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Monitoring internal training load and salivary immune-endocrine responses during an annual judo training periodization

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The objective of this study was to examine the internal training load (TL), IgA, and salivary steroid hormone responses in elite youth judo athletes during an entire annual training periodization. Ten male judo athletes (18±2 years, 72.3±12.3 kg, and 175±6 cm) competing at a state/national level were examined for the TL and salivary imune-endocrine responses variations over an annual judo season, divided in three macrocyles composed by distinct periods denominated preparatory period (PP), competitive period (CP) and transition period (TP). At the end of PP and CP, saliva samples were collected to determine cortisol, testosterone and IgA concentrations. Throughout PP and CP the session-rating of perceived exertion and the total duration of each session were monitored, allowing the internal TL and weekly training strain (TS) calculation. During all macrocycles, significant decreases in TL and TS were observed during CP compared with PP ($P<0.05$), although no significant differences were observed for immune-endocrine concentrations between PP and CP ($P>0.05$). Specific variations were observed comparing periods with similar characteristics throughout the macrocycles as higher TL and TS (PP1 to PP2 and PP3, $P<0.05$), increased testosterone (CP1 to CP3, $P=0.024$) and decreased testosterone-cortisol ratio (PP1 to PP2, $P=0.005$). The present findings suggest that the internal TL variations over an annual multipeak traditional periodization did not influence the resting mucosal immune-endocrinal responses in young judo athletes.

Keywords: Testosterone, Cortisol, Mucosal immunity, Session - rating of perceived exertion, Young athletes

INTRODUCTION

During a competitive judo combat, the glycolytic system is responsible for the maintenance of high-intensity actions during longer periods, the phosphagen (adenosine triphosphate-phosphocreatine) system is responsible by powerful actions during technique applications, while the recovery processes between high-intensity actions and matches are supported by the oxidative system (Franchini et al., 2013). To achieve success in competition, judo athletes engage in training programs involving combat simulation (*randori*), technical preparation (*uchi-komi* and *nage-komi*), and strength and conditioning sessions (Franchini and Takito, 2014).

In the last two decades an increase in the number of competitions during a competitive season has been observed (Sikorski, 2011). This elevated number of competitions across the annual-season might lead judo athletes to an increased risk of illness due to the insufficient period of recovery between both competitions and training sessions. This situation may cause the suppression of the immune system and may lead to an increase of the risk for greater incidence of upper respiratory tract infections (URTI) (Bishop and Gleeson, 2009).

It has been demonstrated in athletes that strenuous training might have an increased risk of infection because of transient immune suppression (Gleeson et al., 2013; Pyne et al., 2001). In judo, there are some reports on the effect of training sessions such as the increase of neutrophil and myogenic enzymes serum con-

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centration after training sessions (Umeda et al, 2008; Yaegaki et al., 2008).

A transient fall in salivary IgA (sIgA) has been showed to be a good predictor for increased risk of URTI in different sports athletes (Gleeson et al., 2013; Moreira et al., 2012; Mortatti et al., 2012; Neville et al., 2008). The role of sIgA is to prevent viral replication and to inhibit the attachment of bacteria and viruses at mucosal epithelium in the mouth, throat, and upper respiratory tract (Mackinnon and Hooper, 1996). Therefore, a decrease in the production and/or concentration of this antibody due to intensified training loads (TL) periods would represent a risk factor for subsequent URTI episodes in athletes (Fahlman and Engels, 2005).

It has been suggested that the TLs monitoring and its consequent manipulation may play a key role in ensuring an appropriate balance between training stress and recovery (Borresen and Lambert, 2009). The variation of training stress could maximize positive adaptations on athletes' performance whilst decreasing the likelihood for negative outcomes such as overuse injury, illness, nonfunctional overreaching, or in extreme cases overtraining syndrome (Brink et al., 2010; Coutts et al., 2007; Foster, 1998; Moreira et al., 2012; Robson-Ansley et al., 2009). In a practical setting, the TL in judo (Agostinho et al., 2015; Garatachea et al., 2012; Papacosta et al., 2013) and other combat sports (Haddad et al., 2011; Milanez et al., 2010) have been extensively quantified by means of the session - rating of perceived exertion (RPE) method.

