. * Significant difference
Significant difference between weeks 1 and 4 (p < 0.05).

The hydration status and body weight data are shown in Table 1. There was a significant difference in urine specific gravity between week 2 and weeks 1 and 4 (F = 4.94; p = 0.008). However, the mean values for all weeks showed that athletes remained within an acceptable range of hydration (<1.030), with some sporadic cases presenting discounts between 1.030 and 1.034. Also, body mass remained constant throughout the period with no significant differences between weeks (F = 0.28; p = 0.83).

The training load was relatively similar across the first 3 weeks of training (Table 2). However, it decreased in the 4th week, with a 50% reduction in *Randori's* total weekly time compared to the 2nd week (Table 2).

Table 2. External Load data description.

TECHNICAL TACTICAL SESSIONS	WEEK 1	WEEK 2	WEEK 3	WEEK 4
OBJECTIVE SESSIONS	3 sessions Strength and Power specific. 1 sessions Newaza. 1 session Anaerobic Resistance Randori.	2 sessions Strength and Power specific. 1 session Newaza. 1 session Anaerobic Resistance Randori. 1 session Aerobic Randori.	2 sessions Strength and Power specific. 1 session Newaza. 1 session Anaerobic Resistance Randori. 1 session Aerobic Randori.	2 sessions Strength and Power specific. 3 sessions Aerobic Randori.
EXERCISES	• Exercise aiming maximal power output in a blow. e.g an uke is held at back by other uke. Tori applies three entrances of blow and at the fourth he throws uke. • Strength resistance exercise to improve gripping. e.g. climbing ropes and crushing grip. • Uchikomi static and linear for velocity Kumi-kata. Grip fighting. • Randori directed. In a pre-determined combat, one judoist only attacks while the other only defends. They switch positions according to the coach. • Randori with transition Ne waza • Golden Score Randori. During the Randori, the judoist who scores first, win.			• Aerobic Uchikomi and Naguekomi • Tandoku-Renshu • Randori (Golden Score)

STATUS HYDRATION	WEEK 1	WEEK 2	WEEK 3	WEEK 4
MEAN ± SD	1.026 ± 0.0026	1.029 ± 0.0024*	1.026 ± 0.0039	1.025 ± 0.0031
MINIMUM	1.020	1.025	1.022	1.022
MAXIMUM	1.029	1.033	1.034	1.032
% Dehydrated	0%	30%	20%	10%
		BODY WEIGHT (kg)		
MEAN ± SD	70.8 ± 20.5	70.8 ± 20.6	70.8 ± 20.6	71.1 ± 21.0
MINIMUM	42.8	42.8	42.7	42.8
MAXIMUM	114	114.4	114.6	115.2

- Randori Free

RATIO EFFORT:PAUSE RANDORI	1:3 and 1:2	1:2 and 1:1	2:1 and 1:1	1:3 and 1:4
TOTAL TIME WEEKLY RANDORI	160 min	155 min	155 min	80 min

Table 2 *cont.*. External Load data description.

STRENGTH AND CONDITIONING SESSIONS				
OBJECTIVE SESSIONS	2 sessions for Strength and Power	2 sessions for Strength and Power	2 sessions for Strength and Power	2 sessions for Strength and Power
EXERCISES	• Squat • Snatch • Clean and Jerk • Stiff • Bench Press • Rower Machine • Judogi dynamic pulling	• Squat • Snatch • Clean and Jerk • Stiff • Bench Press • Rower Machine • Judogi dynamic pulling	• Squat • Snatch • Clean and Jerk • Stiff • Bench Press • Rower Machine • Judogi dynamic pulling	• Squat • Snatch • Clean and Jerk • Stiff • Bench Press • Rower Machine • Judogi dynamic pulling
VOLUME	4 series of 6 repetitions	4 series of 3 repetitions	4 series of 3 repetitions	4 series of 2 repetitions
INTENSITIES	70 % - 80 % 1 RM	80 % - 90 % 1 RM	80 % - 90 % 1 RM	90 % - 95 % 1 RM
PAUSE	1 - 2 MIN	1 - 2 MIN	2 - 3 MIN	2 - 3 MIN

The internal load showed a significant time effect (F = 6.51; p =0.001, Figure 2-A), and both 2nd (p <0.05) and 3rd week (p <0.01) showed higher internal loads than week 4. Monotony was significantly different over time (F =8.07; p =0.0005, Figure 2-B), and week 1 (p <0,001) showed lower Monotony than the other three subsequent weeks. The Strain was significantly different over time (F =4.86; p= 0.007, Figure 2-C), and both the 2nd (p <0.001) and 3rd weeks (p <0.001) showed higher Strain than week 1.

