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Daily Monitoring of the Internal Training Load by the Heart Rate Variability: A Case Study

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ABSTRACT

Ornelas F, Nakamura FY, Dos-Santos JW, Batista DR, Meneghel V, Nogueira WJ, Brigatto FA, Germano MD, Sindorf MAG, Moreno MA, Lopes CR, Braz TV. Daily Monitoring of the Internal Training Load by the Heart Rate Variability: A Case Study. **JEPonline** 2017;20(1):151-163. The objective of this study was to present a descriptive case study with daily monitoring of the internal training load (ITL) according to the heart rate variability (HRV) in an amateur road running athlete. The subject was male (24 yrs old, 67.8 kg, 168 cm, %fat = 13%, 7 yrs of training, 3 times·wk^{-1} in the last 6 months, 6 to 7 hrs·wk^{-1}) with no history of recent muscle, joint, or bone injury (<6 months). The proposed training was of 12 sessions during 3 wks. The maximum aerobic speed (MAS), threshold HRV (ThHRV), and 1 maximum repetition (1RM) at the pre and post training moments were evaluated. The daily HRV monitoring was carried out according to the natural logarithm of the root mean square differences between adjacent normal R-R intervals (lnRMSSD), mean of the weekly lnRMSSD ($lnRMSSD_{weekly}$), coefficient of variation of the weekly lnRMSSD (lnRMSSDcv), and division of the lnRMSSD by the R-R interval (lnRMSSD:RR). Improvements in MAS (11.5%), ThHRV (15.0%) and lnRMSSD (45.8%) were verified after 3 wks, and also in the 1RM for the brench press (5.0%), squatting (14.5%), knee extension (5.6%), and hamstring curl (14.8%) exercises. The descriptive values for weeks 1, 2, and 3 for the variables $lnRMSSD_{weekly}$, ITL, lnRMSSDcv, and lnRMSSD:RR were 3.16, 3.98, and 4.02 ms, 1555, 1950, and 1808 a.u., 7.7, 10.2, and 11.9%, and 3.89, 4.38, and 4.06, respectively. The ITL was smaller in week 1 accompanied by a reduction in lnRMSSDcv. The change in $lnRMSSD_{weekly}$ (1 to 3 = 27%) was related to an improvement in the subject's performance. The individual analysis of the sessions by SWC allowed one to verify recovery periods (>lnRMSSD) and fatigue (<lnRMSSD) accompanied by increases or decreases in ITL. Week 2 caused more stress in the individual due to the tendency to increase vagal saturation (>lnRMSSD:RR) accompanied by a greater ITL.

Key Words: Autonomic Nervous System, Training Load, Running

INTRODUCTION

Currently, monitoring of the training load is considered to be one of the main pillars of sport preparation (2). According to Impellizzeri, Rampinini, and Marcora (15), the load can be divided into the external (ETL) and internal (ITL) training loads. The ITL consists of physiological responses that the subject's organism presents as a function of training stress as determined by the ETL, together with individual physiological and psychological characteristics (15). Among the principal methods used to estimate ITL, those based on the behavior of heart rate variability (HRV) and the rating of perceived exertion (RPE) (1,3) stand out. Also, Foster's method (14), which is based on the "subjective" estimate of the exertion intensity multiplied by the volume in minutes of the training session, provides a global score for the load magnitude.

On the other hand, the HRV is an objective measurement of the autonomic heart modulation (AHM) obtained from the R-R intervals (iR-R), serves as a potentially useful marker for the monitoring of athletes (20). The fatigue generated by the training sessions can be characterized by the reduced recovery of the neuroendocrine reactions and sympathetic dominance of the AHM; whereas, recovery is by the parasympathetic dominance of the AHM functions (4). The daily monitoring of the HRV of athletes allows their trainers to evaluate changes in fatigue and recovery, thus providing support for more precise modifications in the prescription of the ETL (12). Recently, Vesterinen et al. (25) showed that runners who were trained by monitoring the daily HRV of their sessions improved their time performance in the 3000 m more than those in the control group, even with a smaller volume of high intensity sessions.

