Heart rate variability as indicator of internal load in female non-athletes: pilot study

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Summary

Heart rate variability (HRV) is a non-invasive tool capable to evaluate the sympathetic and parasympathetic modulation and it has been proposed as a valid method to assess the individual response to a workload and, therefore, the training load.
The objective is to use the RMSSD-Slope (square root of the mean of the differences of the sum of the squares between adjacent RR intervals) to analyze the recovery after two different treadmill intensities in non-athletic women, as an internal training load (ITL) measure and its possible relation with the external training load (ETL) 9 healthy, physically active women participated in the study. Two tests were performed, separated from each other for 48-72h. The first was a maximum treadmill test, in which the maximal aerobic speed (MAS) was determined. In the second session, an 80% test of the MAS was carried out. In each of the sessions, Borg scale and HRV was monitored (rest, exercise and recovery) for further analysis with the RMSSD-Slope.
The RMSSD-Slope value in the 80% intensity test was 0.97 (± 0.78), and in the Maximum Test it was 0.84 (± 0.36). Both tests show an R^2 with Borg scale of 0.62 and 0.62 respectively. In the case of the R^2 between the ETL and the RMSSD-Slope it was 0.04 and 0.14 respectively.
The recovery slope of the RMSSD is a good ITL assessment tool in physically active women but not athletes.

Key words:
Parasympathetic. Training load.
Heart rate variability. Recovery.

Variabilidad de la frecuencia cardíaca como indicador de carga interna en mujeres no deportistas: estudio piloto

Resumen

La variabilidad de la frecuencia cardiaca (VFC) es una herramienta no invasiva que permite evaluar la modulación simpática y parasimpática y se ha propuesto como un método válido para valorar la respuesta individual a una carga de trabajo y, por tanto, la carga de entrenamiento.
El objetivo es utilizar la RMSSD-Slope (La pendiente de la raíz cuadrada de la media de las diferencias de la suma de los cuadrados entre intervalos RR adyacentes) para analizar la recuperación tras dos intensidades diferentes en tapiz rodante en mujeres no deportistas, como medida de carga interna (CI) y su posible relación con la carga externa (CE).
Participaron 9 mujeres sanas, físicamente activas. Se realizaron dos test, separados entre sí por 48-72 h. El primero fue una prueba máxima en tapiz rodante, en el que se determinó la velocidad aeróbica máxima (VAM). En la segunda sesión, se realizó una prueba al 80% de la VAM. En cada una de las sesiones se hizo un seguimiento la escala de Borg y de la VFC (reposo, ejercicio y recuperación) para su posterior análisis con la RMSSD-Slope.
El valor de la RMSSD-Slope en la prueba del 80% de intensidad fue de 0,97 (±0,78), y en la Prueba Máxima fue 0,84 (±0,36). Ambas pruebas presentan una R^2 con la escala de Borg (0,62 y 0,62) respectivamente. En el caso de la R^2 entre la CE y la RMSSD-Slope fue de 0,04 y 0,14 respectivamente.
La pendiente de recuperación de la RMSSD es una buena herramienta de valoración de CI en mujeres físicamente activas pero no deportistas.

Palabras clave:
Parasimpático.
Carga de entrenamiento.
Variabilidad de la frecuencia cardíaca.
Recuperación.

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Introduction

Heart rate variability (HRV) is a non-invasive tool that allows the sympathetic and parasympathetic modulation[1,2] to be assessed, and has been suggested as a valid method to assess the individual response to a work load, and therefore, training load[3,4]. There has been a recent interest in controlling the training load of athletes[5], on the one hand marked by the administrated load or external load (EL), and on the other hand, the way each subject takes on this load and responds to it, which is known as the internal load (IL)[6].

One method used to assess the training load, is to measure the HRV immediately after exercise to observe the way the values are recovered. However, there is no clear rule in terms of the type of load to assess, with studies that measure work loads based on thresholds (as percentage of the maxHR) without adjusting the intensity to duration in laboratory, either with a single exercise intensity[7] or with different intensities[8-11], whilst others assess days or weeks of training with different load types[3,4,11,12], or designed specifically on-site[13]. Recently, Ruso *et al.* (2019) adjusted the VT1 and VT2 to obtain the same training load, and observed that the parasympathetic reduction is independent of the type of work performed, and is inverse to intensity, concluding that recovery from RMSSD would be a good indicator for assessing IL[14].