Some studies with judo athletes have focused on the simultaneous monitoring of internal TL and immune-endocrine responses (Garatachea et al., 2012; Papacosta et al., 2013). However, these investigations were conducted within 5 to 7 weeks of training. To the best of our knowledge, there are no reports on internal TL monitoring in conjunction with immune-endocrine responses in elite judo athletes during an entire training season. Therefore, this study aimed to examine the internal TL, sIgA, and salivary steroid hormone responses in elite youth judo athletes during an entire annual training periodization.

MATERIALS AND METHODS

Participants

Ten athletes (18±2 years; 175±6 cm; 72.3±12.3 kg; 1st *kyu* [brown belt] to 1st *dan* [black belt]) took part in this study, from two different judo teams. Data were collected throughout an annual season (February to December), a period when all athletes followed the training program elaborated by the same coach (the first author of the present article) in both clubs, and participated in state and national level competitions. During the study the athletes did not present any injury or disease that resulted in training interruption for a period longer than 4 weeks. All participants were informed about the risks and benefits of this research and signed an informed consent form, as well as the parents of the under 18-year-old athletes. All procedures were approved by the local University Research Ethics Committee (approval number: 160.235/2012).

Training design

The traditional training periodization approach was used in the present study, which included three training macrocycles. Before the beginning of the study, the athletes had a 4-week rest period (December) followed by a 4-week introductory period (January), when the selection process to choose the team members was hold. After this period, athletes were submitted to a training periodization divided in three macrocycles. Each macrocyle was composed by three distinct periods: preparatory period (PP), competitive period (CP) and transition period (TP). During the PP, which lasted 6 to 8 weeks, the weekly training was composed by three training sessions emphasizing the technical-tactical development (increase of the amount of techniques performed), three sessions involving combat simulations (*randori*, aiming at aerobic and anaerobic development), two conditioning training sessions (focusing on maximal strength, strength endurance, and muscle power development), and one session designed to flexibility development. During the CP (4 to 7 weeks) athletes performed one to three technical-tactical training sessions (tactical analysis and tactical problem solutions), two to three *randori* sessions (using the competition effort-pause ratio; 3:1 to 2:1) (Miarka et al., 2012) and two physical conditioning sessions aimed to muscle power development. TP between macrocycles were 2 to 4 weeks long, focusing on active rest or meetings to discuss the athletes' evolution. A description of the PP, CP and TP is presented on Table 1.

Internal TL monitoring

Throughout PP and CP, the internal TL was quantified by session-RPE (S-RPE) method as proposed by Foster et al. (2001). Thirty min after the session, athletes answered the question "How was your workout?" avoiding any contact between them. They were requested to ensure that their S-RPE referred to the intensity of the whole session rather than the most recent exercise intensity. The training intensity was measured using a Borg's category ratio 10 RPE scale (CR-10). The reported session-RPE score was multiplied by the total session duration, in minutes, to indicate the

Table 1. Weekly training description during preparatory, competitive and transitory periods over the annual season

Period	Preparatory	Competitive	Transitory
Technical and tactical training (session/wk)	3	2–3	1–2
Volume (min/session)	60–120	50–90	50–60
Randori training (session/wk)	3	2–3	1
Volume (min/session)	60–120	60–100	50–80
Randori sets (randori/session)	4–8	3–5	0–3
Randori volume (min/*randori*)	2–6	2–4	0–3
Randori work to rest ratio	1:2; 1:1; 2:1	1:2; 1:3	1:1; 1:2
Strength endurance-oriented training (session/wk)	1	0	0
Intensity (% of 1 repetition maximum)	50–70	0	0
Exercises per session	5–6	0	0
Exercise sets	3–6	0	0
Repetitions per set	15–20	0	0
Rest (sec)	45–90	0	0
Submaximal and eccentric strength-oriented training (session/wk)	0–2	0	0
Intensity (% of 1 repetition maximum)	85–120	0	0
Exercises per session	3–4	0	0
Exercise sets	1–4	0	0
Repetitions per set	2–6	0	0
Rest (min)	1–5	0	0
Strenght and power oriented training (session/wk)	0–2	2	0
Intensity (% of 1 repetition maximum)	50–75	40–65	0
Exercises per session	4–6	3–4	0
Exercise sets	3–4	2–4	0
Repetitions per set	4–6	2–4	0
Rest (min)	3	3–5	0
Stretching exercises (session/wk)	1	0	1
Exercises per session	2–4	0	2–4
Volume (min per session)	20–30	0	20–30
Training session (session/wk)	8–10	6–8	3–4
Time spent training (min/wk), mean ± SD	420.8 ± 88.7	305.7 ± 76.2	173.5 ± 53.8