Of the parasympathetic HRV indexes (vagal), the natural logarithm (ln) of the root mean square differences between adjacent normal R-R intervals (lnRMSSD) appears to be the most appropriate index for a field evaluation (18). The lnRMSSD is more reliable than other spectral indexes of the HRV (14), and it is widely used in field research with athletes (5,12,13,17,25). On the other hand the lnRMSSD:RR is calculated from the ratio between lnRMSSD and iR-R, which represents the indicator of vagal saturation of the athlete (19). In a case study described by Stanley, D'Auria, and Buchheit (22), a slight decrease in the lnRMSSD accompanied by a trivial change in the lnRMSSD:RR was related to a worse performance in triathlon; whereas, a moderate decrease in both lnRMSSD and lnRMSSD:RR was related to good performance.

Other indexes such as the weekly lnRMSSD and the coefficient of variation (CV) of the lnRMSSD (lnRMSSDcv) have also been used to identify the behavior of the weekly ITL in athletes (19). In female soccer players, a relationship was demonstrated between the pattern of load accumulated weekly according to the RPE and the percent alteration in lnRMSSDcv (9). In addition, the percent change in $lnRMSSD_{weekly}$ from the 1st to the 3rd training weeks was strongly related to the adaptation in maximum oxygen consumption (12). The threshold value of lnRMSSD itself can predict results and the capacity to sustain high intensity loads. It has already been demonstrated that recreational runners with greater parasympathetic predominance at rest at the start of training improved their performance more after intense training than runners with lower values (24).

However, studies of these variables with amateur athletes and runners are still scarce since the monitoring of HRV is a recent methodology (2) based on the daily control of lnRMSSD, $lnRMSSD_{weekly}$, lnRMSSD:RR, and lnRMSSDcv during the week that increases the reliability and sensitivity of the data in the detection of changes caused by the ETL (10,12). The HRV can be influenced by a series of internal and external factors, such as stress, anxiety, fatigue, sleepiness, mood, training load, and competition (2). In this case, daily measurements and weekly indexes provide greater support to the understanding of these internal variations than isolated measurements in the weekly sessions (19). Thus, the objective of this research was to present a descriptive case study with daily monitoring of the ITL by the HRV and subjective perception of exertion (SPE) of an amateur road runner.

METHODS

This was a case study, which is a form of descriptive research in which a single case is studied in depth to achieve greater understanding about other similar cases (23). A line of case study investigation involving monitoring of training by the HRV was followed (19,21,22). The research was carried out according to the Helsinki declaration and all the procedures were approved by the Ethics in Research Commission of the local Institution registered on the Brazilian platform, report nº 950.277/2015.

Subject

A male subject was investigated (24 yrs old, 67.8 kg, 168 cm, %fat = 13%) with a 7-yr history of training for road racing amateur competitions and training frequency of 3 times·wk^{-1} in the last 6 months (6 to 7 hrs·wk^{-1}). He had no history of recent muscle, joint, or bone injuries (<6 months).

Experimental Design

The study was carried out during the first 3 wks of preparation for the 2016 São Paulo marathon, Brazil. Before starting the training period, a maximum incremental aerobic test on a treadmill was done to determine the subject's threshold HRV, maximum aerobic speed, and maximum heart rate (HR). Also, an analysis of the R-R intervals and resting HR was part of the test session. After 24 hrs 1 maximum repetition tests (1RM) were performed for the following exercises: bench press, squatting, knee extension, and hamstring curl. The variables of the maximum incremental and 1RM tests were used to prescribe the training sessions according to the reserve heart rate [Intensity fraction x (maximum HR – resting HR) + resting HR]) and the percentage of 1RM, respectively. The HRV was monitored daily from

Monday to Thursday in 12 training sessions, of which 6 were aerobic and 6 of exertion, plus one more training on the Friday of each week (Table 1). The training sessions were carried out according to the subject's daily routine, following the training sites and time availability, increasing the ecological validity of the research (Table 2). Monitoring of the ITL by the HRV was carried out in the morning before the training sessions, and the SPE was measured at the end of the training sessions.

Table 1. Experimental Design of the Study.

	Pre	Week 1					Week 2					Week 3					Post
	48/72h	M	T	W	Th	F	M	T	W	Th	F	M	T	W	Th	M	48/72h
1RM	X																X
MAS	X																X
AT		AT1			AT2			AT3		AT4		AT5	AT6				
RT			RT1	RT2			RT1		RT2					RT1	RT2		
RPE		X	X	X	X		X	X	X	X		X	X	X	X		
HRV		♥	♥	♥	♥	♥	♥	♥	♥	♥	♥	♥	♥	♥	♥	♥	

Days of the week (M, T, W, Th, F); **1RM** = 1 maximum repetition test; **MAS** = maximum aerobic speed test; **AT** = aerobic training; **RT** = resistance training; **RPE** = rating perception of exertion; **HRV** = heart rate variability

Table 2. Description of the Aerobic and Exertion Training Sessions Carried Out during the 3 Wks the Subject Under Study was Analyzed.

