

Physiological and performance changes in national and international judo athletes during block periodization training

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ABSTRACT: Block periodization (BP) has been proposed as an alternative approach for application in the context of high-level sports. Despite its growing acceptance, there is no empirical evidence of BP adoption in high-level judo athletes. Therefore, this study aimed to compare the maximal strength, muscle power, judo-specific performances, and hormonal concentration changes of state/national level (NG) and international level (IG) judo athletes subjected to BP. Twenty-one elite judo athletes (international level = 10; 21.7±1.9 years, 167.2±7.6 cm, 67.6±9.4 kg, 15.7±1.9 years of practice; national level = 11; 21.9±3.0 years, 167.5±9.1 cm, 71.8±16.5, 15.9±3.0 years of practice) were subjected to 13-week BP training (5-week accumulation phase [ACP], 5-week transmutation phase [TP], and 3-week realization phase [RP]). The judo-specific performance (SJFT) increased as there was observed a decrease in the SJFT index (final heart rate [HR] (bpm) + HR1 min after the test divided by the number of throws) for both NG (effect size [ES] = 0.83) and IG (ES = 0.53) from ACP to TP ($p < 0.05$). The row exercise maximal strength decreased ($p < 0.05$; ES = 1.35) after the ACP but returned to the baseline level after the TP, for the whole group (ES = 1.39). The athletes did seem to cope appropriately with the demands of BP, as besides increases in SJFT performance no significant changes were observed for cortisol and testosterone concentrations. This is the first study to demonstrate that judo athletes from different competitive levels subjected to BP improved SJFT, likely due to an appropriate balance between training loads and recovery. Thus, the BP approach may be a useful alternative periodization strategy for high-level judo athletes.

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INTRODUCTION

Judo is a high-intensity intermittent grappling combat sport, demanding both technical-tactical and physical excellence to achieve success in competition [1, 2]. Since the introduction of the international ranking system in 2009 by the International Judo Federation [3], judo athletes compete regularly in seven to ten competitions per year [4]. Thus, training organization has gained even greater relevance in the last few years.

The organization of the training process is a complex task, which is normally based on periodization approaches [5, 6]. Multidirectional block periodization (BP) has been proposed as an alternative approach to be used in the contemporary high-level sports context [5, 6]. Multidirectional BP presupposes the consecutive development of three main types of “mesocycles” which have been named ‘accumulation’, which focuses on basic abilities, ‘transmutation’, which focuses on sport-specific abilities and ‘realization’, which focuses on recovery and peaking towards competition or trials.

Despite the growing acceptance of this alternative periodization training approach and in spite of claims for its adoption in judo athletes [7], there is no empirical evidence on BP in high-level judo athletes. Additionally, most of the studies investigating physiological and performance adaptation to judo training involved only a few weeks [4, 8, 9, 10, 11, 12, 13], young judo athletes [14, 15], specific procedures associated with the intensification and tapering phases [16] or limited performance-related variables [4, 8, 9, 10, 12, 13], notably, adopting non-judo-specific tests [4, 8, 9, 12, 13].

In order to quantify training load during periodization training, some studies on judo athletes have used the session rating of perceived exertion (session-RPE) method [14, 16, 17, 18]. Morales et al. [18] reported that 4 different methods of internal training load quantification (work endurance recovery method, session-RPE, Lucia and Stagno methods) did not differ among them and were significantly correlated ($r = 0.59$ to 0.87). Additionally, Agostinho et al. [14]

evaluated 10 male judo athletes (15.9 ± 1.3 years) competing at a regional/state level during a 2-year training period and demonstrated the usefulness of session-RPE using system modelling that consisted of mathematically relating the training load of the training sessions (system input) to the change in performance (system output). Recently, Agostinho et al. [17] reported that internal training load (TL) assessed by the session-RPE method described appropriately the external load during 2 different training macrocycles on 10 male judo athletes (18 ± 2 years); the authors reported that the internal TL decreased significantly during the competition phase in each macrocycle compared to the preparatory phase, but internal TL did not influence the resting immunoglobulin A (mucosal immune parameter) or salivary testosterone and cortisol concentrations.

