ORIGINAL

TRAINING LOAD AND HRV IN A FEMALE ATHLETE: A CASE STUDY

CARGA DE ENTRENAMIENTO Y VFC EN UNA ATLETA FEMENINA: ESTUDIO DE CASO

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ABSTRACT

The purpose of this study was to describe a methodology to monitor a female athlete who combines ultra-trail running (UTR) and Ironman during 16 weeks using heart rate variability (HRV).

The daily training load (TL) was previously programmed and the weekly total was recorded. The RR (ms) intervals in resting conditions were recorded every morning

for 5 minutes. From these, RMSSD (square root of the mean of the squares of the differences between adjacent RR intervals) was measured as an index of parasympathetic activity and the stress score (SS) as a measure of sympathetic activity.

Daily morning HRV measurements seem to be an effective tool to monitor sympathetic-parasympathetic balance in athletes before tackling a training session. This monitoring would allow for early detection of fatigue states and for modification of the training load planning.

KEY WORDS: Sympathetic-parasympathetic activity, trail runners, Ironman, female.

RESUMEN

El objetivo de este estudio fue describir una metodología de seguimiento en una atleta que combina el Ultra Trail Running (UTR) y el Ironman durante 16 semanas, mediante variabilidad de la frecuencia cardiaca (VFC).

La carga de entrenamiento (CE) diaria se programó y se cuantificó el sumatorio semanal. Se registraron los intervalos RR (ms) en reposo cada mañana durante 5 minutos y a partir de ellos se midió la RMSSD (raíz cuadrada de la media de las diferencias de la suma de los cuadrados entre intervalos RR adyacentes) como medida de la actividad parasimpática y el índice de estrés (SS) como actividad simpática.

Los registros diarios de VFC matutinos parecen ser una forma útil para monitorizar el estado de equilibrio simpático-parasimpático en deportistas antes de abordar las sesiones de entrenamiento. Esta monitorización serviría para detectar precozmente estados de fatiga y para poder monitorizar la planificación de las cargas.

PALABRAS CLAVES: Actividad simpática-parasimpática, trail runners, Ironman, mujer

INTRODUCTION

Given that heart rate variability is a non-invasive tool that allows for sympathetic and parasympathetic modulation assessment (Sandercock, Bromley, & Brodie, 2005; Stanley, Peake, & Buchheit, 2013), it has been proposed as a valid method to examine the individual response to workload and, therefore, to training load (Kiviniemi, Hautala, Kinnunen, & Tulppo, 2007; Pichot et al., 2000). It has also been suggested as a method to determine the role of the autonomous nervous

system in overtraining states, fatigue and response to workload (Cachadiña, de la Cruz Torres & Orellana, 2012).

In this regard, and according to the literature, RMSSD (square root of the mean of the squares of the differences between adjacent RR intervals) has been the most widely used statistic when assessing parasympathetic activity (Buchheit, Papelier, Laursen, & Ahmaidi, 2007; Halson, 2014) using the time domain (Task Force, 1996). Moreover, Poincaré scatter plot provides information regarding the sympathetic and parasympathetic divisions of the autonomous nervous system (Tulppo, Makikallio, Takala, Seppanen, & Huikuri, 1996) based on its transverse (SD1) and longitudinal (SD2) axes. Since SD2 is an inverse indicator of sympathetic activity, stress score (SS) can be calculated as the inverse of SD2 multiplied by 1,000 to obtain a direct indicator of sympathetic activity (Naranjo Orellana, De la Cruz Torres, Sarabia Cachadiña, De Hoyo, & Dominguez Cobo, 2015).

In line with this, there is great interest in monitoring training load in athletes (Bourdon et al., 2017), distinguishing between the administered or external load (EL), on one hand, and the way every athlete assimilates the administered load and responds to it, known as internal load (IL) (McLaren et al., 2018), on the other. Some authors have recently suggested that the changes in HRV during exercise and recovery may be affected by both intensity and volume (Michael, Graham, & Davis, 2017) and may allow for distinguishing the immediate recovery periods at different intensities (Kaikkonen, Hynynen, Mann, Rusko, & Nummela, 2010; Michael, Jay, Halaki, Graham, & Davis, 2016).