Aerobic Training (AT)	Resistance Training (RT)
AT1 = 1 x 4000m at 80% to 90% of the reserve HR with 5 min. passive pause + 1 x 3000 m at 80 to 90% of the reserve HR **AT2** = 2 x 6000 m at 70 to 90% of the reserve HR + 1000 m at 70 to 80% of the reserve HR **AT3** = 3 x 3000 m at 70% to 90% of the reserve HR with 3 min. passive pause **AT4** = 6 x 3000 m at 70% to 90% of the reserve HR with 3 min. passive pause **AT5** = 20 x 400 m at 90% to 100% of the reserve HR with 1 min passive pause **AT6** = 3 x 3000 m at 80 to 90% of the reserve HR with 4 min. passive pause + 2000 m at 80 to 90% of the reserve HR	**RT1** = 5 series of 5 repetitions at 80% of 1RM for knee extension, bench press, squatting (1 min passive pause between series and 2 min between exercises with 1.5 sec in the eccentric phase and 1.5 sec in the concentric phase). **RT2** = 5 series of 5 repetitions at 80% of 1RM for hamstring curl and squatting + 5 series of 5 repetitions of back stretching on a fixed bar with body mass (1 min passive pause between series and 2 min between exercises with 1.5 sec in the eccentric phase and 1.5 sec in the concentric phase).

Rating Perception of Exertion
For the 12 sessions carried out, the SPE was collected 30 min after the end of each session, with the subject marking his perception on a 0 to 10 scale (14). In order to calculate the ITL of the session, the perception value reported by the subject was multiplied by the total time of the exercise session in minutes. Subsequently the ITLs for weeks 1, 2, and 3 were calculated as the values corresponding to the sum of the loads calculated for the 4 sessions in each week. The data were expressed in arbitrary units (a.u.).

Heart Rate Variability
The values for iR-R were taken daily in the mornings soon after the subject woke up. The subject was use to the procedure used to measure the HRV (done 7 times before starting the study), and was requested not to ingest alcohol or stimulating beverages during the course of the experiment. On waking up and before measuring the HRV, the subject was instructed to empty his bladder (11). Then, he would place the heart rate monitor in position, go back to bed and stay there in a lying down position without moving with his eyes open and breathing spontaneously (8). The recording time was 5 min of iR-R of which the first 2 min were discarded as a measure of stabilization (18).

The Firstbeat Bodyguard® device (Firstbeat Technologies, Jyväskylä, Finland) was used to record the iR-R. The R-R intervals were first exported to the Firstbeat Analysis Server® software (version 5.3.0.4), and then transferred to the Kubios HRV 2.1® software (Biomedical Signal Analysis Group, University of Kuopio, Finland) to analyze the HRV variables. All the iR-R with difference greater than 20% from the adjacent interval were automatically filtered, removing inadequate and premature beats (low filter). Subsequently, information in the time domain was generated in the Kubios software and the variable RMSSD (root mean square differences between adjacent normal R-R intervals) was calculated.

The RMSSD is more reliable than other HRV indexes (14) and can be obtained during spontaneous breathing (4). Due to the distorted nature of the HRV recordings, the RMSSD data were transformed into their natural logarithm (ln RMSSD) (19). In addition the ln avoids extreme values (outliers) and simplifies the analysis (8,13). Three variables were calculated from the lnRMSSD: the lnRMSSD_{weekly} (mean of the lnRMSSD values for the 4 sessions in the week), the lnRMSSD_{cv} (coefficient of variation [weekly standard deviation/ weekly mean x 100] of the 4 $\text{sessions} \cdot \text{wk}^{-1}$) and the lnRMSSD:RR (lnRMSSD divided by the value for iR-R of the measurement) (19).