Concerning the neuromuscular parameters, MSH was significantly different over time (F =11.60; p <0.001, Figure 2-D), with the 3rd and 4th weeks showing higher values than the 1st and 2nd weeks (p <0.01). On the other hand, the ESH was not significantly different over time (F =0.84; p =0.48, Figure 2-E). However, the CMJ was significantly different over time (F =7.72; p =0.0007, Figure 2-F), and the 4th week showed a higher CMJ height than the 1st week (p <0.001).

Regarding the physiological variables, the LnRMSSD did not vary during the observation weeks (F =1.07; p =0.36, Figure 2-G). In contrast, the LnRMSSDcv showed a significant time effect (F = 3.48; p =0.02, Figure 2-H), and both the 3rd and 4th weeks presented lower values than the 1st and 2nd weeks (p <0.05).

Regarding perceptual aspects, the Hooper Index showed a significant time effect (F =2.97; p =0.04, Figure 2-I), but pairwise comparison did not reveal differences between weeks.

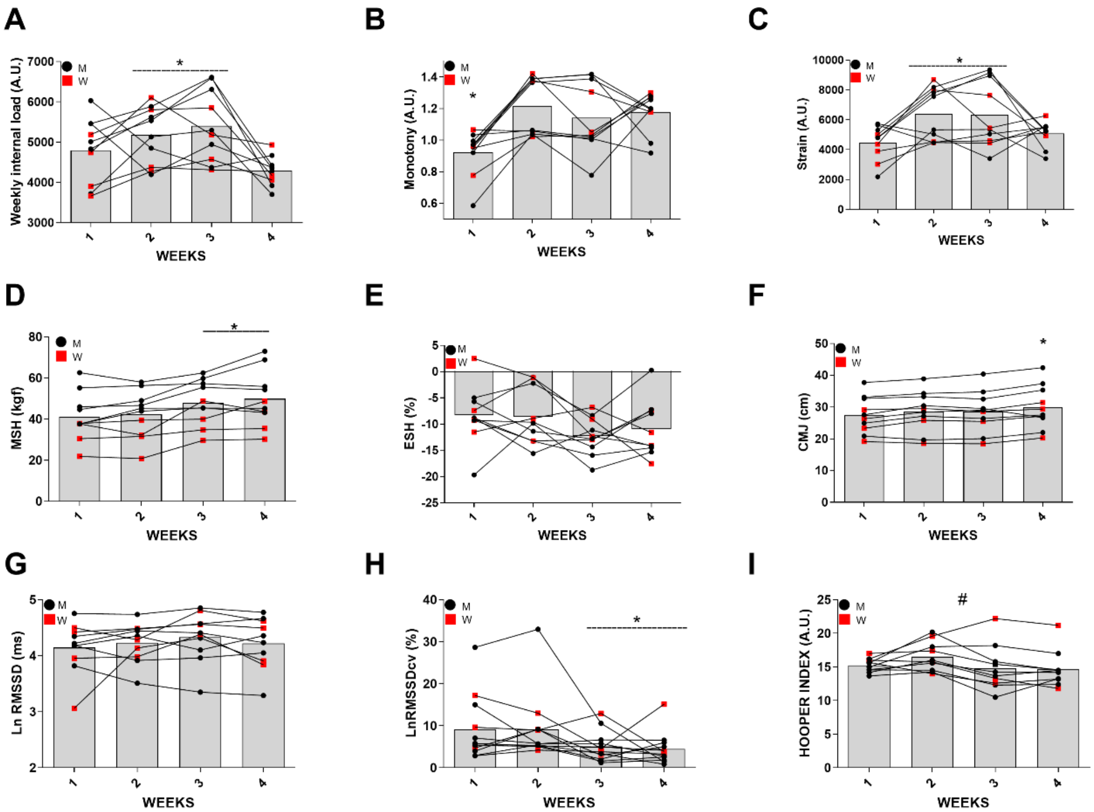

Figure 2. Perceptual, neuromuscular and physiological variables over time. M: man; W: woman. *Significant difference from other weeks ($p < 0.05$). #Main effect time ($p < 0.05$).

