Autonomic responses and internal load analysis through acute assessment of heart rate variability after a high-intensity functional training session

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Summary

Backgroud: Heart rate variability (HRV) measurement is an important tool that may help indicate possible physiological changes, and HRV monitorization could be a great strategy for clinical analysis (autonomic control) and performance (internal load).
Objective: The aim of the present study was to evaluate autonomic responses and internal load through HRV during a high-intensity functional training (HIFT) session.
Material and method: Thirty-three individuals (22 men and 11 women) participated in the study (Age: Mean = 34.9 ± 7.2 years; Weight: Mean = 72.3 ± 13.7 kg; Height: Mean = 1.72 ± 0.1 m; BMI: Mean = 24.4 ± 3.0 kg/m²). All participants engaged in a 60-to-90-minute HIFT session. HRV analysis was performed during the specific warm-up period (targeted warm-up or skill training that followed the general mobility and light cardiovascular warm-up), during exercise (approximately 50 minutes), and in the recovery phase (10 minutes post-training). A Polar H10 heart rate monitor chest strap (Kempele, Finland®) was used to collect HRV and was connected to the Elite HRV mobile application. The data were further transferred to Kubios HRV Standart software, version 3.3.1, in order to process the acquired data.
Results: For isolated analyzes (pre- and post-), differences were found for SDNN (P<0.001), RMSSD (P<0.001) and HF (P=0.041), yet not for LF / HF (P=0.483). In the analysis of HRV kinetics, significant results were found between moments for RR, SDNN, RMSSD, LF and HF (P<0.05). In the analysis of the internal load, the highest level of stress was identified in 40 (P=0.010) and 50 minutes of exercise (P=0.001), as well as in recovery (P<0.001), this assessment being carried out through HRV through the LnRMSSD index. A negative correlation was observed between maximum heart rate (HRmax) and LnRMSSD at 40 (r=-0.51) and 50 minutes of exercise (r=-0.58). In recovery, the correlation was positive, yet insignificant (r=0.032).
Conclusion: The present study observed that HIFT could alter HRV and thus cause changes in autonomic behavior. In addition, this type of modality can offer significant levels of training loads, thus affecting the physiological responses and consequently the individual's functional efficiency.

Key words:
Heart Rate Variability. Autonomic Response. Training Load. High-Intensity Functional Training. CrossFit.

Respuestas autonómicas y análisis de la carga interna mediante la evaluación aguda de la variabilidad de la frecuencia cardíaca tras una sesión de entrenamiento funcional de alta intensidad

Resumen

Introducción: La medición de la variabilidad de la frecuencia cardiaca (HRV) es una herramienta importante que puede ayudar a indicar posibles cambios fisiológicos. La monitorización de la HRV podría ser una gran estrategia para el análisis clínico (control autonómico) y el rendimiento (carga interna).
Objetivo: El objetivo del presente estudio fue evaluar las respuestas autonómicas y la carga interna a través de la VFC durante una sesión de entrenamiento funcional de alta intensidad (HIFT).
Material y método: Treinta y tres individuos (22 hombres y 11 mujeres) participaron en el estudio (Edad: Media = 34,9 ± 7,2 años; Peso: Media = 72,3 ± 13,7 kg; Altura: Media = 1,72 ± 0,1 m; IMC: Media = 24,4 ± 3,0 kg / m²). Todos los participantes participaron en una sesión HIFT de 60 a 90 minutos. El análisis de la VFC se realizó durante el periodo de calentamiento

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específico (calentamiento dirigido o entrenamiento de habilidades que seguía al calentamiento cardiovascular ligero y de movilidad general), durante el ejercicio (aproximadamente 50 minutos) y en la fase de recuperación (10 minutos después del entrenamiento). Se utilizó una banda de pecho con pulsómetro Polar H10 (Kempele, Finlandia®) para recoger la VFC y se conectó a la aplicación móvil Elite HRV. Los datos se transfirieron posteriormente al software Kubios HRV Standart, versión 3.3.1, para procesar los datos adquiridos.