Maximum Aerobic Speed Test on the Treadmill
The protocol described by Cotin et al. (7) was used to carry out the maximum aerobic speed test on the treadmill. After a 10 min warm up on the treadmill with a low load, the subject carried out the maximum speed test which consisted of an initial load of 8 $\text{km} \cdot \text{h}^{-1}$ for 1 min followed by load increases of 0.5 $\text{km} \cdot \text{h}^{-1} \cdot \text{min}^{-1}$ up to the point of exhaustion. An inclination of 1% of the treadmill was maintained throughout the test. The maximum aerobic speed [MAS] was identified as the speed of the last stage completed using the Movement model RT 250® treadmill with 1% of inclination. The heart rate was monitored during the test using the Firstbeat® software (Firstbeat Technologies, Jyväskylä, Finland). The threshold HRV (ThHRV) was then identified and also the maximum HR of the test. The ThHRV was obtained from the non-linear SD1 index calculated from the *poincaré* plot, corresponding to the 1st stage of the incremental exercise in which the difference between the SD1 of 2 consecutive

stages was less than 1 ms (16). The ThHRV was identified by visual inspection by 3 independent examiners, being defined when there were at least 2 evaluations in agreement.

1 RM Dynamic Muscle Strength Test

The dynamic maximum voluntary muscle strength was determined by way of the 1RM test for the brench press, squatting, leg extension, and hamstring curl exercises following the procedures described by Brown and Weir (3). The subject carried out a general warm up for 3 to 5 min followed by a specific warm up for the exercises, carrying out a series of 10 repetitions with 40 to 60% of the estimated 1RM. The protocol used to determine 1RM consisted of three attempts to lift the greatest load possible using concentric actions with valid execution (complete amplitude of the movements). Three to 5 min pauses were employed between attempts, as also between increments or decrements of the loads until a complete muscle action was configured.

Statistical Analysis

The mean of the data and standard deviation (SD) of the mean were presented. The percent delta (%Δ) of the difference between the pre- and post-training moments was calculated, as also for the difference in monitoring of variables lnRMSSD_{weekly}, lnRMSSD_{cv}, lnRMSSD:RR, and ITL. The smallest worthwhile change (SWC) (1) was used for the daily monitoring of the sessions. In the case of the lnRMSSD the SWC was fixed at 3% (4) and, in the present study, was calculated as ± 0.11 ms. For the lnRMSSD:RR the SWC was calculated as 0.2 x the standard deviation of the subject for the variable in question (1), obtaining a value of ± 0.06 ms in the present study. The SWC zones were defined as the grey areas of the graphs.

RESULTS

The values found for lnRMSSD_{weekly} were 3.16 ms, 3.98 ms, and 4.02 ms, respectively, for weeks 1, 2, and 3. The values found for the weekly accumulated ITL were 1555 a.u. for week 1, 1950 a.u. for week 2, and 1808 a.u. for week 3. The value for lnRMSSD_{cv} increased from week 1 (7.7%) to week 2 (10.2%) and week 3 (11.9%); whereas, lnRMSSD:RR showed a similar behavior to lnRMSSD_{weekly} with lower values for weeks 1 (3.89) and 3 (4.06) when compared to week 2 (4.38). Figure 1 shows the results for the variables monitored during the 1st, 2nd, and 3rd weeks of training and the percent delta of the difference between the weeks.

Figure 2 shows the daily values for the variables of ITL, lmRMSSD, and lnRMSSD:RR during the 12 sessions. The highest values for ITL, (i.e., sessions 9 and 11) implied in the decreases in the values for lnRMSSD in the monitoring before the next session, thus demonstrating a direct relationship with lower parasympathetic dominance after application of a load of greater magnitude. Similarly, in recovery periods (before sessions 6 and 11), there was a progressive increase in lnRMSSD, demonstrating greater parasympathetic predominance of the subject under analysis. With the exception of sessions 7, 9, and 10, the lnRMSSD:RR showed behavior similar to that of lnRMSSD.