IL can be assessed with HRV, with studies carried out observing changes in the sympathetic-parasympathetic modulation as indicators of IL in team[15] and individual[16] sports. Along this line, Naranjo *et al.*[17] have proposed a simple tool for assessing IL, through the immediate recovery of the root mean square of successive differences between the adjacent RR intervals (RMSSD) after an exertion of any nature.

Until now, the use of this IL index has been limited to young, physically active demographics[17]. However, there are not yet any literary studies that assess the immediate recovery following exercise in the general, non-athlete population, using the tool proposed by these authors. Even though some indices have been described[9], everyday use on a demographic of active yet non-athlete females has not been implemented.

For this reason, the aim of this study is to use this analysis instrument post-exercise, after two different intensities on a treadmill, on physically active yet non-athlete females, as a measurement of IL and the possible relationship with EL.

Material and method

This study used 9 healthy females, physically active yet non-athletes and non-smokers (age 31.67 ± 4.00 years; body mass 64.82 ± 6.97 kg; height 164.04 ± 0.03 cm; BMI: 24.10 ± 2.90).

Following the general indications of *Task Force*[18], all the subjects were advised not to drink alcoholic and/or caffeinated drinks, and not to participate in any physical activity in the 24 hours prior to each test.

Each subject underwent a medical check to rule out that they were receiving any other treatment or had any cardiovascular disorders, or any other aspects that could impinge upon or alter the state of the autonomic nervous system. All the subjects were informed about the procedure to follow and gave their written consent to participate in the experiment. The local Ethics Committee approved the study, which adhered to all the principles expressed in the Helsinki Declaration[19]. The total duration of the experiment was 1 week, with 2 sessions separated by 48-72 hours, approximately at the same time of day and under stable environmental conditions (temperature and humidity).

In the first session, each subject filled out a questionnaire about antecedents, they were measured and weighed. An incremental and maximum exertion test was carried out on a treadmill (ErgoRun Medical 8, Daum Electronic; Fürth, Germany) following a scaled protocol with an initial load of 6 km/hr and increases of 1 km/hr every 3 minutes to exhaustion, with a gradient of 1%. Between successive levels, a 1 minute break was performed to obtain a finger-prick blood sample to take lactate measurements in capillary blood using a Lactate Pro 2 (Minneapolis, USA) measurer.

For this study, once each test was finished, the maximum aerobic capacity (VO_2max) was established, considering this to be the final level completed to the volitional limit, always when accompanied by a HR of at least 95% of the theoretical maximum HR of each individual and a maximum lactate over 8 mM/l.

In the second session, each subject ran for 20 minutes at a speed of 80% of VO_2max, consistently and without a previous warm-up.

In each session, the EL was calculated as the product of intensity (speed) by volume (time). By expressing the speed in km/hr and time in hours, the EL is expressed as the distance covered in kilometres.

Heart rate variability measurements

A Polar V800 heart rate monitor was used with a chest band H10 HR Sensor (Polar Inc., Kempele, Finland), approved for HRF measurements[20]. The heart rate monitor was started 10 minutes prior to the test and continued for 15 minutes after the test. All the measurements were performed with the subject sitting, in a calm and silent environment. To do this, the subject was asked to sit down immediately after finishing the test (with no active recovery) for the recovery to be measured.

All the registers analysed were five minutes in duration. The final 5 minutes of the rest (Rest) and exercise (Exer.) registers were taken in each session. In terms of recovery, measurements were taken from minute 5 to 10 once the test was over (Rec. 10).

The series of RR time were downloaded using the Polar FlowSync application (version 2.6.2) to be analysed with the Kubios VFC software (version 2.1, University of Eastern Finland, Kuopio, Finland). Each register was examined beforehand to detect the possible presence of abnormal artefacts and/or beats, and where necessary the corresponding filters were applied.

In each exercise session, the subjective perceived exertion rate was recorded using the Borg scale 1-10[21].

RMSSD is the most frequently used variable in assessing parasympathetic activity[2]. Following the methodology proposed by Naranjo *et* *al.*[17], and applying the nomogram put forward, the recovery curve was calculated from the RMSSD values to minute 10 and starting from the final value of the exercise for each of the intensities performed in the experiment (80% and maximum test). The values obtained in both tests were included in the nomogram for graphic representation.

Statistical analysis

First, a descriptive study was carried out, presenting all the data using average and standard deviation. To establish if there were significant differences between the EL and IL variables, the paired t-Student test was applied. In all cases a confidence level of 95% and a $p < 0.05$ value were set. To analyse the connections between the gradients proposed and other load variables, a Pearson correlation analysis was performed. Specifically, the graphic link between the RMSSD gradients at the two intensities was explored.