Resultados: En los análisis aislados (pre y post), se encontraron diferencias para SDNN (p <0,001), RMSSD (p <0,001) y HF (p = 0,041), pero no para LF / HF (p = 0,483). En el análisis de la cinética de la VFC, se encontraron resultados significativos entre momentos para RR, SDNN, RMSSD, LF y HF (p <0,05). En el análisis de la carga interna, el mayor nivel de estrés se identificó en 40 (p = 0,010) y 50 minutos de ejercicio (p = 0,001), así como en la recuperación (p <0,001), realizándose esta valoración mediante la VFC a través del índice LnRMSSD. Se observó una correlación negativa entre la frecuencia cardiaca máxima (FCmáx) y el LnRMSSD a los 40 (r = -0,51) y 50 minutos de ejercicio (r = -0,58). En la recuperación, la correlación fue positiva, aunque insignificante (r = 0,032).

Conclusiones: En el presente estudio se observó que el HIFT podía alterar la VFC y, por tanto, provocar cambios en el comportamiento autonómico. Además, este tipo de modalidad puede ofrecer niveles significativos de cargas de entrenamiento, afectando así a las respuestas fisiológicas y, en consecuencia, a la eficiencia funcional del individuo.

Palabras clave:
Variabilidad de la frecuencia cardíaca. Respuesta autonómica. Carga de entrenamiento. Entrenamiento funcional de alta intensidad. CrossFit.

Introduction

Heart rate variability (HRV) is an important parameter for analyzing autonomic behavior and might be an excellent tool for physiological assessment[1]. As known, HRV is a time (measured in milliseconds) between two adjacent heartbeats (rate a rate — RR)[2]. Higher values determine better cardiac conditions and, consequently, indicate a greater balance of the autonomic nervous system[3]. For this matter, it is possible to have a prognosis of an abnormality related to the cardiovascular system through HRV, as well as for other systems, and also to assess the physiological and functional condition of a certain individual[4].

Traditionally, HRV is widely used to assess autonomic responses (sympathetic and parasympathetic interaction) and thus identify certain unwanted reactions, preserving health and functional integrity[5]. Additionally, HRV can change because of intrinsic reasons such as aging[6] and according to sex characteristics[7,8], as well as extrinsic factors such as supplementation[9] and type of training[10]. However, HRV seems to be an easily accessible tool for clinical assessment[11] and for determining physical condition[12].

In the identification of better autonomic responses, different HRV indices (commonly time and frequency domain) can detect physiological changes that could serve for important adjustments favoring cardiovascular health[4]. On the other hand, HRV could also be useful for analyses of physical performance[13] and, consequently, help control stress and fatigue[14], preventing individuals from getting injured[15] and providing a greater assessment of an individual's adaptation to a given training sequence[16].

In a sports environment, HRV has been used for analyzing not only the autonomic balance (cardiovascular health) but also internal load (performance), providing greater efficiency of an individual, regardless of their level[15]. In terms of internal load assessment, HRV has already been used as an important strategy for the assessment of possible stresses and high levels of fatigue resulting from overtraining[13,14,17]. In order to assess clinical condition and performance, studies have used HRV to identify changes that can generate negative responses in exercisers/athletes of different modalities[18].

One of the modalities that have been gaining popularity is high intensity functional training (HIFT), supported by the well-known CrossFit® brand. Due to the high physiological demand of this activity[19], studies with physiological behavioral analyzes are extremely useful for better understanding of the repercussions caused by the training load in exercisers or athletes. Studies on HRV in HIFT are still scarce[20], therefore, it is extremely viable to further analyze this variable in exercisers or athletes of this modality. In this activity, the control of the training load (mainly internal) is indispensable since it is a type of training with high physiological demand, thus avoiding possible disorders and even the risk of injuries. Therefore, the aim of the present study was to evaluate the autonomic and internal load responses through HRV in a HIFT session.