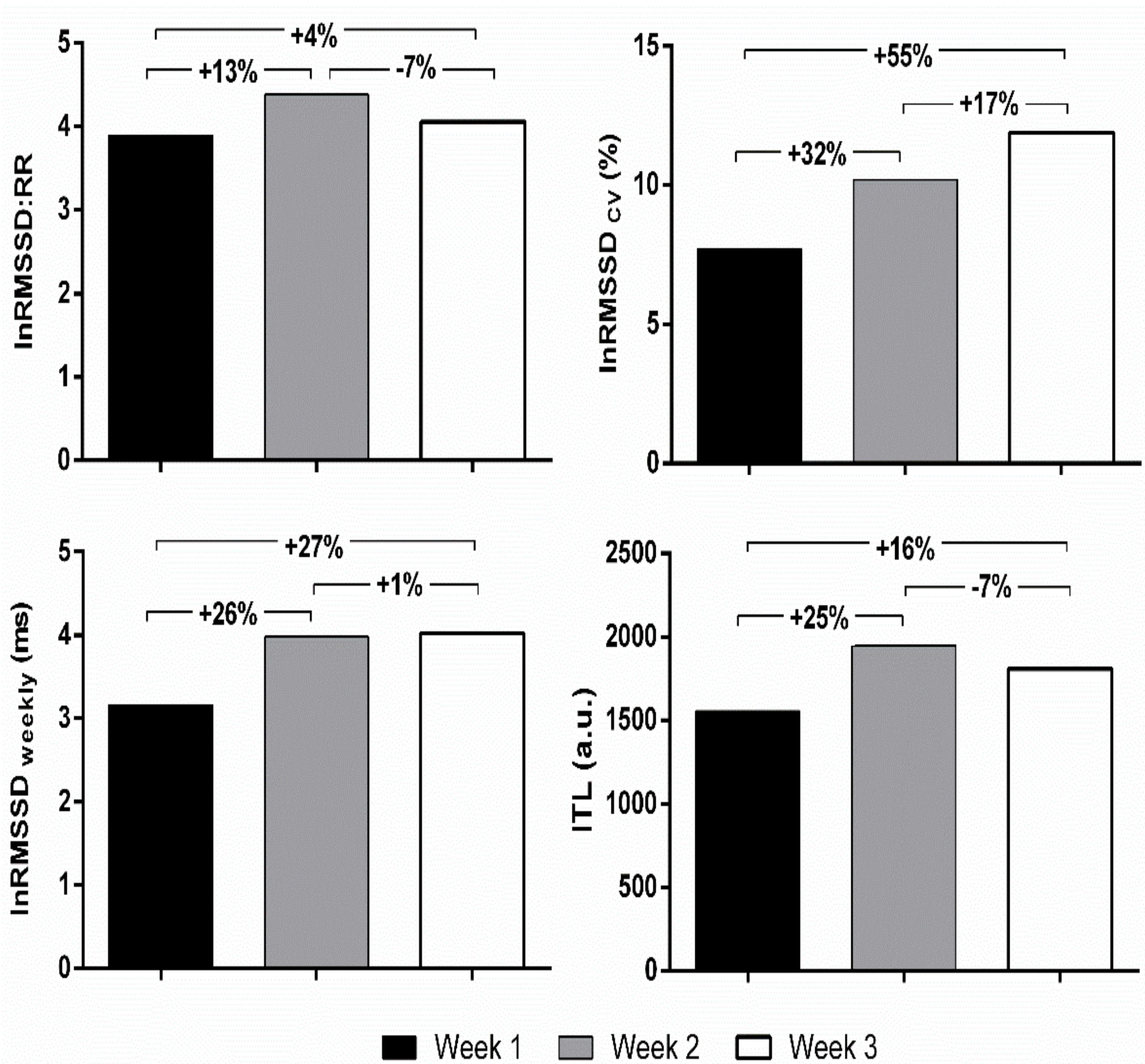

Figure 1. Results Obtained for the Variables Monitored during Week 1 (Black Column), Week 2 (Grey Column) and Week 3 (White Column) of Training for the Amateur Road Runner Under Analysis. **ITL** = internal training load accumulated in the week, **lnRMSSD** = natural logarithm of the root mean square differences between adjacent normal R-R intervals, **lnRMSSD$_{cv}$** = coefficient of variation of the lnRMSSD, **lnRMSSD:RR** = value of the lnRMSSD divided by the value of the R-R interval.

Table 3 presents the values for percent delta for the pre- and post-differences for the variables monitored of the subject’s performance. After 12 training sessions, improvements were found for the variables of the maximum aerobic speed test (%Δ MAS = 11.5%, %Δ ThHRV = 15.0%), at rest (%Δ iR-R = 56.4%, %Δ lnRMSSD = 45.8%), and the 1RM test (%Δ 1RM bench press = 5.0%, %Δ 1RM squatting = 14.5%, %Δ 1RM knee extension = 5.6%, and %Δ 1RM hamstring curl = 14.8%).

Table 3. Results for the Variables of the Subject Analyzed at the Pre and Post Moments of the 12 Training Sessions.