These findings suggest that judo athletes could achieve positive adaptation due to an appropriate balance between TL and recovery, and that salivary testosterone and cortisol changes might be used to monitor the adaptation of the body to the imposed TL, but not as a TL indicator *per se*. Nevertheless, the dynamics of the internal TL, steroid hormonal concentrations, and performance measures during BP in high-level judo athletes is still unknown. Thus, the objective of the present study was to compare state/national level to international level judo athletes concerning maximal strength, muscle power, and judo-specific performances, as well as the hormonal responses, to three different training time points during BP.

MATERIALS AND METHODS

Participants

The sample included 21 elite judo athletes. Eleven judo athletes (5 males and 6 females, 21.9 ± 3.0 years, 167.5 ± 9.1 cm, 71.8 ± 16.5 , 15.9 ± 3.0 years of practice) were included in the state/national group, and ten judo athletes (6 males and 4 females, 21.7 ± 1.9 years, 167.2 ± 7.6 cm, 67.6 ± 9.4 kg, 15.7 ± 1.9 years

of practice) in the international group according to their competition schedule during and after the last phase of the assessed BP (realization phase [RP]). Prior to the beginning of the study, all athletes underwent medical screening to indicate health status. The athletes' training schedule comprised 8-10 sessions per week, with the duration of each session typically 90-120 min; habitually, athletes performed strength and conditioning training sessions in the morning and specific judo training in the afternoon. All the athletes had experienced at least one BP training cycle and were familiar with all the training and tests procedures before participating in this study. After being informed of the experimental procedures, including benefits and potential risks, the players gave written consent for participation in the study. The local University Research Ethics Committee approved the study.

Design

The BP concepts were adopted. A 13-week training stage was investigated and was divided as follows: five weeks of accumulation training phase (ACP), followed by a 5-week transmutation phase (TP), and 3-week realization phase (RP) (Figure 1). The main physical training content developed during the ACP included strength exercises, which were mainly performed using weight training exercises, and conditioning workouts aimed at developing judo-specific strength (i.e., muscle power in lower and upper body and strength-endurance in the upper body – especially forearm muscles – and core regions). These conditioning workouts were performed according to judo-specific actions, using, for example, bouts of *uchi-komi* and *randori*. During the ACP the technical preparation was mainly developed throughout *uchi-komi* and *nage-komi* exercises. The aim of the physical training during TP was to develop muscle power. The physical training content included explosive weight training, jumps, and throws, while technical and conditioning workouts were performed according to judo-specific activities, such as *uchi-komi* and *randori*.

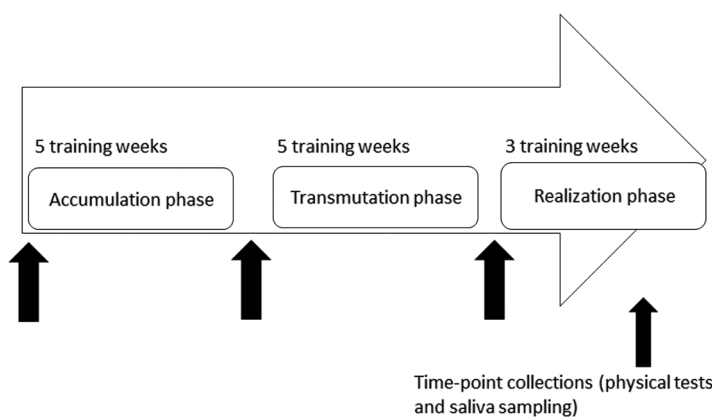


FIG. 1. Schematic representation of experimental study design. The 13-week block periodization training.

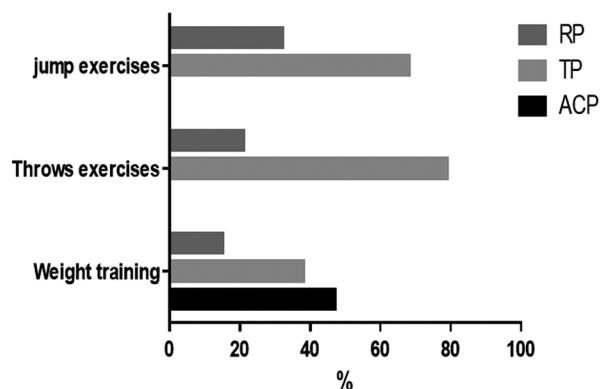


FIG. 2. Percentage of the type of performed exercise in each block periodization phase. Note: ACP = accumulation phase; TP = transmutation phase; RP = realization phase).