Material and method

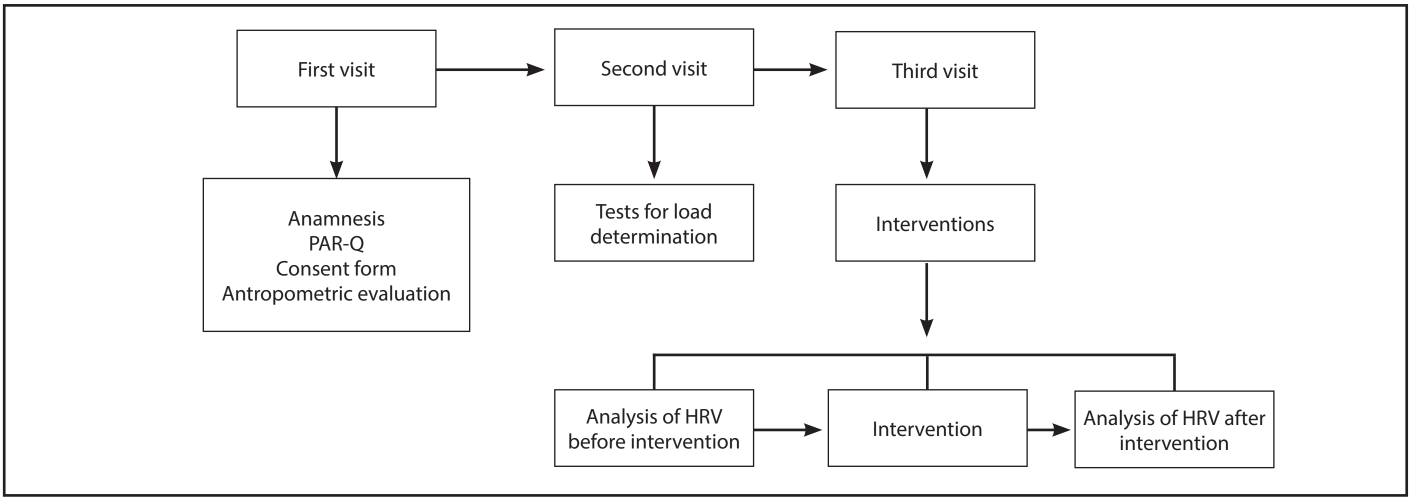
Participants

33 individuals participated in the study (22 men and 11 women) (Table 1), all of them were HIFT exercisers with regular practice of at least 3 months, with training frequency of at least 3 times per week. The exclusion criteria were medication use and / or ergogenic resources that could influence the expected results (i.e., pharmacological drugs for blood pressure control, beta-blockers, drugs related to cardiovascular control, performance enhancers, among others) and presenting musculoskeletal disorders that would compromise the interventions. In

Table 1. Anthropometric characteristics of the participants.

Variables	Participants (n=33) M±SD
Age (years)	34.9 ± 7.2
Weight (kg)	72.3 ± 13.7
Height (m)	1.72 ± 0.1
BMI (kg/m^2)	24.4 ± 3.0

Figure 1. Experimental design flowchart.



addition, all participants received a recommendation not to eat foods that could interfere with cardiovascular responses (excessive consumption of salt, caffeine, alcohol, high-calorie foods, among others).

Experimental design

Further on (Figure 1), the entire organization of the phases of the experimental activities of the present study follows. The research was carried out in a cross-sectional experimental manner.

Procedures

Before the start of the training session, the participants filled out the sociodemographic questionnaires. The Polar H10 was paired with the Elite HRV application. In the application, at the beginning of the warm-up, the activity recording started.

After performing joint mobility exercises and the warm-up with light to moderate intensity, the participant went on to the fundamental part of the training (technical/strength part) and then to the workout of the day (WOD). The 10 minutes after the end of the training were complete rest or light stretching. After the end of the measurement, the txt file was transferred to the computer with the participant's code. On average, the session lasted for 1 hour and 10 minutes.

Training protocol

The training session lasted for up to 70 minutes and consisted of the physiological adaptation phase (mobility exercises and light warm-up), the fundamental part, the WOD, and the recovery. The training session used was the one prescribed by the head coach of the CrossFit box for the very day, being in accordance with the CrossFit® training methodology.

Since the research protocol was based on time, the exercises were performed by running time (minutes) rather than distance or repetitions: Thus, the WOD was performed as follows: Initial phase: 10 min warm-up, using mobility exercises and dynamic stretching. Main phase: 5 rounds of 10 min, composed of: 5 min of out door running in flat space (in high effort zone), 1 min squats, 1 min burpee, 1 min mountain climbers, 1 min push ups and 1 min passive recovery. Final phase: 10 min. stretching and relaxation exercises. All participants were asked to perform the exercises in the greatest possible bearable effort zone. And throughout the series, everyone was recommended to perform the movements with the highest level of quality.