Results

Characteristics of the tests

Table 1 displays the intensity data (speed), duration, EL and the Borg scale for each of the tests.

Table 2 displays the lactate and heart rate values in the 80% test. For the RMSSD, the levels of the final 5 minutes of exercise are used, following 10 minutes of recovery, and the calculation of the RMSSD-Slope.

Table 3 displays the lactate and heart rate values in the maximum test. For the RMSSD, values are displayed from the final 5 minutes of exercise, after 10 minutes of recovery and the calculation of the RMSSD-Slope.

The values of the RMSSD-Slope for the 80% test (Table 2) and the maximum test (Table 3) do not reveal significant differences ($p = 0.52$).

Figure 1 displays the graphic association between the Borg scale[1-10] and the RMSSD-Slope of the 80% test (A) and with the maximum test (B). The Pearson correlation coefficient for both comparisons was -0.76 and -0.70 respectively.

Figure 2 displays the graphic association between the RMSSD-Slope of the 80% test and the maximum test. This association shows a Pearson correlation coefficient of 0.70.

Figure 3 displays the graphic association between the external load (EL) and the RMSSD-Slope of the 80% test and the maximum test. These relations reveal a Pearson correlation coefficient of -0.19 and -0.37 respectively.

Table 1. Characteristics of the tests.

	80% test	Maximum test
Speed (km/h)	10.62 ± 1.43	13.28 ± 1.79
Time (h)	0.33±0.00	0.42±0.08
External load (km)	3.51 ± 0.47	3.53 ± 0.78
Borg scale (1-10)	6.56 ± 1.01	8.44 ± 0.73

Table 2. Data from the 80% test.

80% test					
Subject	Lact.	HR	RMSSD Exer.	RMSSD Rec.	RMSSD -Slope
1	5.5	173	2.9	32.00	2.91
2	4.7	166	4.3	11.00	0.67
3	5.7	176	4.1	10.20	0.61
4	5.6	184	4.2	11.40	0.72
5	4.9	184	4.2	13.90	0.97
6	6.6	177	2.3	4.60	0.23
7	7.8	173	3.1	9.40	0.63
8	4.9	173	4	17.00	1.30
9	5.6	162	3.1	10.08	0.70
Average	5.70	174.22	3.58	13.29	0.97
SD	0.97	7.28	0.73	7.77	0.78

Lact: lactate (Mmol); HR: heart rate (b/m); root mean square of successive differences between the adjacent RR intervals; Exer: Exercise; Rec: Recovery; SD: Standard deviation.

Table 3. Data from the maximum test.

Maximum test					
Subject	Lact.	HR	RMSSD Exer.	RMSSD Rec.	RMSSD -Slope
1	13.5	189	4	18.04	1.40
2	15.4	187	3.47	8.55	0.51
3	12.4	183	3.56	10.88	0.73
4	9.5	182	2.59	16.36	1.38
5	11.1	187	4.72	14.32	0.96
6	12.2	181	2.86	6.77	0.39
7	8.2	175	4	9.88	0.59
8	11.4	183	4.13	13.14	0.90
9	15.6	167	4.57	11.52	0.70
Average	12.14	181.53	3.77	12.16	0.84
SD	2.47	6.77	0.72	3.66	0.36

Lact: lactate (Mmol); HR: heart rate (b/m); root mean square of successive differences between the adjacent RR intervals; Exer: Exercise; Rec: Recovery; SD: Standard deviation.