During the RP, the training content for both strength and conditioning, and technical workouts were similar to those developed during TP, but the training volume was substantially reduced and the specific judo technical actions became the main focus of the training programme. Figure 2 illustrates the training volume percentage (number of sets and repetitions performed at each BP phase divided by the total volume performed over the entire BP) for the main physical training exercises over the BP phases. Performance tests and saliva collections were performed at the beginning of the ACP (T1), after ACP (T2), and after the TP (T3). Athletes were required to have their last meal (lunch) at least 2 h before saliva sampling and performance assessment. The samples were always collected at the athletes' training facility at 9:00 a.m. Athletes' session-RPE was recorded ~30 min after each training session using the adapted Borg 10-point scale (CR-10 scale) [19]. Session-RPE was derived by asking each judo athlete "How intense was your session?". Athletes were already familiarized with the scale before this study. Daily training load (TL) was calculated by multiplying session-RPE by the session duration [19].

Saliva collection and analysis

All athletes remained in a seated position, with eyes open, head tilted slightly forward, and making minimal orofacial movement during saliva collection. Unstimulated saliva was collected in a pre-weighed sterile 15 mL centrifuge tube. The collection time was 5 min for each participant to allow for collection of a sufficient sample volume (at least 2 mL). The samples were stored at -80°C until assayed. After thawing and centrifugation (10,000 g for 10 min at 4°C), the samples were tested for cortisol and testosterone concentrations in duplicate using competitive enzyme-linked immunosorbent assays (ELISA, Expanded Range, EIA Kit – 1x96 wells – Salimetrics) in accordance with standard procedures [20, 21, 22]. The intra-assay coefficients of variation for cortisol and testosterone concentrations were ~4-5%.

Vertical jumps (CMJ and SJ)

Athletes performed both countermovement (CMJ) and squat jumps (SJ). For CMJ, they initially lowered themselves from an initial standing position to a self-selected position and performed a jump as quickly as possible with maximal effort, keeping their hands placed on their hips. While no restrictions were placed on the knee angle attained during the eccentric phase of the jump, judo athletes were instructed to maintain straight legs during the flight. The SJ was performed as a concentric only movement (i.e. no sinking down before the jump). Three jumps were performed for each type of jump with a 2-min rest period between jumps. All jumps were conducted on an electronic jump mat (Ergojump Jump Pro 2.0 – CEFISE, Brazil). This jump mat provides a valid measure of jump height compared with a criterion system ($r = .967$) [23]. Pilot testing conducted with players from the present study indicated that this jump mat also provides reliable measures ($\text{CV} < 2.0\%$).

Rowing maximum strength test

Maximum dynamic strength (1RM) for the row exercise was assessed in accordance with procedures previously used by Franchini et al. [11]. Briefly, the athletes lay on an elevated bench, with the chest, abdomen, and thighs in contact with the bench. After lower and upper limb stretching exercises, the athletes performed a set of 5 repetitions at approximately 50% of the estimated 1RM followed by another set of 3 repetitions at 70% of the estimated 1RM. Warm-up sets were separated by a 2-min interval. After completion of the 2nd set, subjects rested for 3 min. Subsequent lifts were single repetitions of progressively heavier loads, until failure. Maximum dynamic strength (1RM load) was determined as the maximum weight that could be lifted once with proper technique. The interval between 1RM attempts was 3 min, and a maximum of 5 attempts was allowed. The athletes were thoroughly familiarized with both the test procedures and the row exercise, which was habitually performed during their physical training sessions. Strong verbal encouragement was provided during all lifts.

Special judo fitness test (SJFT)

The SJFT is a specific test divided into three effort periods (A = 15 s; B and C = 30 s each) with 10 s intervals between them [24]. Briefly, each partner is positioned 6 m apart and the executant is required to run towards each partner and then throw them as many times as possible using the *ippon-seoi-nage* technique. Heart rate (HR) is measured immediately after and 1 min after the end of the test. The number of throws is summed and an index is calculated as follows: final HR (bpm) + HR 1 min after the test (bpm) divided by the number of throws. The lower the index, the better is the SJFT performance. This test has been shown to be highly reliable ($\text{ICC} = 0.89$ for the index [24]).