Heart rate variability analyzes

HRV analysis was performed during the warm-up period (10 minutes - pre-time). For the moments between exercises (50 minutes) and recovery (10 minutes - post time). During the complete session (70 minutes), HRV was monitored continuously. A Polar H10 heart rate monitor chest strap was used to collect HRV. For analyzing HRV data, the data were transferred to the computer for their posterior uploading to Kubios HRV Standart Software, version 3.3.1.

For the analysis of data acquired from HRV, for all moments, windows of 5 minutes (300s inter-beats interval) were used, the moments with the highest stable level of HRV were used[1]. All analyzes were performed manually by a researcher with experience for a certain type of analysis. For greater reliability of the collected data, a percentage of up to 2% of artifacts (possible interferences in the collected data) as considered at all times evaluated.

The calculation of the mean of the time domain indices (RR, RMSSD, SDNN and PNN50) and the frequency (LF, HF and LF / HF) was used[4]. In the time domain normal RR (time between two adjacent heartbeats) and, based on statistical or geometric methods (mean, standard deviation and indexes derived from the histogram of RR intervals), the fluctuation indexes of the duration of cardiac cycles were calculated, with RMSSD (square root of the square mean of successive differences between adjacent normal RR intervals, in a time interval, expressed in ms), SDNN (standard deviation of all normal RR) intervals recorded in one time interval, expressed in ms) and the PNN50% (represents the percentage of adjacent RR intervals with a difference in duration greater than 50 ms). The RMSSD and PNN50% represent parasympathetic activity, while the SDNN represents sympathetic and parasympathetic activity (global index), yet does not allow to distinguish when changes in HRV are due to increased sympathetic tone or withdrawal of vagal tone, thus indicating an interaction between sympathetic and parasympathetic[11].

For the analysis of HRV in the frequency domain, low frequency components (Low Frequency — LF) were used, which correspond to the joint action of the parasympathetic and sympathetic systems in the heart, with a predominance of the sympathetic and high-frequency component (High Frequency — HF) which corresponds to respiratory modulation and represents the activation of the vagus nerve. Finally, the LF/HF ratio was used, which, despite several limitations in its use in the autonomic balance[21], could indicate the sympathetic-vagal balance[2]. In this sense, all the data collected were calculated and presented in accordance with different standards so that there are broad interpretations in relation to HRV. For data presentation, a pre- (rest) and post- (recovery) comparison using the SDNN (global index), RMSSD (parasympathetic index), HF (parasympathetic index), and LF/HF (a possible indicator of sympathovagal balance) was performed. The objective was to understand the influence of the type of intervention on parasympathetic activation or reactivation of these individuals. Additionally, an analysis of the HRV kinetics (rest, 10, 20, 30, 40, 50 minutes of exercise and recovery) was performed before the entire experimental session (rest, exercise and recovery) using all indexes and, thus, assessing the complete autonomic behavior in relation to the type of effort.

Load training analyzes

The internal load analysis was performed using the HRV RMSSD index[22]. For this assessment, the RMSSD values were transformed into logarithms (LnRMSSD)[17] and the same HRV collection moments were used for general calculations of this variable. In the presentation of the data, kinetics (rest, 10, 20, 30, 40, 50 minutes of exercise and active recovery) of the LnRMSSD index (rest, exercise, and active recovery) was elaborated in order to identify the possible point of greater intensity of the internal load for this type of training, which was determined when there were major reductions in the values of the lnRMSSD index.