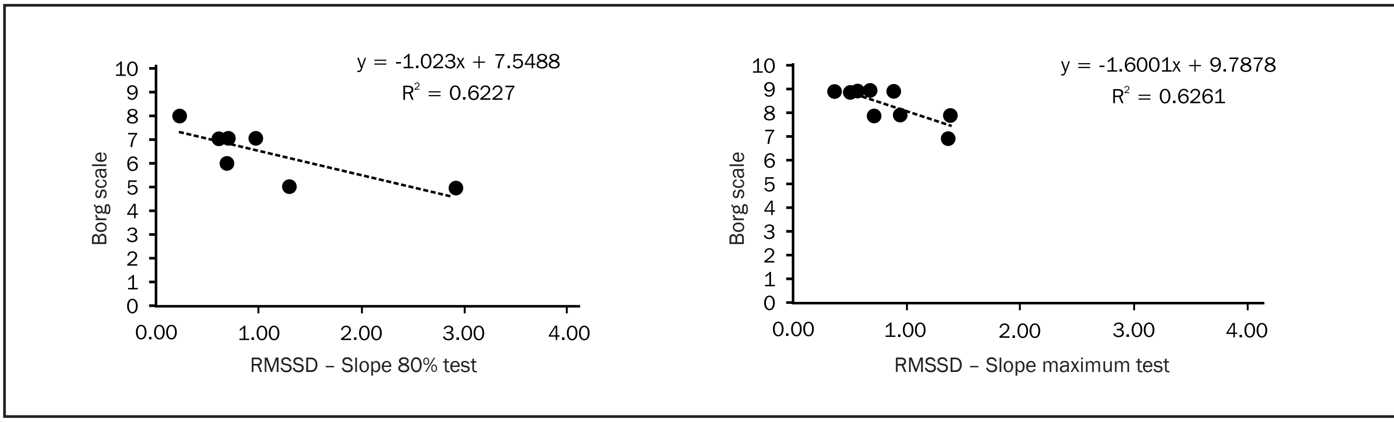
Figure 4 displays the individual results of the RMSSD-Slope from the 80% tests and the maximum test on the nomogram proposed by Naranjo *et al.*[17].

Discussion

The main contribution of this study is the application of the nomogram valuing the post-exercise IL in physically active females, yet non-athletes, after exertions at two different intensities.

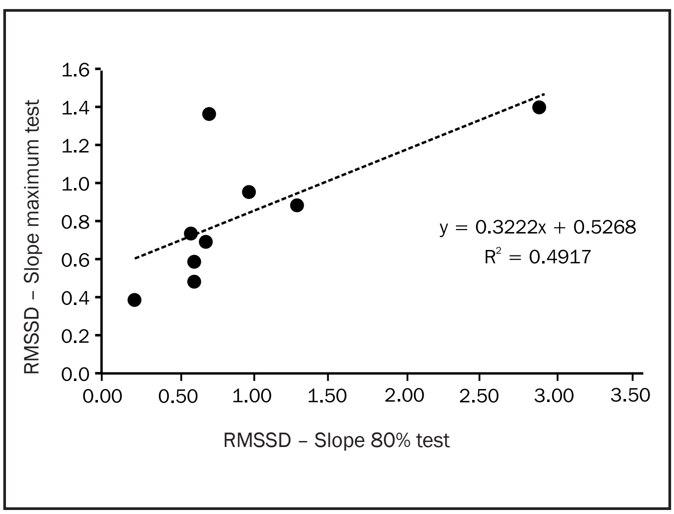
The study performed by Naranjo *et al.*,[17] revealed that the reactivation of the RMSSD after exercise behaves in a linear fashion, at least during the first 30 minutes, allowing for a calculation of the gradient at any time during this time. In our study, the average EL obtained in

Figure 1. Relationship between the Borg scale (1-10) and the RMSSD-Slope.



RMSSD: root mean square of successive differences between the adjacent RR intervals.

Figure 2. Relationship between the RMSSD-Slope of both tests.



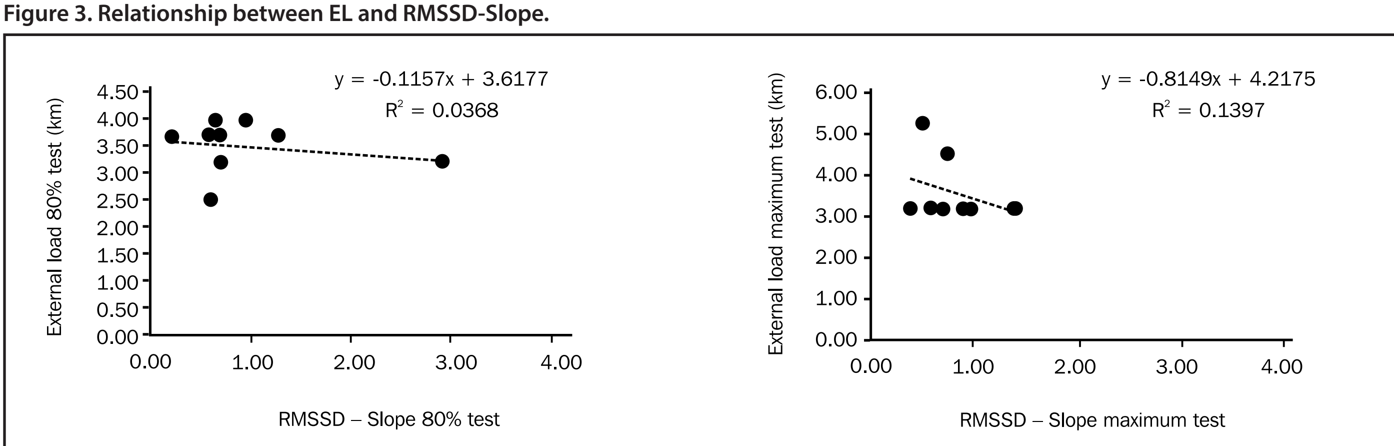
RMSSD: root mean square of successive differences between the adjacent RR intervals.