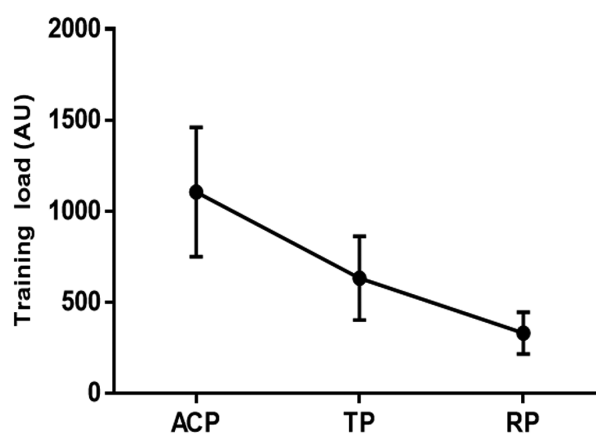


FIG. 3. Training load of physical training sessions performed during accumulation (ACP), transmutation (TP) and realization phase (RP) (mean \pm SD).

Statistical analysis

Descriptive values are shown for the average TL for each periodization phase (Figure 3). A two-way analysis of variance (two-way ANOVA; level [state/national and international groups] and time-point assessments [T1, T2, and T3]) with repeated measures in the second factor were used after checking for data normality (Shapiro-Wilk test) and homoscedasticity (Levene's test). The sphericity of data was assumed according to the Mauchly's test results. In the event of a significant difference, a Bonferroni post-hoc test was used to identify any localized effects. Statistical significance was set at $p < 0.05$. The effect size (ES) for comparisons between each pair of time-point assessments (T1 vs T2, T1 vs T3, T2 vs T3) was calculated for the whole group and separately for a single group (state/national or international group) when appropriate. Cohen's *d* statistics represented effect sizes with thresholds of 0.20-0.50, > 0.50-0.80, and > 0.80, interpreted as *small*, *moderate* and *large* effects, respectively [25].

RESULTS

The training load (TL) of physical training sessions is presented in Figure 3. Large effects for changes in physical training load among the phases were observed (ES = 1.6, 3.3, and 1.7, for ACP vs TP, ACP vs RP, and TP vs RP, respectively).

For both cortisol and testosterone no effects of competitive level, training phase, or interaction were detected ($p > 0.05$) (Table 1).

The results of performance tests for SJ, CMJ and rowing maximum strength are presented in Table 2. For SJ and CMJ no effects of competitive level, training phase, or interaction were observed. For rowing maximum strength, a training phase effect was found, with a lower value at T2 (after accumulation phase) compared to T1 (beginning of the accumulation phase; ES [T1 vs T2] for the whole group = 1.35) and T3 (after the transmutation phase; ES [T3 vs T2] for the whole group = 1.39) ($p < 0.001$ for both comparisons). However, no effects ($p > 0.05$) for competitive level or interaction were detected.

The number of throws for each set and HR (immediately after and 1 min after the test) are presented in Table 3. The number of throws during set A did not differ ($p > 0.05$) between competitive levels. However, there was an effect of training phase ($p < 0.001$) and competitive level and training phase interaction ($p < 0.001$). A higher number of throws was performed at T3 compared to T1, and T3 vs T2 ($p < 0.001$ for both comparisons; ES for the whole group = 0.77 and 0.76, respectively). The interaction effect indicated that this increase was a consequence of the higher number of throws performed by the state/national group at T3 (vs T1 and vs T2; $p < 0.001$ for both comparisons; ES for state/national group = 2.00

TABLE 1. Cortisol and testosterone concentrations at the three time-points collection (mean \pm SD).

	Cortisol ($\eta\text{mol}\cdot\text{L}^{-1}$)		Testosterone ($\mu\text{mol}\cdot\text{L}^{-1}$)	
	IG	NG	IG	NG
T1	5.7 \pm 1.8	6.4 \pm 3.9	414.8 \pm 215.0	381.5 \pm 98.6
T2	6.4 \pm 1.6	8.6 \pm 2.3	358.8 \pm 174.3	389.9 \pm 108.8
T3	7.4 \pm 3.2	5.5 \pm 1.7	519.2 \pm 221.6	360.3 \pm 90.8

T1 = beginning of the accumulation phase; T2 = after accumulation phase; T3 = after the transmutation phase; IG = International group; NG = national group.

TABLE 2. Performance tests across the block periodization training.