Statistical analyzes

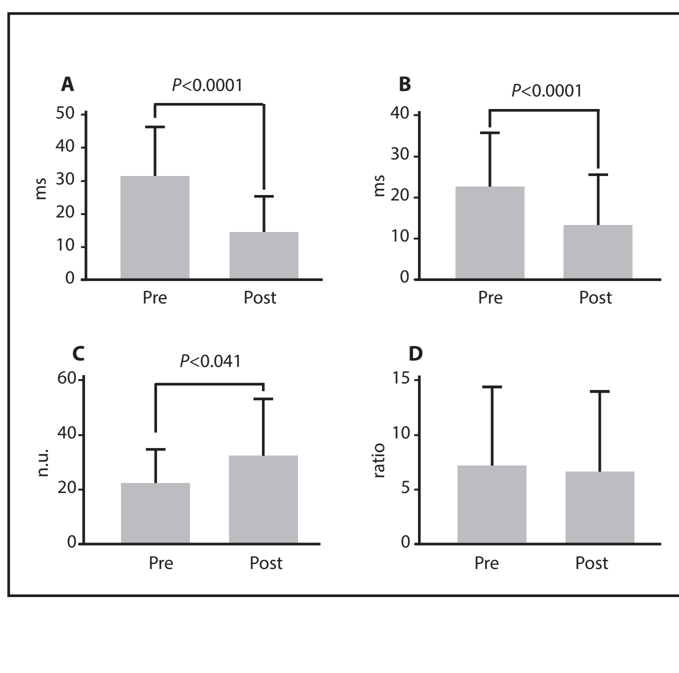
In the descriptive analysis, the means and standard deviation of the variables were calculated. The normality of the data was not rejected by the Shapiro-Wilk test. For isolated analyzes (pre-and post-) of HRV (SDNN, RMSSD, HF, and LF / HF) the T-Test was used. For analysis of the kinetics (all index) of each index (moment) the ANOVA (one-way) was applied repeatedly. Tukey's test was used to perform multiple comparisons, when necessary. Finally, the Pearson test (parametric data) was used for correlation analysis (HR with lnRMSSD). All statistical analyzes were performed using the GraphPrism software version 8.0.1, with a significance level of 5% ($P<0.05$).

Results

For isolated analyzes, the SDNN (Figure 2 A), RMSSD (Figure 2 B), HF (Figure 2 C) and LF/HF (Figure 2 D) indices were used. A significant difference was observed for the pre (warm up) and post (recovery) condition in the SDNN index ($P<0.001$), meaning that, when there were reductions in the values, there was a significant vagal withdrawal. In the RMSSD, there was a reduction in this index after effort ($P<0.001$), indicating a high sympathetic activation resulting from exercise. However, in the evaluation of the HF index, an increase of this index was observed at the time of recovery ($P=0.041$), which means that even under high stimuli, in the post-effort moment, there was a significant capacity for parasympathetic reactivation, which is important in post-activity cardiovascular recovery. Finally, no significant difference was observed in the pre-and post- LF/HF evaluation ($P=0.483$).

An assessment of HRV kinetics (Table 2) was carried out throughout the experimental session (rest, exercise, and recovery) using time domain (RR, SDNN, RMSSD, and PNN50%) and frequency (LF, HF, and LF/HF) (Table 2). The objective of this evaluation was to propose an analysis of the sympathetic-vagal behavior at different times, such as warm-up, exercise, and recovery. In the RR index, significant reductions were observed, in relation to the pre-moment, in 30 ($P=0.010$), 40 ($P=0.000$) and 50 minutes of exercise ($P<0.001$), as well as in recovery ($P<0.001$). For SDNN, there was a significant reduction in this index compared to pre-, in 40 and 50 minutes of exercise ($P=0.002$ and $P<0.001$, respectively) and in the post-effort moment ($P<0.001$). In comparison with 10 minutes of exercise, there was a difference in 40 ($P=0.018$) and 50 minutes ($P<0.001$), as well as in the post time ($P<0.001$). When compared to 20 minutes of exercise, a difference was also observed in relation to 40 ($P=0.044$) and 50 minutes ($P<0.001$), as well as in recovery ($P=0.000$). Still, for SDNN, there was a difference between the 30 and 50 minutes of exercise ($P=0.018$). These findings (RR and SDNN) demonstrated that the inter-

Figure 2. Pre- and post-effort, for SDNN (A), RMSSD (B), HF (C), and LF/HF (D).



vention promoted a high sympathetic activation, thus significantly inhibiting the parasympathetic system, especially in the final phase of the session.

Summarizing the results above, in assessing the behavior of the RMSSD index, the wide vagal withdrawal was notorious. In comparison with the pre-moment, there was a reduction in moments 40 (P=0.001) and 50 minutes of exercise (P<0.001), as well as after the effort (P=0.00). Regarding 10 minutes of exercise, for the same moments, significant reductions were observed (P=0.010, P=0.000 and P=0.001, respectively). In the same way, when compared to 20 minutes of activity, there was a reduction in 40 (P=0.036) and 50 minutes (P=0.000) of exercise, as well as in recovery (P=0.007). In addition, there was also a significant difference between the 30 and 50 minutes of exercise (P=0.023). Analytically, these findings were similar to the RR and SDNN indices for the same time points., which affirms a high discrepancy in the sympathetic vagal performances due to the high-intensity nature of the exercise. However, for PNN50%, no difference was found (P>0.05), and this may indicate a positive ability of the parasympathetic to act during the effort, as there was no significant reduction in the values related to this index.