Variables	Pre	Post	Δ%
MAS ($km \cdot h^{-1}$)	13.0	14.5	11.5
ThHRV ($km \cdot h^{-1}$)	10.0	11.5	15.0
Maximum HR ($beats \cdot min^{-1}$)	174	174	0.0
HR at Rest ($beats \cdot min^{-1}$)	64	65	1.5
R-R Interval at Rest (ms)	775	1212	56.4
lnRMSSD (ms)	2.88	4.20	45.8
1RM Bench Press (kg)	80	84	5.0
1RM Squatting (kg)	140	160	14.5
1RM Knee Extension (kg)	108	114	5.6
1RM Hamstring Curl (kg)	81	93	14.8

MAS = maximum aerobic speed; **1RM** = 1 maximum repetition; **HR** = heart rate; **ThHRV** = threshold of the heart rate variability; **lnRMSSD** = natural logarithm of the root mean square differences between adjacent normal R-R intervals.

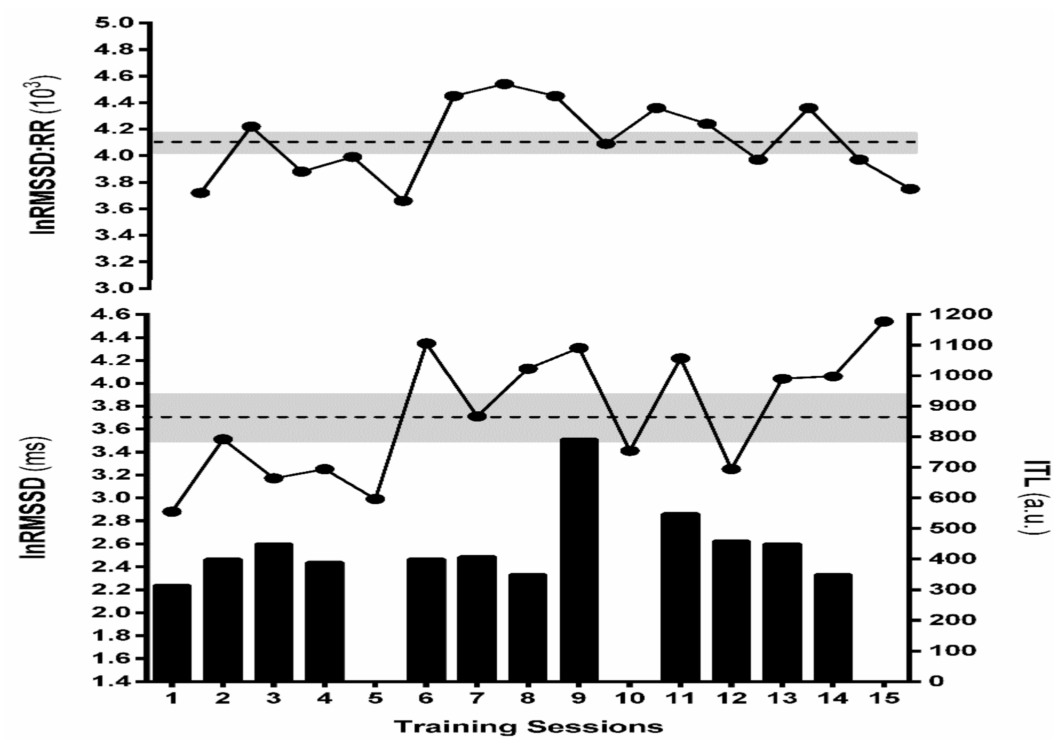

Figure 2. Internal Training Load (ITL), Natural Logarithm of the Root Mean Square Differences between Adjacent Normal R-R Intervals (lnRMSSD), lnRMSSD Divided by the Value of the R-R Interval (lnRMSSD:RR) during the 12 Sessions Carried Out by the Subject during the Study. The grey area represents the zone of the smallest worthwhile change (SWC). For the variable lnRMSSD the SWC was fixed at 3% (4), giving ± 0.11 ms in this study. For the variable lnRMSSD:RR the SWC was calculated by multiplying the standard deviation of the subject x 0.2 (1) giving ± 0.06 ms in this study.