SD, standard devaition.
Randori, combat simulation.

internal TL. Additionally, training monotony was calculated from the average daily internal TL divided by its standard deviation calculated over a week. A measure of training strain was also obtained by multiplying the monotony by the accumulated weekly internal TL (Foster, 1998).

Saliva collection and analysis

At the end of PP and CP, saliva samples were collected to determine cortisol, testosterone and IgA concentrations. Salivary samples were collected in the morning at 8:30 a.m., within 120 min after the athletes waking up and 90 min after the breakfast. Saliva samples were collected by means of cotton-swabs (Salivette, Sarstedt, Rommelsdorf, Germany). Each saliva collection was performed on the same time of day. Athletes were asked to place the cotton swab into their mouth for at least 2 min while chewing and then insert it back into a special plastic tube. Samples were returned to the laboratory and stored and the saliva collecting tubes were centrifuged at 3,000 rpm for 15 min at 4°C, and stored at -80°C until assayed. All samples were tested in the same series to avoid any variations between tests. The cortisol and testosterone samples were tested using enzyme-linked immunosorbent assays (ELISA) in accordance with the manufacturers' instructions (DIAsource ImmunoAssays AS, Louvain-la-Neuve, Belgium). The salivary IgA samples were also tested using ELISA according to the manufacturers' instructions (Bioclin, Belo Horizonte, Brazil). The relative amount of salivary cortisol (sC), sali-

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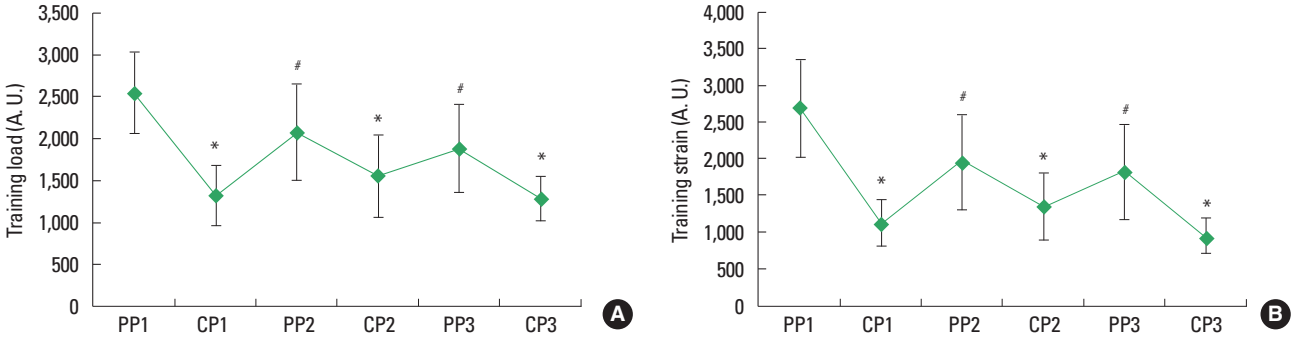

Fig. 1. Changes in training load (A) and training strain (B) during three preparatory periods (PP) and three competitive periods (CP), Values are presented as mean ± standard deviation. *$P < 0.05$, different from preceding value. #$P < 0.05$, different from PP1 values.

vary testosterone (sT), and sIgA to protein were determined by dividing their absolute concentration by the total protein concentration. Concentrations of total protein (mg/mL) in the saliva were measured using colorimetric assay according manufacturers' instructions (Labtest Diagnóstica S.A., Lagoa Santa, Brazil). The coefficients of variation were 3.6%, 2.9%, and 3.3% for sC, sT, and sIgA, respectively.