the 80% test and the maximum test were the same (3.51 ± 0.47 and 3.53 ± 0.78 km) (Table 1). This fact proves that there is no difference between the recovery curve of RMSSD at both intensities (p=0.52), as the response seems to be adjusted to the total load, which in this case is the same. This is referred to by Naranjo *et al.*[17] when the work load exceeds 80% among university students. However, other authors, using different methodologies, report different RMSSD values exceeding intensities of 80%[9,22].

In our studies, during the exercise there is a drop in RMSSD values regardless of the intensity. For the 80% test it is 3.7 ms and for the maximum test it is 3.5 ms (Tables 2 and 3), coinciding with Michael *et al.*,[23] and Naranjo *et al.*[17], referring to values of 5 and 4 ms respectively. Therefore, we can confirm that the suppression of the parasympathetic stimulus during physical exercise is also total in untrained females, regardless of the load performed.

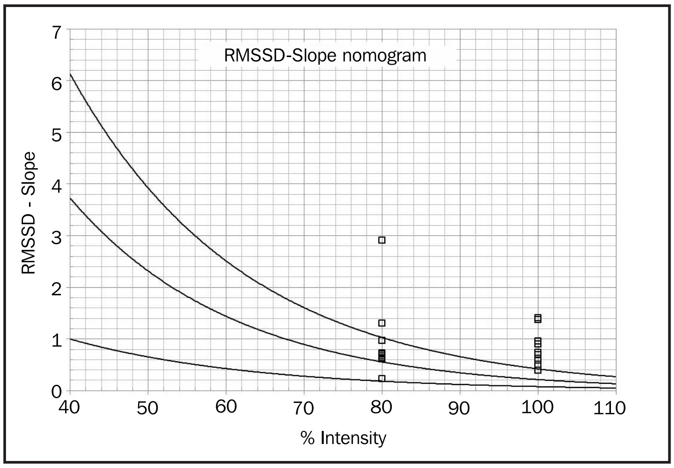
When comparing the IL of both tests with the Borg scale (Figure 1), we find a good linear relationship with a R^2 of 0.62 for the 80% test and 0.63 for the maximum test. It also occurs with Pearson correlation coefficient (r = -0.76 for the 80% test and r = 0.70 for the maximum test),

Figure 3. Relationship between EL and RMSSD-Slope.



RMSSD: root mean square of successive differences between the adjacent RR intervals; CE: external load..

Figure 4. RMSSD-Slope nomogram.



RMSSD: root mean square of successive differences between the adjacent RR intervals.

which even reveals better values than those found by Naranjo *et al.*[17] (r = -0.67) among university students. Therefore, we reaffirm that the positive correlation of the RMSSD-Slope with the Borg scale confirms it as a good IL tool.

By linking the IL values between both tests, an r = 0.70 correlation is obtained, though with a lower linear relationship (Figure 2: $R^2 = 0{,}49$). No links were found between IL and HR, or with Lactate. Likewise, the non-athlete females did not reveal any correlation between the EL and the RMSSD-Slope (Figure 3), giving r values of -0.19 and 0.37 in each test. The data obtained reveals a totally individual response, in that each subject took on the load administered and responded to it.

The average RMSSD-Slope value proposed by Naranjo *et al.*[17] to assess the results of a physical load in the second ventilatory threshold is 0.29 and 0.28 for the maximum aerobic speed. In our results (Figure 4) in the 80% test, the females presented an average value of 0.97, and 0.84 for the maximum test. This indicates that both the group average as well as each of the individual responses can be considered positive, not entailing a large IL. One limitation of this study is the low sample size, being a pilot study that will require future research to establish its practical use in a demographic of other characteristics.

It can be concluded that the recovery curve of the RMSSD proposed by Naranjo *et al.*[17] is a useful tool for assessing IL in physically active yet non-athlete females.

Conflict of interest

The authors claim to have no conflict of interest whatsoever.

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