	NG			IG		
	T1	T2	T3	T1	T2	T3
SJ (cm)	20.81 \pm 3.41	22.28 \pm 2.99	22.15 \pm 3.15	24.36 \pm 4.64	25.30 \pm 2.73	24.66 \pm 3.15
CMJ (cm)	23.10 \pm 5.23	23.86 \pm 7.80	24.10 \pm 7.08	28.36 \pm 3.99	29.08 \pm 4.96	29.76 \pm 4.12
Rowing 1RM (kg/kg) ^{***}	1.05 \pm 0.24	0.76 \pm 0.22	1.08 \pm 0.26	1.09 \pm 0.17	0.77 \pm 0.15	1.13 \pm 0.17

T1 = at the beginning of the accumulation phase; T2 = after accumulation phase; T3 = after the transmutation phase; SJ = squat jump; CMJ = countermovement jump; 1RM = one-repetition maximum; ^{***} significant difference ($p < 0.001$) between T2-T1, and T2-T3 for both groups. NG = national group; IG = International group.

TABLE 3. The number of throws for each set and HR for each time-collection point (mean \pm SD).

SET	Number of throws						HR		HR 1min	
	A		B		C		IG	NG	IG	NG
	IG	NG	IG	NG	IG	NG				
T1	6.5 \pm 0.5	5.7 \pm 0.4	11.5 \pm 1.1	10.8 \pm 0.9	10.8 \pm 0.8	10.0 \pm 0.8	180 \pm 6.4	183 \pm 5	165 \pm 8	170 \pm 6
T2	6.5 \pm 0.5	5.5 \pm 0.4	11.8 \pm 1.0	10.8 \pm 0.9	11.0 \pm 0.7	10.3 \pm 0.7	181 \pm 5.4	185 \pm 5	164 \pm 7	166 \pm 7
T3	6.5 \pm 0.5	6.5 \pm 0.5	12.0 \pm 0.7	10.8 \pm 0.9	11.0 \pm 0.7	10.5 \pm 0.5	183 \pm 5.4	185 \pm 5	162 \pm 5	165 \pm 6

T1 = beginning of the accumulation phase; T2 = after accumulation phase; T3 = after the transmutation phase; IG = International group; NG = national group; HR = heart rate immediately after the test; HR 1min = heart rate 1 minute after the test.

and 1.72, respectively). For set B, no effects ($p > 0.05$) of competitive level, training phase or interaction were detected. The number of throws during set C differed between training phases ($p < 0.05$), with a higher number of throws performed at T3 compared to T1 (ES for the whole group = 0.50). However, no effects of competitive level or interaction were found ($p > 0.05$). For total number of throws there was no effect ($p > 0.05$) of competitive level, but an effect of training phase ($p < 0.001$) and competitive level and training phase interaction was found ($p < 0.05$). Total number of throws was lower at T1 compared to T2 ($p < 0.05$; ES for the whole group = 0.15) and T3 ($p < 0.001$; ES for the whole group = 0.50), and an increase was observed from T2 to T3 ($p < 0.001$; ES for the whole group = 0.31). The interaction indicated that the state/national level group performed a higher number of throws at T3 compared to T2 and T1 ($p < 0.001$ for both comparisons; ES for state/national group = 0.60, and 0.70, respectively).

HR immediately after the test varied across the training phases, with higher values at T3 compared to T1 ($p < 0.01$; ES for the whole group = 0.43). No effects of competitive level or interaction were detected ($p > 0.05$). For HR 1 min after the test a similar result was found, i.e., an effect of training phase was detected, with higher values at T1 (vs T2; $p < 0.05$; ES for the whole group = 0.31) and vs T2 ($p < 0.001$; ES for the whole group = 0.54). However, no effects of competitive level or interaction were observed ($p > 0.05$).

For the SJFT index there was no effect ($p > 0.05$) of competitive level. However, a training phase ($p < 0.01$) and a training phase and competitive level interaction were detected ($p < 0.001$). The SJFT index was higher at T1 vs T2 ($p < 0.05$; ES for the whole group = 0.16) and when T2 was compared to T3 ($p < 0.001$; ES for the whole group = 0.31) a decrease was detected: T1 vs T3 ($p < 0.001$; ES for the whole group = 0.50) (Figure 4A). The magnitude of this change was greater for the lower level group ($p < 0.001$ for both

comparisons). The interaction effect indicated that the state/national level group presented a decrease in the index at T3 compared to T1 and T2 ($p < 0.001$ for both comparisons). Comparing the SJFT from the beginning of the BP periodization (T1) with the end of the transmutation phase (T3), a greater ES was observed for the state/national group compared to the international group (T1 vs T3; ES = 0.86 for state/national and 0.53 for the international group) (Figure 4B).