Statistical analysis

Data are described using mean and standard deviation. Internal TL data were grouped according to training period. Data normality was tested and confirmed via Shapiro–Wilk test. Dependent variables (TL, training strain, sC, sT, and sIgA) in the different training periods were compared using mixed model analysis for repeated measurements, followed by Bonferroni test as *post hoc*. Cohen *d* was calculated to determine the effect size (Cohen, 1988) and classified as proposed by Hopkins (2016): ≤0.20 (trivial); ≤0.60 (small); ≤1.20 (moderate); ≤2.0 (large); ≤4.0 (very large); >4.0 (extremely large). Significance level was set at 5%.

Only the statistical significant results between periods from each macrocycle and between periods with similar characteristics throughout the macrocycles were reported, while the comparisons between different training periods were omitted.

Analyses were conducted using the SAS 9.3 (SAS Institute, Cary, NC, USA).

RESULTS

There was an effect of training period on internal TL ($F[5, 38] = 31.41$; $P < 0.001$), with higher values in the different PP compared to the CP in the first ($P < 0.001$, $d = 2.89$; very large), second ($P = 0.004$, $d = 0.98$; moderate) and third macrocycles ($P < 0.001$, $d = 1.45$; large). Furthermore, the PP values in the first macrocycle were higher than the PP values in the second ($P = 0.007$, $d = 0.88$; moderate) and third macrocycles ($P < 0.001$, $d = 1.34$; large) (Fig. 1A).

For training strain there was a period of training effect ($F[5, 38] = 29.98$, $P < 0.001$), with higher values in the PP compared to CP in the first ($P < 0.001$, $d = 3.04$; very large), second ($P = 0.016$, $d = 1.09$; moderate) and third macrocycles ($P < 0.001$, $d = 1.83$; large). When PP were compared, there were higher values in the first macrocycle compared to the second ($P = 0.001$, $d = 1.12$; moderate) and third macrocycles ($P < 0.001$, $d = 1.34$; large) (Fig. 1B).

There was an effect of training period on sC ($F[5, 38] = 2.86$, $P = 0.027$) and sT concentrations ($F[5,39] = 3.15$, $P = 0.018$), and on the testosterone-cortisol ratio ($F[5, 38] = 3.76$, $P = 0.007$). For the sC concentration the *post hoc* did not confirm the difference, while for sT higher values were observed in the CP of the third macrocycle compared to the CP of the first macrocycle ($P = 0.024$, $d = 1.2$; moderate). For the testosterone-cortisol ratio, values in the PP of the second macrocycle were lower than in the PP of the first macrocycle ($P = 0.005$, $d = 0.9$; moderate).

For sIgA concentration no effect of training period was detected ($F[5, 1] = 0.60$, $P = 0.746$) (Fig. 2).

DISCUSSION

This study on young elite judo athletes examined internal TL dynamics and immune-endocrine responses over an annual periodized training season. The internal TL decreased significantly during CP in each macrocycle compared to PP, and presented higher values during the first macrocycle's PP compared to the same period of other macrocycles. Conversely, salivary immune-endocrine concentrations did not change between PP and