Data are scarce on the changes induced by the different types of exercise on HRV in athletes that are regularly exposed to high training loads, but they seem to suggest that daily variations can be useful to measure the progression to a good or bad adaptation (Plews, Laursen, Kilding, & Buchheit, 2012). Thus, Stanley et al. (2015) reported in a case study that a decrease in LnRMSSD in an elite triathlete the week prior to competition was an indicator of optimal performance. Nevertheless, the simultaneous training that an athlete undergoes to prepare for the competition period in ultra-trail running (UTR) and long-distance triathlon (Ironman) offers the possibility of combining training volumes and intensities adjusted to each type of competition along the same period of time. No study was found in the reviewed literature that addresses the effect of TL on daily basal HRV measurements in athletes who are training for Ironman and UTR (75-km distance).

The aim of the present study is to describe a methodology based on daily HRV measurements to monitor an athlete who combines UTR and Ironman (training and competition) during a 16-week period. Simple parameters have been selected (LnRMSSD and LnSS) to make this methodology easy to use during training, trying to distinguish between EL and IL.

MATERIAL AND METHOD

Participant

A female amateur national-level athlete was monitored (age: 34 years old; height: 157cm; body mass: 46.5kg) during a 16-week competition period that included a 75-km distance and 3,293-m elevation gain ultra-trail race on week 6 and an Ironman race on week 15. Weekly training time during the monitored period was 15±3 hours and it was composed of 15.6% swimming, 35.4% cycling, 25% running and 24% UTR.

The athlete completed a medical questionnaire to make sure she was not receiving any treatment or suffered from any cardiovascular disease or of any other type that could alter the autonomous nervous system. The participant was informed about the procedure to be followed and provided written consent to participate in the study, which met all principles described in the Declaration of Helsinki (The World Medical Association, 2018).

Procedure

Basal HRV measurements were conducted for 92 consecutive days at 6.00 am during 5 minutes. A Polar V800 (Polar, Kempele, Finland) heart rate monitor with chest strap, validated for HRV measurement (Giles, Draper, & Neil, 2016), was used. The RR time series was downloaded from the device through an USB cable using the brand's app FlowSync (version 3.0.0.1337) and subsequently analysed with Kubios HRV software (version 3.1.0, University of Eastern Finland, Kuopio, Finland). Each recording was previously analysed in order to detect potential artefacts and/or anomalous beats. The corresponding filters were then applied if needed.

The time domain was used and the variable RMSSD in ms was calculated (Task Force, 1996), as well as its natural logarithm (LnRMSSD) in order to assess the parasympathetic activity. Besides, taking SD2 from Poincaré scatter plot (Tulppo et al., 1996), SS (Naranjo Orellana et al., 2015) and its natural logarithm (LnSS) were calculated as indicators of the sympathetic activity. Lastly, the ratio between SS and SD1 provided information on the relationship between the sympathetic and parasympathetic dimensions (S/PS ratio) (Naranjo Orellana et al., 2015).

Design of EL

EL was designed and administered according to the mesocycle planning and it was quantified by the weekly total (of each microcycle). In general terms, training load is intensity times volume (Halson, 2014), but the training programme of this athlete was made of four different modalities for which EL had to be quantified.

In running, intensity is given by speed, while duration is the volume. Therefore, in this case, the product of intensity and volume is the distance expressed in km. In continuous running the covered distance was used as EL, while total cumulative distance (km) was used for set training on the track. In UTR sessions, the covered distance (km) was multiplied by the mean gradient. In swimming, since the training was divided into sets, cumulative distance (km) was used as EL.

In both cycloergometer and road cycling, the total distance covered (km) was taken as EL. The most common in cycling is to use power in watts but, since the covered distance was used as EL in the other disciplines, it was decided to do the same here with the purpose of being able to compare the measurements.

Statistical analysis

Data are presented as mean and standard deviation (SD), together with the corresponding coefficient of variation (CV). The effect size (ES) was measured by calculating Cohen's d for 90% confidence intervals. The interpretation scale proposed by Hopkins (Hopkins, Marshall, Batterham & Hanin, 2009) was applied: trivial (below 0.2), small (0.20 to 0.59); moderate (0.6 to 1.2) and large (above 1.2). Pearson's correlation coefficient (r) was used to determine the correlation between variables.

RESULTS

Table 1 displays the weekly EL, as well as the weekly total, for every activity along the three mesocycles and the two competitions.

Table 1. Mean weekly external load (EL) in kilometres for every mesocycle. Results are presented as mean±standard deviation.