Nevertheless, it could be suggested that the sympathetic-vagal interaction of these individuals was positive. In the frequency domain, for LF (high sympathetic activation) there was a difference (reduction of values) between 10 and 50 minutes of exercise (P=0.045). This difference was also observed when compared to 20 minutes of exercise for 50 minutes (P=0.003) and recovery (P=0.012). Interestingly, in the HF (parasympathetic), the differences (increase in values) were for the same LF moments, 10 and 50 minutes (P=0.045) and 20 minutes compared to 50 minutes of exercise (P=0.003) and after effort (P=0.017). These findings may suggest that, at the end of the particular session (even with fatigued subjects), there was excellent parasympathetic control over sympathetic activity. However, in the evaluation of a possible sympathetic-vagal balance (LF/HF), no significant difference was observed (P=0.262). It could imply that, even with its limitations, the LF/HF showed results that could sustain a positive behavior between sympathetic and parasympathetic, as there was no significant increase in this value compared to rest.

Additionally, the internal load of the individuals during a HIFT session was evaluated. For this evaluation, the RMSSD index transformed into logarithm values (LnRMSSD) was used. Thus, it was possible to identify at which moments of the training session there was a more significant internal load (Figure 2). The findings of the present study demonstrated that the peak internal load was in the final phase of training, including the recovery phase. This demonstrated a high fatigue index after exercise. With regard to the pre-moment, significant differences were observed at moments 40 (P=0.010) and 50 minutes of exercise (P=0.001), as well as in the recovery phase (P<0.001).

To complement the internal load assessment, an analysis of the maximum heart rate kinetics (HR_{max}) and LnRMSSD (Figure 3) was performed. The use of HR_{max} can be indicative of stress and, consequently, serve to monitor the training load[25]. Therefore, the dynamics of HR_{max} was similar to that of LnRMSSD, but in the opposite direction. As HR_{max} increased, LnRMSSD decreased, thus indicating sympathetic behavior. Also, where there was a greater increase in HR_{max}, there was also a

Figure 3. Internal load analyses for all moments.

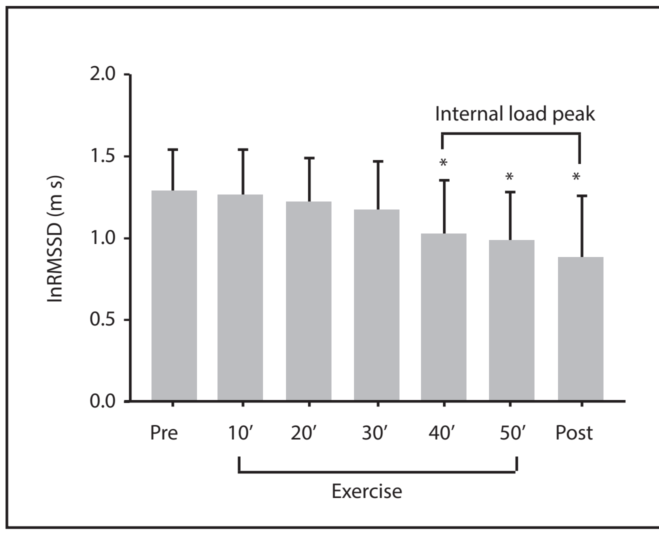
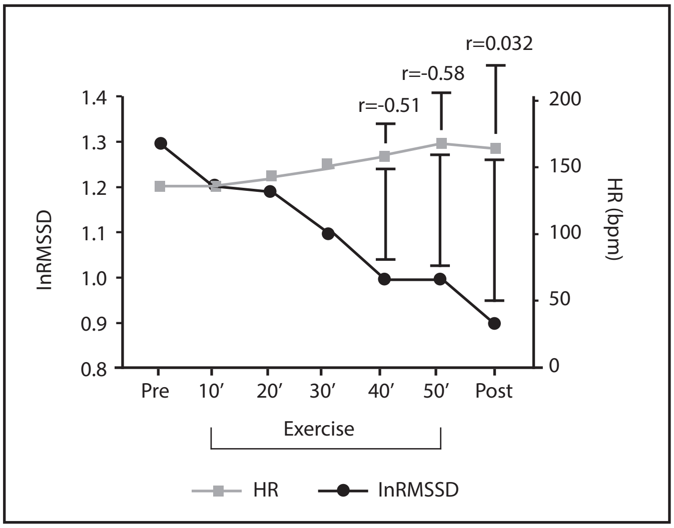


Table 2. Behavior HRV, for all analyses moments.