DISCUSSION

The main findings of the present study were that 1) the judo-specific performance and row exercise maximal strength were sensitive to changes in training content across BP phases. However, this response was not clearly observed for muscle power measurements; 2) the judo-specific performance increased across the training phases, and this increase was higher for the state/national competitive level group than the international group; 3) the row exercise maximal strength decreased after the accumulated phase (from T1 to T2) but returned to baseline level after T3 (after the transmutation phase) for the whole group; 4) the judo athletes did cope appropriately with the demands of BP, as besides increases in SJFT performance, no changes were observed for cortisol and testosterone concentrations across BP training phases.

The results of the present study provide evidence to support claims for separating voluminous physical training content and intensive sport-specific training programmes into appropriate block mesocycles. The specific judo test performance (SJFT) was significantly increased for both state/national and international athletes, demonstrating that the BP approach may be a useful alternative periodization strategy for high-level judo athletes. In addition, it is worth noting that this increase was not accompanied by changes in hormonal profile, suggesting an appropriate physiological adaptation of the assessed athletes.

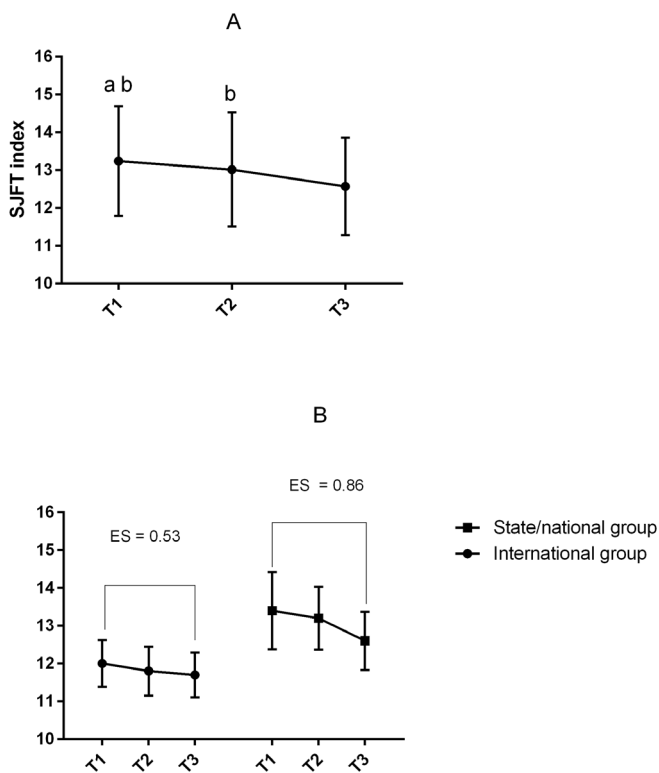


FIG. 4. SJFT index at each assessed time point for the whole group (A) and the SJFT index at each assessed time point separated by groups (B).

Note: mean \pm SD; a = different from T2 ($p = 0.016$); b = different from T3 ($p < 0.001$). T1 = beginning of the accumulation phase; T2 = after accumulation phase, and T3 = after the transmutation phase. ES = effect size.

Interestingly, the state/national judo athletes demonstrated higher increases in the SJFT. This result is novel and suggests that the higher the level of the judo athlete is, the lower are the expected increases. This finding corroborates the speculation from Papacosta *et al.* [16], who suggested that judo athletes of lower technical development might be more responsive to improvements in the SJFT than judo athletes with a higher technical level. Nevertheless, these authors did not compare judo athletes of different levels, but formulated this hypothesis due to the fact that in their study only half of the athletes presented improvements in the SJFT test after a tapering phase following a 1-week overloading phase. Indeed, Papacosta *et al.* [16] reported no significant improvements in SJFT.

A possible explanation for the discrepancy between the results from Papacosta *et al.* [16] and the present investigation for SJFT changes may be likely attributed to the duration of the experimental period and the training content performed by athletes. During the study of Papacosta *et al.* [16] the judo athletes undertook a 2-week intensification period followed by a 2-week tapering period. The intensification period was completed by doubling the “normal” training of the assessed athletes. Nevertheless, it is important to highlight that even when doubling the normal training volume, the athletes in

the Papacosta *et al.* [16] study performed half of the typical training volume compared to that of the sample of the present study. Therefore, it is possible that both the training duration and the structure of the training content might have influenced the differences between the studies’ results. Therefore, it seems prudent to admit that the current findings indicate the effectiveness of adopting the BP for high-level judo athletes and the possibility of using the SJFT as a useful means of training monitoring responses in high-level judo athletes.