Weeks	Swimming		Cycling		Running		UTR		TOTAL EL	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
(1 to 6) M1	2.83	0.99	55.40	37.19	18.89	29.48	92.50	36.81	275. 85	120.56
(7 to 11) M2	4.00	2.31	71.11	52.77	38.03	25.41	111.20	94.68	359.78	141.05
(12 to 16) M3	2.67	1.15	56.18	39.55	22.67	25.63	37.80	26.74	224.25	133.05

M1-M3: refers to each of the mesocycles under study.

Table 2 shows the values (mean±SD), as well as CV, of the HRV variables for every mesocycle.

Table 2. HRV variables for the three mesocycles.

	Mesocycle 1 (weeks 1-6)			Mesocycle 2 (weeks 7-11)			Mesocycle 3 (weeks 12-16)		
	Mean	SD	CV	Mean	SD	CV	Mean	SD	CV
SD1 (ms)	83	14.87	18%	89	12.95	15%	95.9	16.00	17%
SD2 (ms)	156.5	64.18	41%	235	88.94	38%	194.0	88.16	45%
SS	7.2	2.36	32%	5.0	2.39	47%	6.1	2.83	47%
LnSS	1.9	0.36	19%	1.5	0.42	28%	1.7	0.46	27%
S/PS Ratio	0.09	0.04	46%	0.0	0.03	51%	0.07	0.03	49%
RMSSD (ms)	117.7	20.93	18%	126	19.10	15%	135.6	22.56	17%
LnRMSSD	4.7	0.21	5%	4.8	0.15	3%	4.9	0.16	3%
HR (bpm)	36.0	1.51	4%	38	3.60	9%	37.8	2.80	7%

HRV: heart rate variability; SD1: transverse axis in Poincaré scatter plot; SD2: longitudinal axis in Poincaré scatter plot; SS: stress score; LnSS: natural logarithm of SS; S/PS Ratio: sympathetic/parasympathetic ratio; HR: heart rate; RMSSD: square root of the mean of the squares of the differences between successive RR intervals; CV: coefficient of variation; SD: standard deviation.

Table 3 contains the values of EL, RMSSD, SS and S/PS ratio expressed as their natural logarithms. Mean, SD and SE (d) of every week compared to the previous one are presented.

Table 3. EL and HRV variables for the three mesocycles.

MESO	Week	LnEL (km)			LnRMSSD (ms)			LnSS			S/PS Ratio		
		MEAN	SD	d	MEAN	SD	d	MEAN	SD	d	MEAN	SD	d
	1	5.70	4.91		4.76	0.06		2.15	0.26		0.11	0.02	
	2	5.85	4.58	0.33	4.69	0.21	2.29	2.13	0.22	0.32	0.11	0.03	0.24
1	3	5.93	4.80	0.23	4.86	0.05	0.69	1.79	0.29	1.52	0.07	0.02	1.93
	4	5.95	4.69	0.26	4.81	0.11	0.80	1.47	0.51	1.71	0.06	2.00	1.28
	5	4.95	3.65	1.02	4.62	0.44	1.70	1.96	0.37	0.69	0.12	0.08	0.86
Competition	6	4.70	3.90	0.51	4.77	0.10	0.52	1.64	0.48	0.25	0.07	0.03	0.45
	7	5.81	4.92	0.02	4.86	0.08	0.38	1.81	0.44	0.81	0.08	0.04	0.04
	8	5.82	4.70	0.63	4.75	0.15	1.14	1.45	0.37	0.51	0.06	0.02	0.51
2	9	5.11	3.87	0.22	4.92	0.20	0.95	1.24	0.26	0.34	0.04	0.01	0.73
	10	6.32	5.07	0.31	4.94	0.12	0.11	1.35	0.30	0.30	0.04	0.02	0.28
	11	6.01	4.77	0.26	4.88	0.19	0.42	1.48	0.45	0.72	0.05	0.03	0.41
	12	5.39	4.37	0.51	4.91	0.17	0.14	1.85	0.36	0.41	0.07	0.03	0.59
	13	5.86	4.91	0.33	4.96	0.15	0.25	2.02	0.35	0.41	0.08	0.03	0.26
3	14	5.66	4.34	0.27	4.90	0.10	0.37	1.63	0.33	1.09	0.06	0.02	0.66
Competition	15	3.71	2.93	0.40	4.79	0.15	0.96	1.91	0.29	0.63	0.08	0.03	0.91
	16	3.40	2.98	0.16	4.71	0.19	0.42	2.23	0.25	0.78	0.11	0.02	0.78

HRV: heart rate variability; MESO: mesocycle; LnEL: natural logarithm of the external load; LnRMSSD: natural logarithm of the square root of the mean of the squares of the differences between successive RR intervals in ms; LnSS: natural logarithm of the stress score; S/PS Ratio: sympathetic/parasympathetic ratio; SD: standard deviation; d: effect size.