DISCUSSION

The present study described the training load in a typical judo training routine and the resulting internal load. We hypothesized that physiological, perceptual, and performance variables may reflect alterations in judo training loads, like increasing or reducing weekly randori times, and that this could present temporal similarities with physiological, perceptual, and neuromuscular responses. Therefore, the study hypothesis was accepted. Regarding the latter, the athletes perceived a more significant internal load and Strain during the second and third weeks of observation within the competitive period. However, maximal upper body strength increased significantly despite the higher load accumulation during the second and third weeks. Still, vertical jump performance improved when the internal load decreased in the fourth week of observation. Furthermore, the reduction in the LnRMSSDcv indicated a positive cardiac autonomic response during the third and fourth weeks of observation, suggesting that the athletes were coping well with the loads accumulated during the four weeks of monitoring.

The present study described the types of training used in tactical-technical training during a competitive period in a high-level judo team. Previous studies have shown that judo training sessions are typically 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* (18). Olympic judo athletes perform *Uchikomi* exercises, divided into Shadow — technique repetition alone; Static —technique with a partner in a static position; Dynamic — practice with a moving partner; Strength —technique against two or more other athletes who try to resist the technique application; Speed — technique performed as fast as possible (20). In the present study, these variations of *Uchikomi* were used to meet the general objectives of the sessions, and the first 3 weeks prioritized exercises to develop strength and power 3 times a week. Regarding the use of *randori* with Olympic athletes, they are usually performed in all sessions and can last 60 minutes per session (20). During training sessions, *randori* is the exercise that most closely mimics competitive matches (8). It comprises multiple periods of high-intensity intermittent combat sessions within high post-exercise blood lactate concentrations (18). Impacts on the psychophysiological responses of judo athletes during traditional technical-tactical training depend on the different organizations of the effort: pause ratio and volume of *randori* (11). In this study, the maximal *randori* time per session reached 40 minutes with variations throughout the week in the effort: pause ratio to possibly activate different metabolic pathways. This shorter *randori* time observed in the present study may be due to the level of athletes, who still demand more time dedicated to exercises for technical development. Therefore, the 4th week aimed to offer a short taper. For this reason, coaches reduced the weekly volume of *randori* and used lighter techniques such as *tendoku renshu* (an exercise in which the athlete performs fighting movements alone). However, to maintain intensity, *randori* exercises were used in the golden score format, where the first player wins, and thus, athletes have a shorter *randori* time.

Although in the present study, the first three weeks of training had similar characteristics to the training load in judo, the individual responses to internal load in the 2nd and 3rd weeks showed a significant increase compared to the first training week. The internal load can be the individual's physiological response to the prescribed external load (5). It has been broadly observed that the internal load is greater in preparatory than competitive periods (1) and that when well administered, it probably causes positive physiological adaptations. The present study was conducted during the competitive period but presented internal loads well above those reported in the literature (1). Higher internal loads associated with increased Strain indicate more significant physiological strain and can lead to negative performance responses due to overreaching (40). Despite the high internal loads in the present study, the significant performance responses corroborate previously reported data. Furthermore, the refined manipulation of the internal load progression allows positive adaptations in judo performance (1,2,17,19).

The subjects of the present study presented increasingly higher MSH values during the observation period. The reduction of the MSH during official matches is inversely correlated with combat efficiency (27). Improving the grappling predominance through improving MSH may result in a higher probability of success and superiority over the opponent (24). Various training loads are imposed on the athlete during the mesocycle, but adequate recovery provides the conditions to elicit positive adaptation and performance enhancement. Franchini et al. (17) showed an improvement in the maximal strength of judo athletes over 8 weeks of linear and undulatory strength training periodization. However, other studies (22) did not identify an improvement in handgrip strength during a short training period, probably due to a direct relationship with the training load or even the training level of the athletes. In the present study, MSH apparently adapted positively, even though this was not expected due to the short-term study design.