DISCUSSION

The primary results described in the present study suggest smaller values for the indexes $lnRMSSD_{weekly}$, lnRMSSD:RR, $lnRMSSD_{cv}$ and ITL in week 1 as compared with weeks 2 and 3. The individual values for the sessions with larger ITLs implied in the deceases in the lnRMSSD index in the next session, demonstrating a direct relationship with a lower parasympathetic dominance after application of a larger load (>a.u.). In recovery periods (before sessions 6 and 11), a progressive increase in lnRMSSD was verified, that is, values below the lower limit of the trivial zone of SWC and an abrupt increase for values above the SWC, thus demonstrating a return to the recovery state (parasympathetic predominance). The index lnRMSSD:RR of vagal saturation presented a similar behavior to that of lnRMSSD, except for sessions 7, 9, and 10. In addition, the training and monitoring carried out implied in positive adaptations for MAS (+11.5%), ThHRV (+15%), the at rest indexes for HRV and the 1RM tests.

The $lnRMSSD_{cv}$ can provide important information about the disturbance of homeostasis induced by the ETL (4). Individuals with lower values for $lnRMSSD_{cv}$ show higher levels of aerobic conditioning and can support elevating training loads better (5,11). Lower $lnRMSSD_{cv}$ values are related to weeks with lighter training loads (<a.u.) (9). In the present case, the lower values obtained by the subject for $lnRMSSD_{cv}$ (7.7%) in week 1 indicate that less disturbance of his physiological homeostasis occurred in this period than in weeks 2 (10.2%) and 3 (11.9%). This lower physiological disturbance ($<lnRMSSD_{cv}$) was related to the lower ITL in week 1 (1555 a.u.) as compared to weeks 2 (1950 a.u.) and 3 (1808 a.u.). These results are similar to those found by Flatt and Esco (9) for soccer players (ITL = 3031 a.u./ $lnRMSSD_{cv}$ = 13.7%, ITL = 2580 a.u./ $lnRMSSD_{cv}$ = 9.9%, ITL = 2200 a.u./ $lnRMSSD_{cv}$ = 9.8%) and Plews et al. (19) for female triathlon athletes ($<lnRMSSD_{cv}$ and decreases in the $lnRMSSD_{weekly}$ = non-functional overreaching), supporting the $lnRMSSD_{cv}$ as an index to determine physiological disturbance caused by the magnitude of the training load.

On the other hand, the $lnRMSSD_{weekly}$ reflects the daily variation in parasympathetic activity during the week (17), the baseline value for lnRMSSD at the start of this study was 2.88 ms. This value is lower than those found in studies by Plews et al. (19), Flatt and Esco (9), and Stanley, D'Auria, and Buchheit (22) (~5.0 ms, ~4.49 ms and 4.0 ms, respectively). Lower initial values for lnRMSSD can also explain the lower value found for $lnRMSSD_{weekly}$ in week 1 (3.16 ms) as compared to weeks 2 (3.98 ms) and 3 (4.02 ms) since this index is characterized by the weekly mean for lnRMSSD. In addition, Plews et al. (21) already indicated that recreational athletes show lower values for $lnRMSSD_{weekly}$ and greater variability of the daily lnRMSSD in the initial training weeks, when compared to elite athletes (e.g., lnRMSSD of recreational runners in week 1 = 3.4 ± 0.4 ms and elite triathletes in week 1 = 4.2 ± 0.2 ms). Five daily measurements of the lnRMSSD are necessary in the week for recreational athletes, as compared to three in elite athletes due to the greater variability in the measurements (21).

The daily variation in elite athletes is less prone to the influence of 'the initial values law', especially during high load training. For example, the $lnRMSSD_{cv}$ is lower in elite athletes in periods of functional overreaching, and the $lnRMSSD_{weekly}$ is higher in recreational athletes (21) who, for their part, show greater variability in the $lnRMSSD_{cv}$ for similar training loads. Since the athlete under investigation in the present study was amateur / recreational, one can presume that the lower values for $lnRMSSD_{weekly}$ in the first week of the study were related to his reduced level of conditioning, and that the lower values for $lnRMSSD_{cv}$ were indeed associated with the lower ITL in week 1 when compared to weeks 2 and 3.

On the other hand, it can be seen that the subject under study showed an increment of 27% in the $lnRMSSD_{weekly}$ from week 1 to week 3. Esco, Flatt, and Nakamura (12) showed that for soccer players the difference in $lnRMSSD_{weekly}$ from week 1 to week 3 of the training program adopted was strongly associated (r = 0.90) with the increment in VO_2 max. The change in $lnRMSSD_{weekly}$ during 3 of the 5 wks of training correlated (r = 0.50) with the improvement in the intermittent running capacity of the soccer players (19). These indicators are related to those found in the present study for the maximum aerobic speed (%Δ MAS = +11.5%) and the threshold HRV (%Δ ThHRV = +15.0%) after 12 sessions in 3 wks of training. In this case, the percent alteration in the $lnRMSSD_{weekly}$ in the first weeks of training is an indication of the improvement in aerobic aptitude for both the capacity (ThHRV) and the aerobic power (MAS).