Pearson's correlation coefficients were calculated between EL and the HRV variables, yielding the following values: r = 0.42 for LnRMSSD, r = -0.39 for LnSS and r = -0.42 for S/PS ratio.

The evolution of the daily morning LnRMSSD and LnSS measurements is presented in figure 1. The value ranges considered normal for every variable are drawn. The UTR and Ironman competitions are indicated on days 34 and 91.
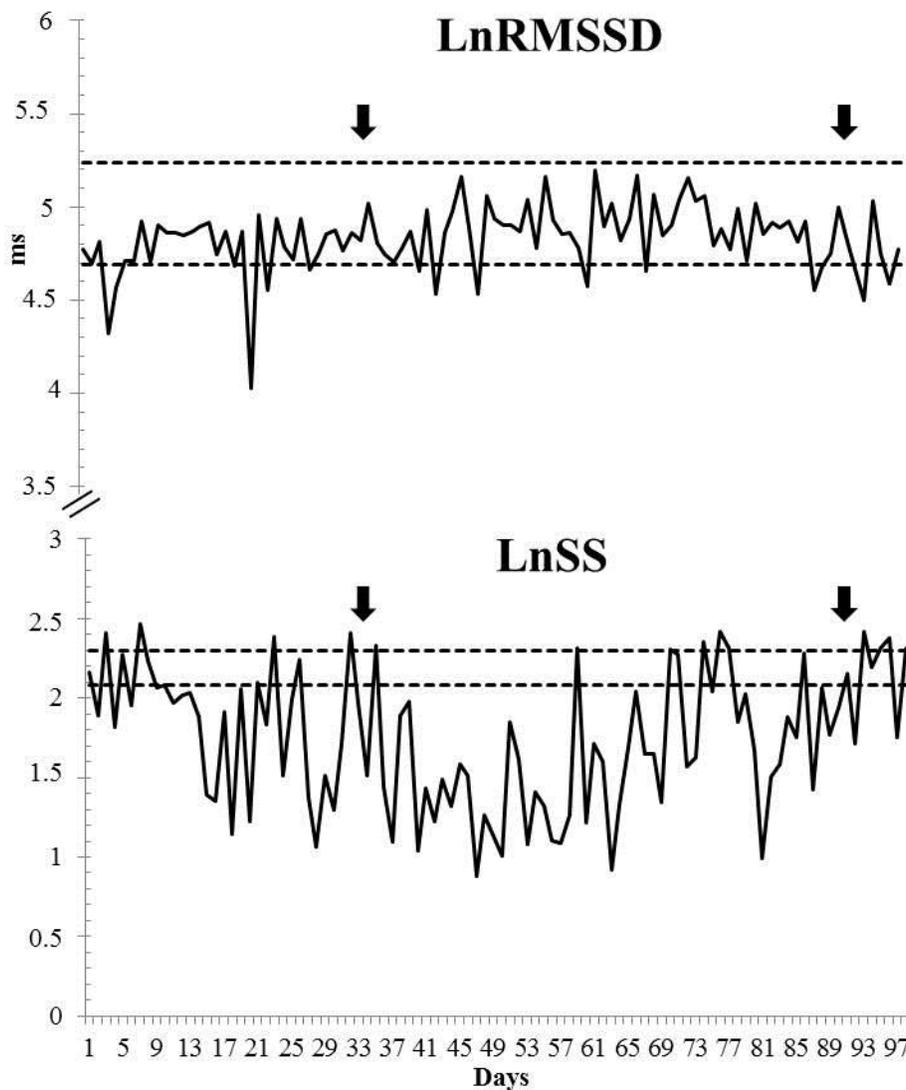

Figure 1. Evolution of the daily morning LnRMSSD and LnSS measurements.

LnRMSSD: natural logarithm of the square root of the mean of the squares of the differences between adjacent RR intervals in ms; LnSS: natural logarithm of the stress score. The UTR and Ironman competitions are indicated on days 34 and 91.

DISCUSSION

The main contribution of this study was to establish a daily HRV monitoring routine trying to distinguish between IL and EL in a female athlete who combines UTR and Ironman disciplines.