Index				Moment			
Time Domain	**Pre**	**10′**	**20′**	**30′**	**40′**	**50′**	**Post**
RR (ms)	562.9 ± 104.2	556.3 ± 117.6	531.9 ± 103.3	488.8 ± 126.3[a,b]	463.3 ± 92.5[a,b,c]	430.1 ± 99.7[a,b,c]	437.9 ± 86.6[a,b,c]
SDNN (ms)	30.96 ± 14.9	29.20 ± 14.5	28.27 ± 12.5	26.04 ± 14.3	18.88 ± 12.07[a,b,c]	12.71 ± 8.2[a,b,c,d]	14.05 ± 10.5[a,b,c]
RMSSD (ms)	26.75 ± 15.5	25.22 ± 15.9	24.13 ± 15.0	21.28 ± 14.3	15.40 ± 11.1[a,b,c]	12.12 ± 8.1[a,b,c,d]	13.95 ± 12.2[a,b,c]
PNN50 (%)	4.35 ± 4.8	3.93 ± 6.1	3.55 ± 4.8	2.76 ± 3.4	1.59 ± 2.3	1.45 ± 2.1	1.66 ± 3.8
Frequency Domain	**Pre**	**10′**	**20′**	**30′**	**40′**	**50′**	**Post**
LF (n.u.)	7.63 ± 11.8	78.98 ± 12.0	82.22 ± 11.5	74.85 ± 17.0	75.45 ± 18.0	66.43 ± 23.3[b,c]	67.90 ± 20.6[c]
HF (n.u.)	22.46 ± 11.7	20.94 ± 12.0	17.73 ± 11.5	24.73 ± 16.8	24.26 ± 17.62	33.36 ± 23.2[b,c]	31.47 ± 20.4[c]
LF/HF (ratio)	4.74 ± 2.9	5.10 ± 3.0	6.86 ± 5.0	4.79 ± 3.5	5.27 ± 3.6	4.72 ± 5.0	4.49 ± 4.5

[a]Significant difference compared to the pre- moment (P<0.05). [b]Significant difference compared to 10 minutes (P<0.05). [c]Significant difference compared to the time 20 minutes (P<0.05). [d]Significant difference compared to the 30 minute moment (P<0.05).

Figure 4. Between correlation HR and lnRMSSD in the session.



greater reduction in HRV (LnRMSSD). However, when the correlation was applied, the results did not show a high correlation between the variables. For 40 minutes of exercise, there was an average negative correlation (r=-0.51) and in the same way it was for 50 minutes of exercise (r=-0.58). This indicates that when variable A increases (HR), B decreases (LnRMSSD). These correlations are acceptable and despite being average, we can suggest that, in these individuals, HRmax can be an internal load parameter. However, in the recovery phase, the correlation was positive (variable A increases, B also increases) but insignificant (r=0.032) (Figure 4).

Discussion

The aim of the present study was to evaluate the autonomic responses and the internal load through HRV during a HIFT session. For the analysis of autonomic behavior, HRV indices in the time domain (RR, SDNN, RMSSD, and PNN50%) and frequency (LF, HF and LF/HF) were used[1]. For the evaluation of the internal load, the lnRMSSD was used, and this parameter is suitable for analyzes of the training load[17].

Regarding HRV pre and post intervention, the findings of the present study demonstrate important changes in the time domain via the SDNN and RMSSD indices ($P<0.001$), where a significant vagal (parasympathetic) withdrawal was demonstrated due to the high sympathetic activity. In the time domain, significant differences were observed in the HF index ($P=0.041$), where, even with a high training load, after the effort there was a significant parasympathetic reactivation, with this behavior being important for cardiovascular recovery. However, for LF/HF, no significant differences were observed ($P=0.483$), possibly generated by high sympathetic activity. This index, even though there are limitations and controversies in its interpretation[21], could indicate a possible balance between sympathetic and parasympathetic activities, thus determining better autonomic behavior[23].