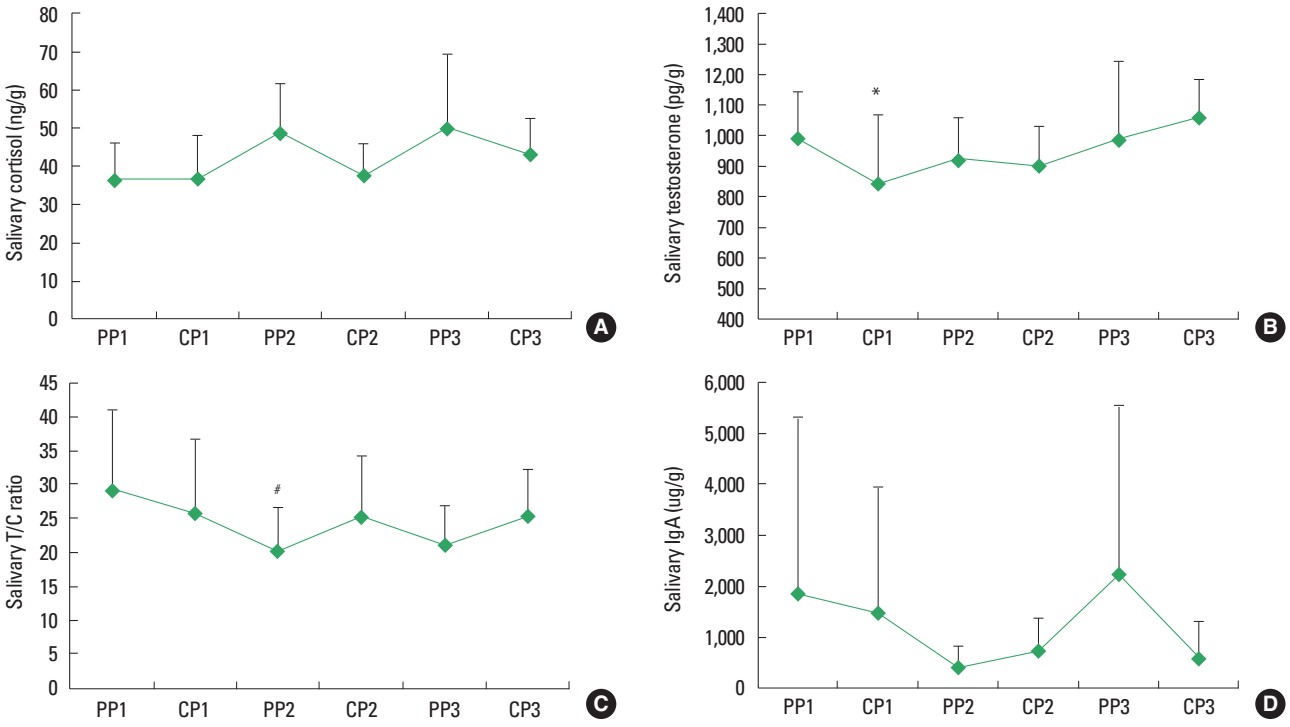

Fig. 2. Changes in salivary cortisol (A), testosterone (B), testosterone to cortisol (T/C) ratio (C), and salivary IgA (D) during three preparatory periods (PP) and three competitive periods (CP), Values are presented as mean ± standard deviation. *$P<0.05$, different from CP3 values. #$P<0.01$, different from PP1 values.

CP over macrocycles, presenting only variations between periods with similar characteristics throughout the macrocycles such as an increase for sT (CP1 to CP3) and a decrease for the testosterone-cortisol ratio (PP1 to PP2).

It is worth noting that the data from salivary immune-hormonal responses indicated that the changes in TL over the 3-macrocycle training period did not greatly influence the hypothalamic pituitary adrenal and hypothalamic pituitary gonadal axis activity, as well as the mucosal immunity function of the assessed judo athletes. It is important to highlight that hormone responses to athletic activity has been thought to be useful to provide valuable information regarding training stress, adaptation and exercise performance (Gröschl, 2008). Indeed, psychological stress may affect immune function through autonomic nerves innervating lymphoid tissue and by stress hormone-mediated alteration of immune cell functions (Cohen et al., 1991). Additionally, the monitoring of salivary hormones, such as cortisol and testosterone, has also been proposed and adopted in recent studies analysing judo athletes' adaptation to competition season (Papacosta et al., 2016).

Taking into account the present results and the above cited reports from the literature concerning the association between TL, stress from competition, and immune-hormonal responses, it seems plausible to assume that judo athletes did cope well with changes in TL undertook across the season, whilst leading appropriately with the stress imposed not only from the TL *per se*, but also with the well-known inherent stress of the CPs (Elloumi et al., 2003; Moreira et al., 2010; Moreira et al., 2012; Suay et al., 1999). Therefore, the absence of relevant changes in resting testosterone and cortisol concentrations over the investigated period suggest that athletes were able to achieve a positive adaptation due to an appropriate balance between TL s and recovery.