Despite the improvement in the judo-specific test, lower-body muscle power (assessed via CMJ and SJ) did not change across the training phases. Investigations with adult judo athletes [4, 9, 26] that used vertical jump tests also did not find any significant change across different training duration and protocols. As a possible explanation for these results, Franchini *et al.* [4] suggested that as the CMJ is shorter than the duration of a judo throwing technique (~ 1.14 s), the typical judo training adaptation would not be noticed in this physical ability. Therefore, it might be assumed that CMJ and SJ are not sensitive enough to detect possible changes in physical performance of elite judo athletes.

Rowing 1RM performance was lower at T2 compared to T1, but returned to baseline at T3. Considering the training stimulus from the accumulation phase, the high training loads to which the judo athletes were submitted can explain this response. Studies investigating 18 weeks of judo training periodization [4] or 8 weeks of undulating versus linear strength periodization in judo athletes [11] reported increases of 8% and 11.5% in row 1RM. Thus, this test also seems to be sensitive to specific training load manipulations and can be used to evaluate judo athletes subjected to different training protocols.

It is worth noting that the data from salivary hormonal responses indicated that the judo athletes did cope well with the magnitude and the organization (distribution within the BP phases) of the training load, and therefore, in conjunction with the observed increases in SJFT performance, this finding reinforces the assumption that the BP approach may be an interesting alternative for training periodization of elite judo athletes. The absence of changes in testosterone and cortisol concentrations over the investigated period suggest that regardless of the training content as well as its distribution within the phase, athletes achieved positive adaptation due to an appropriate balance between training loads and recovery. For example, Kraemer *et al.* [27] demonstrated that an elevated level of testosterone was associated with performance in strength and power tasks, whereas diminished levels of testosterone and increased levels of cortisol have been linked to overtraining and reduced performance. It seems prudent therefore to assume that the separated block training content might be an important factor for the positive hormonal response observed in the present study.

While the data here are novel, there are limitations that should be acknowledged. It is possible that training load, intensity, distribution of training content during BP phases, and the types of training

sessions adopted in the current study may differ from other contexts (specific training schedules and other investigations). Moreover, we have only described the training dose using the session-RPE method. This method was recently reported to be significantly correlated with heart rate-based methods of internal training load quantification, more specifically with the Lucia method ($r = 0.64$) and Stagno method ($r = 0.59$) [18], even considering the potential limitation of heart rate to monitor high-intensity supramaximal exercises [28], as those typically observed in judo [29]. While this method has been shown to be valid for different sports, it describes one construct of dose, and other measures of training load (e.g. accelerometers) [30] may provide other relevant information concerning loads applied to judo athletes.

Moreover, it is worth noting that there was no assessment after the RP due to operational limitations mainly regarding the athletes' participation in different competitions as well as travel schedules. This information might contribute to an even deeper understanding about the BP. Regarding the effect of gender on the present results, it is possible that male and female judo athletes respond differently to BP. However, to avoid a significant impact of gender distribution on the results of the present study, we used a similar number of male and female judo athletes in each group. In addition, while the present findings might support the use of BP for high-level judo athletes, further studies should compare the effect of BP and those from the traditional periodization approach to improve our understanding regarding periodization strategies in high-level judo athletes.

CONCLUSIONS

This is the first study to describe physical and hormonal responses to BP in judo athletes from different competitive levels. The perfor-

mance in the SJFT improved for both state/national and international athletes, with state/national judo athletes presenting higher increases, suggesting that for higher level judo athletes, lower increments would be expected. Moreover, it is important to emphasize that this increase was not accompanied by changes in testosterone and cortisol concentrations, demonstrating that athletes had positive adaptation due to an appropriate balance between training loads and recovery. The present results demonstrated that the BP approach might be a useful alternative periodization strategy for judo athletes. However, while the present findings appear to be sufficiently robust to support the use of BP for high-level judo athletes, in a practical setting coaches should be aware that there is still a lack of empirical evidence that BP may be more appropriate than 'traditional' periodization, which implies using concurrent exercises (i.e. strength exercises and aerobic exercises) within phases.

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