The index lnRMSSD:RR represents the vagal saturation from the relationship of the parasympathetic activity (lnRMSSD) to the R-R interval (or from the heart rate). Previously, Buchheit et al. (6) showed that a greater ETL in the week (18 $h \cdot wk^{-1}$ vs. 4 to 6 $h \cdot wk^{-1}$) could lead to a decrease in vagal activity (<lnRMSSD) accompanied by a reduction in HR or iR-R. When the vagal activity is already high, there seems to be a limit on the HRV, like a vagal modulation marker. One possible explanation for this saturation in individuals with high parasympathetic activation levels is the loss of phasic efferent vagal discharge or saturation of the acetylcholine receptors (19). This normally occurs in non-functional overreaching periods or periods of intensified training in elite athletes and above all in endurance modalities (4). The fact that the index lnRMSSD:RR showed higher values in week 2 as compared to week 3 (-7%) was related to the reduction in iR-R, which was probably as a consequence of the greater accumulation of ITL in week 2 (1950 a.u.) compared to week 3 (1808 a.u.), since the values for $lnRMSSD_{weekly}$ were similar for the two weeks (4.02 vs. 3.98 ms). This could suggest a tendency for greater vagal saturation in week 2, since other studies have shown that a greater weekly volume (6) and intensified training periods (19) are related to reductions in the vagal HRV indexes (i.e., lnRMSSD) accompanied by a reduction in the iR-R.

Although studies (2,21) have highlighted the importance of analyzing the weekly values (i.e., $lnRMSSD_{cv}$ and $lnRMSSD_{weekly}$) as a consequence of the daily values of the indexes, the present study proposed (Figure 2) to relate the ITL, lnRMSSD and lnRMSSD:RR to the training sessions on a daily basis. With this procedure, a decrease in the lnRMSSD after sessions with greater ITL could be observed (9 and 11). In addition, when the analysis was carried out after recovery sessions (5 and 10), the lnRMSSD showed an increase in relation to the upper limit of the SWC trivial zone that demonstrated a return to the recovery state (parasympathetic dominance). The use of the SWC trivial zone for lnRMSSD could be important methodology for prescribing and monitoring, since it appears to be sensitive to adjustments in the ETL during a training sequence. Vesterinen et al. (25) showed that the applicability of the ETL guided by the SWC of the daily and weekly lnRMSSD promoted a greater increase in aerobic performance than a previously stipulated plan without daily control.

Thus, the data described in this case study could serve as a parameter for future research with a greater number of subjects and different training modalities and protocols. As a practical application, it was possible to establish the relationship between the daily indices of the parasympathetic activity of the HRV and the internal training load of the subject during the 3 wks, and also search for relationships with the potentiation of the aerobic performance and strength during training. In this sense, Plews et al. (21) pointed out that measurements of vagal indexes related to HRV are promising tools to monitor the state of training in resistance sports, although they pointed out that the responses of HRV are individual and depend on the level of conditioning and training history of the subject, thus increasing the importance of case studies in different athletes as proposed in the present research.

CONCLUSIONS

The daily and weekly indexes calculated by the RMSSD can aid trainers and athletes to understand the physiological disturbance caused by the training loads. It was possible to verify that the $\ln RMSSD_{cv}$ is sensitive in monitoring the magnitude of the weekly load. The values for the internal training load were lower in week 1 accompanied by a lower value for $\ln RMSSD_{cv}$ when compared to weeks 2 and 3. In addition, the percent alteration of the $\ln RMSSD_{weekly}$ (1 to 3) was related to improvement in the aerobic aptitude, strength, and HRV indexes at rest. The individual analyses of the sessions by SWC allow one to verify recovery (>lnRMSSD) and fatigue (<lnRMSSD) periods accompanied by the increase or decrease in training load. The higher internal load observed in week 2 reflected in greater stress of the individual due to the increase in vagal saturation (>lnRMSSD:RR), accompanied by a greater weekly internal load. All this information could be important for trainers and athletes in the organization of training on a long term basis, avoiding negative adaptation states (i.e., non-functional overreaching) as well as enhancing performance.

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