There have been reported that chronic and sustained psychological stress may induce to decreases in sIgA levels (Deinzer et al., 2000; Jemmott et al., 1983). For example, in sports setting, a situation that combined an intensive training period and psychological stress for an important championship was found to decrease the level of sIgA-mediated immune protection at the mucosal surface in both staff and athletes, with greater changes observed in the athletes (Moreira et al., 2008). Moreover, Papacosta et al. (2013) reported changes in hormonal responses, mood state, and muscle soreness which preceded improvements in performance and mucosal immunity, suggesting that there would be an association between alterations in steroid hormones, such as sC and sT, and changes in sIgA in judo athletes due to changes in TL, notably,

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when tapering phases follow a previous intensified training period. The absence of significant changes in sIgA over the investigated period might be also viewed as a positive adaptation of the judo athletes to the differences sources of stress experienced during the season, in particular regarding their mucosal immunity function.

Nevertheless, while these salivary responses might be assumed as a positive adaptation of the assessed judo athletes, other possible explanations should be considered. Firstly, it is worth noting that there are discrepancies among the literature regarding immune-hormonal responses in athletes from various sports. For instance, Coutts et al. (2007) demonstrated that the changes in plasma cortisol and testosterone measures were not correlated to the changes in TL or performance in the monitored rugby athletes. The authors also pointed out that biochemical parameters might not be useful as an early maker of overreaching in a practical training environment. In addition, Moreira et al. (2013) reported a lack of changes in resting sC concentration during a 4-week period of futsal training in spite of the existence of a large variation in internal TL. Moreover, Nunes et al. (2014) reported similar findings in elite female basketball players showing a lack of change in sT and sC concentrations during a 12-week period before an international championship, which included two overloading and tapering phases. Additionally, the authors reported no changes for sIgA which is consistent with previous research (Robson-Ansley et al., 2007; Slivka et al., 2010).

Another possible explanation for this lack of changes in salivary measures, might be associated with the frequency of sampling protocol (Gleeson et al., 2002; Moreira et al., 2008) and with fact that in the present study only resting salivary measures were used to analysis the possible effect of changes in TL in these salivary parameters (Hough et al., 2013; Meeusen et al., 2004; Meeusen et al., 2010). Therefore, a more frequent saliva sampling protocol would be required to observe changes in immune and hormonal parameters as suggested by Gleeson et al. (2002) and Moreira et al. (2009) who both proposed that a more frequent saliva sampling protocol may be needed to identify temporal changes in sIgA, especially during periods of intensified training and competition that are assumed to be accompanied by greater physiological and psychological stressors. Concerning the possible limitation of using only resting salivary measures for examining hormone responses over the season, despite the absence of consensus in the literature, there have been some claims for advocating that there is still no strong evidence that resting circulating cortisol and testosterone concentrations and the cortisol/testosterone ratio are reliable markers of overreaching/the overtraining syndrome (Hough et al., 2013). Some authors have been proposed that instead of examining the resting levels of these hormones during training or experimental studies an examination of the exercise induced hormonal responses may offer a better scenario of the hormonal changes which might occur during training or even during states of nonfunctional overreaching and syndrome of overtraining (Hough et al., 2013; Meeusen et al., 2004; Meeusen et al., 2010).

While this approach may be an interesting alternative to monitor athletes training responses, it is also imperative to highlight the consideration of Moreira et al. (2012) who pointed out that even assumed that the sC responses to a standard exercise bout could also be assessed as a monitoring tool, because of the expense and logistical difficulty of implementing this approach with large groups of elite athletes, its practical usefulness may be limited.

In summary, the current findings suggest that a three-peak annual periodization did not change immune-endocrine responses despite changes in internal TL, suggesting that the assessed athletes did cope well with the inherent psychophysiological stress from both training and competition loads. However, further studies including a more frequent saliva sampling protocol over annual seasons would be required to confirm these results.

CONFLICT OF INTEREST

No potential conflict of interest relevant to this article was reported.

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