Through the analysis of HRV kinetics in the effort, it is possible to identify potential cardiovascular overloads and, in this way promote important adjustments to avoid health damage and/or poor performance. In the present study, a HIFT session was able to generate significant (negative) changes ($P<0.05$) in HRV identified through the indices (time domain), RR (starting at 30 minutes), SDNN (starting at 40 minutes), RMSSD (starting at 40 minutes). Interestingly, it seems that during the HIFT activity, there may be a physiological compensation, through which balance is promoted, even with high intensity and a higher level of fatigue. The frequency domain indices (LF and HF), showed positive results ($P<0.05$) at the end of the session (50 minutes and recovery phase), showing less sympathetic activity (LF) and greater parasympathetic activity (HF).

Additionally, in the evaluation of the internal load, the present study showed a greater peak of stress at the end of the session (starting at 40 minutes), lasting until recovery. Also, HRmax also showed higher values correlating with HRV for the same moments of higher levels of the internal load identified through the LnRMSSD index, and can thus be used as an internal load control parameter[15]. HRV is considered an important tool for the analysis of autonomic behavior[3] and internal load[14]. However, studies that evaluated HRV in HIFT are still few. Tibana *et al.*[20] identified positive results (preparation phase) and negative results (competition phase) of LnRMSSD in a 38-week follow-up, stating that the greater the training load, the greater the repercussion the internal load. Despite being acute, our findings may elucidate this premise, where greater changes in HRV were identified at the moments of greater loads (longer activity time).

HIFT is a modality that is widely used for improving physical fitness and conditioning, and is characterized by a high level of motivation[24]. HIFT is a type of activity with high physiological demand, which can lead to high levels of hormonal, metabolic and inflammatory changes, thus being able to generate both positive and negative responses in physiological adaptations[25]. In order to increase the information on this training method, the present study evaluated HRV responses to health and performance. Our findings replicate those of Kliszczewicz *et al.*[26], who also observed significant changes in HRV that can affect autonomic control (cardiovascular health) and also the training load, enabling greater reduction in performance.

With regard to mechanisms, HIFT is an activity that generates high physiological (acute and chronic) changes[27] interfering in biochemical[19], metabolic[25] and cardiovascular components[26]. These changes are affected by high intensity imposed by the exercises performed in HIFT and, consequently, generate changes in HRV that, in several acute episodes (training session), can affect a sum of stress causing negative changes in a chronic way[20]. Like these metabolic or biochemical factors, changes in cortisol, testosterone, norepinephrine may have a negative impact on cardiac behavior and, consequently, alter HRV. These changes affect the central nervous system, which in turn influences all organic physiology and, as a result, there is a reduction in health and performance[28]. However, through HRV it is possible to observe these changes and thus control possible undesirable events[14,29]. In HIFT, the use of HRV can be a great strategy to monitor the individual's training load in response to the training. Also, it can be applied outside the exercise (f.ex., during rest) for the assessment of the individual's recovery state, helping control the following training sessions even better.

Limitations

The present study has some limitations, and these may have affected the observed results. In order to verify HRV responses specifically for exercise, measurement in resting-state was not applied, only in exercise (warm-up, main training phase, and active recovery). The exercise session time (70 minutes) was somewhat shorter than that normally used in real practice (around 90 minutes on average), which may underestimate or overestimate the HRV reactions in autonomic behavior and internal load. Finally, the experiment was held during only one session, not letting to extrapolate the findings in order to allow for chronic interpretations. Nevertheless, there might be a possible explanation of what could have happened if there were no assertive control of the intensity and a variation of stimuli. Therefore, this study contains important information that could be used by coaches in their HIFT planning and prescription.

Practical applications

This study contains important information that can be used by coaches when planning and prescribing HIFT. Through the findings of this research, it is possible to have a visualization about what can happen in autonomic behavior when performing exercises related to HIFT and so, being able to control the training load more to avoid loss of performance and promote the preservation of health.

Conclusion

The present study observed that high-intensity functional training can alter HRV and thus cause changes in autonomic behavior. In addition, this type of modality can provide significant levels of training loads, affecting physiological responses and, consequently, the individuals' functional efficiency. Training prescriptions for this type of activity should be composed in the way that there are no imbalances capable of generating damage to health and performance.

Conflict of interest

The authors do not declare a conflict of interest.

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