One of the main methodological problems of HRV is the day-to-day variability and even the within-subject variability, yielding CV values up to 30%. Therefore, some authors recommend measuring several days a week in order to analyse the mean value (Buchheit et al., 2013; Le Meur et al., 2013; Plews, Laursen, Stanley, Kilding, & Buchheit, 2013), while others suggest using the coefficient of variation of the values recorded as assessment tool (Flatt, Esco, & Nakamura, 2017; Plews et al., 2012). In our case, the CV ranged between 3 and 5% for LnRMSSD and between 19 and 28% for LnSS.

Consequently, in this case, CV is not the best indicator to assess the state of the parasympathetic system, since a CV of 3 to 5% is perfectly acceptable. However, as shown in figure 1, the daily evolution of both variables is highly sensitive to changes during the training period. In spite of this, following the proposal of Buchheit et al. (2013), Le Meur et al. (2013) and Plews et al. (2013), the weekly means were calculated, as shown in table 2.

Given that there was no relationship between CE and the HRV variables measured, it is reasonable to think that these variables are mainly assessing IL. The changes in RMSSD and SS have been used in some studies as indicators of IL in team sports (Miranda-Mendoza et al., 2019). Thus, daily basal measurements of LnRMSSD provide information regarding the degree of recovery of the parasympathetic tone after the previous day workload. Likewise, LnSS reveals whether the sympathetic tone observed in basal conditions falls within the expectations for a full recovery or, on the contrary, any secondary alteration has been induced by the previous stressful load. For this reason, table 3 contains the relative changes (measured through ES) between every week and the previous one.

During the UTR competition week, a slight decrease in EL was observed (d = 0.51), together with a small increase in LnRMSSD (d = 0.52) and a small decrease in LnSS (d = 0.25). In the case of Ironman, EL increased slightly (d = 0.40), while there was a moderate reduction in LnRMSSD (d = 0.96) and a moderate increase in LnSS (d = 0.63) (table 3). Therefore, our data do not agree with those of Stanley et al. (2015), since we found that the changes occurred in the week prior to competition are not relevant and, therefore, they can hardly be used as indicators related to competition. As our athlete had a double profile UTR-Ironman, we do not

know to what extent this situation may have affected the variables analysed compared to studies conducted only with triathletes.

The strategy of taking basal measurements every morning allowed us to determine in which conditions our athlete would begin every training session. No value ranges deemed as normal for LnRMSSD or LnSS were found in the literature. Nonetheless, there exist percentile tables for all variables of the different HRV domains (Corrales, de la Cruz Torres, Garrido Esquivel, Garrido Salazar, & Naranjo Orellana, 2012) from which the corresponding Ln values can be obtained. We can therefore confirm that the mean weekly LnRMSSD values for our athlete (table 3) lay between 75th (4.69ms) and 95th (5.24ms) percentiles for female athletes. When it comes to using the stress score (SS) as sympathetic stress indicator (Naranjo Orellana et al., 2015), its authors recommend taking 75th and 90th percentiles to establish an alert zone (Naranjo, De la Cruz, Sarabia, De Hoyo, & Dominguez-Cobo, 2015). This corresponds to SS values between 8 and 10, their Ln being 2.08 and 2.30, respectively. Mean weekly LnSS values for this athlete (table 3) lay in general below 2.23 (75th percentile).

The sympathetic and parasympathetic responses of this athlete to the load applied seem to indicate that positive adaptations to training occurred, since their values stayed within the normal ranges, not giving signs of fatigue or overtraining. Thus, the different sessions did not constitute an abnormally high IL for the athlete in any of the measurements despite the variability observed in EL.

The CV values of LnRMSSD (table 2) ranged between 3 and 5% in the present study, much lower than those reported by Buchheit et al. (2014), which were between 10 and 20%. However, other studies found fluctuations between 4 and 9% during training periods in elite rowers (Plews et al., 2013) and elite triathletes (Plews et al., 2012; Le Meur et al., 2013), which is more in line with our results.

Lastly, the S/PS ratio values (table 3) were far below 0.25, the value suggested by Naranjo et al (2015), what may reflect a complete autonomous balance in the basal measurements.

CONCLUSIONS

Daily 5-min HRV measurements performed in the morning seem to be an effective tool to monitor an athlete's sympathetic-parasympathetic balance before tackling a training session. This monitoring would allow for early detection of fatigue states and for modification of the training load planning when necessary.

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