On the other hand, the ESH did not differ over the observation weeks. Other studies have found an improvement in strength endurance over more extended training periods (21). Therefore, it is tempting to speculate that strength endurance needs a longer time or specific training to elicit positive adaptations. However, it is essential to emphasize that ESH has been accessed in the present study to verify possible acute alterations reflecting training load fluctuations. Furthermore, the fact that ESH did not present significant variations within the observation period indicates that ESH was not sensitive to distinguishing the training load variations used with the study subjects.

Not surprisingly, CMJ performance significantly improved in the 4th week, coinciding with a substantial reduction in weekly *randori* time and internal loads. Vertical jump performance depends on muscle-elastic mechanisms such as the stretching-shortening cycle (CAE). This ability to generate potential elastic force is related to a higher number of throwing and greater efficiency in a judo match (13,26). In addition, the reduction in internal load may have generated an acute performance improvement effect like a tapering period. These findings follow studies that showed vertical jump improvements in judo athletes after tapering (33). Performance improvements are also accompanied by increased testosterone-cortisol ratio, immune system function, and perception of recovery (33).

The present study showed significant changes during the training process in the autonomic nervous system. Although LnRMSSD was not significantly different across the weeks, LnRMSSDcv was reduced towards the end of the observation period. HRV responds negatively to exaggerated volumes of judo training (29); however, when well-balanced, the training load does not influence cardiac vagal activity in the short term (6), which probably explains the present study results. However, this is the first study to observe in judo that even though the internal load was increased in weeks 2 and 3, HRV daily fluctuation (LnRMSSDcv) responded positively by reducing its value. This effect has already been shown in other sports (14,30). Thus, the reduction of LnRMSSDcv may have occurred due to a reduction in the training-induced autonomic disturbance and reflected a positive adaptation to the training program despite its short duration. Flatt and Howells (14) noted that LnRMSSD did not vary substantially during an observation period of 3 weeks, while LnRMSSDcv showed to be a more sensitive training-response marker among elite-level players.

Nevertheless, it is still likely that LnRMSSD is meaningful at the individual level when monitored over regular training periods in elite players, as persistent reductions in LnRMSSD may reflect a more severe level of maladaptation (36). Furthermore, maintaining a good hydration status in the current study is essential since HRV can be affected by alterations in

plasma volume due to baroreflex and other regulatory mechanisms (10). Thus, the present study results demonstrate that LnRMSSDcv can help monitor physiological responses to different training loads in judo athletes.
This study describes how training load in judo was kept constant for 3 weeks in a 4-week observation period of a traditional judo training program. This training load may have led to a progressive increase in the internal load, enabled performance improvements of the upper limb's maximal strength, increased lower limb performance, and allowed proper maintenance of the autonomic function. The occurrence of a positive perceptual response is corroborated through the maintenance of the Hooper Index. An adequate interaction between the prescribed training and internal load may explain the observed results. This balance allows a satisfactory autonomic adjustment, performance increases, and a proper psychophysiological recovery.

We would like to reinforce the present study's descriptive nature, which is relevant considering the scarce information on the investigated topic in the literature. We also did not control the menstrual cycle phase of the female athletes who participated in the investigation. This is due to the short-duration fashion of the study, which would not allow a comparison of the measured values in one menstrual cycle with the data collected in a subsequent cycle. This is a limitation of the study. However, the authors believe that, even though responses may be attenuated or increased depending on the menstrual cycle phase, these variations would not alter the overall response pattern.

Conclusion: The present study describes the training load in a traditional training period in judo and its internal load response. Manipulating the total *randori* time can reflect the internal load and possibly allows performance increases in the lower and upper limbs and the maintenance of an adequate autonomic function, which goes along with the maintenance of the Hooper index, an indicator of a positive perceptual response. Furthermore, these findings indicate that recording the prescribed load, especially the whole weekly *randori* time, can help coaches plan adequate training loads, which may be particularly relevant during tapering periods.

Regarding using different variables to monitor the response to the applied training load, the present study demonstrates that neuromuscular, physiological, and perceptual adaptations present various time courses. Thus, there is a need to monitor more than a single variable or more than a single psychophysiological response. Therefore, load monitoring in judo requires understanding the different time courses of physiological, neuromuscular, and perceptual adaptations.

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