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Fatigue and stress responses in athletes performing functional-fitness workout and its association with well-being

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Abstract: We monitored fatigue and stress using heart rate variability and session rating perceived exertion in trained athletes performing a single bout of functional-fitness training workout. Also, we verified the association between heart rate variability and session rating perceived exertion with well-being. In the first week of tapering, eleven national athletes (age: 25.7 ± 3.3y; body mass index: 27.7 ± 2.8 kg·m-2; training history: > 4y) participated in this study. Heart rate variability was analyzed basal, before and after the experimental protocol. Session rating perceived exertion was analyzed after the experimental protocol, and after the assessments, the association between them and well-being was performed. Repeated measures of ANOVA were performed to compare condition x time, and Pearson correlation was used to analyze the associations. Heart rate variability decreased its values after the training workout (ηp2=11.5, p<0.001), and session rating perceived exertion was high (25.8 ± 6.9 a.u.). We did not find associations between heart rate variability or session rating perceived exertion and well-being (r between -0.34 and 0.35, p>0.05). This study did not support the idea of a significant relationship between objective/subjective, physiological assessments and well-being in one bout of training workout. Functional-fitness coaches and athletes should know the limited evidence about objective/subjective assessments and well-being.

Keywords: Training Load, High Intensity Interval Training, Heart Rate Variability, Crossfit.

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1. Introduction

Stress and fatigue are part of the athletes' routine (Iwamoto & Takeda, 2003). Most individual sports are even more intense and evoke more physiological stress than team sports (Marino, 2011). The functional-fitness training (FFT) is an individual training program designed to work multiple movements from gymnastics, weightlifting to cardiovascular exercises in high intensity (for instance, CrossFit®, Insanity®, Gym Jones®, and others). FFT programs are growing in number of practitioners and popularity. The training responses given by this program are in constant debate between researchers and coaches about which theoretical concepts may be used in daily practice to prevent stress and fatigue (Aune & Powers, 2017). The scientific reports have shown the significant stress related to the FFT program. (Tibana *et al.*, 2016) investigated the effect of two consecutive days of FFT in trained men analyzing pro- and anti-inflammatory responses (age: 26.7 ± 6.6 y; training experience: 2.5 years). The results showed increased pro-inflammatory responses, but it was insufficient to decrease the anaerobic power.

Recently it has been proposed that FFT programs that use more volume and intensity impact physiological and psychological responses (Jacob et al., 2020). Heart rate variability (HRV) is one of the most used tools to quantify stress and recovery in sports (Zecchin-Oliveira, 2021). It has yet to be widely investigated in the FFT programs. Maia *et al.,* investigated three trained participants performing two days of competition. They analyzed the athletes HRV f unction at the beginning of the first and second day and at the end of the first and second day (assessments 5min before the start day 1 and 2, and 5min after the last training workout on day 1 and day 2), (male participant A, age: 30 years; body mass: 93kg; female participant B, age: 28 years; body mass: 68kg; female participant C, age: 28 years, body mass: 59kg). The main results showed that participants B and C did not decrease their HRV function during the two days of the FFT competition. The HRV depends on multiple factors such as sleep quality, training phase, diet, age, training status, and others (Sammito & Böckelmann, 2016). (Mangine *et al.,* 2019) found lowered HRV values in recreational-trained FFT practitioners through two long training workouts in two FFT workouts in recreational participants (5 males, age: 34 ± 3.8y, body mass: 80 ± 9.7kg; 5 females, age: 35 ± 7y, body mass: 76 ± 21.4kg). The results showed impairment in HRV function through 30 minutes after the FFT workout one. The second FFT workout started with the HRV function not fully recovered, and after FFT workout two, the HRV function was worsened. Interestingly this study associated the decreased HRV function with higher anxiety levels (utilizing a validated questionnaire).

Questionnaires are widely used in sports in order to avoid fatigue and stress. The advantage of using questionnaires is that they can be relatively inexpensive and straightforward. However, questionnaires investigating fatigue and stress corroborate with internal training loads, such as heart rate, VO_{2max}, blood pressure, and others (Borresen & Lambert, 2009; Saw *et al.,* 2016). There are plenty of questionnaires that were validated to be applied in multiple sports (Kallus & Kellman, 2001; Kenttä & Hassmén, 1998; Rushall, 1990). The well-being questionnaire has been used for long-term fatigue and stress analysis because of its easy and fast application (McLean *et al.,* 2010). This questionnaire has only five questions about fatigue, sleep quality, general muscle soreness, stress level (internal), and mood. It is plausible that this questionnaire can prevent and report stress and fatigue induced by external training load, such as the volume and intensity of the training session. Foster *et al.,* developed the session rating perceived exertion (sRPE) composed of the relationship between training intensity and training volume. Recently (Williams *et al.,* 2017) reported that sRPE is the most sensible method to record workloads in the FFT program. These data are needed because no studies reported the relationship between subjective and objective assessments such as HRV and sRPE with well-being involving the FFT program in athletes. However, there is no investigation into HRV function and sRPE and their relationship with well-being in a short acute FFT workout.

Thus, we aimed to monitor the fatigue and stress through HRV function and sRPE in well-trained FFT athletes performing a single FFT training workout Fran. The secondary objective was to analyze the athletes' well-being and determine if there is an association between HRV function, sRPE and well-being. Based on the literature, we hypothesized that HRV function would lower after the training workout. There are negative associations between subjective assessment represented by sRPE and objective assessment represented by HRV function with well-being, based on a previous (Williams *et al.,* 2017) study.

2. Materials & Methods

2.1 Participants

Male well-trained FFT athletes from Brazil (N= 11, age: 25.7y ± 3.3, height: 174 ± 7.2cm, weight: 84.4 ± 10kg, 1RM back squat: 173 ± 23.5kg) were selected randomly out of a pool FFT athletes (randomization was compute using an Excel® spreadsheet) and performed a single FFT benchmark workout named Fran. A power analysis was computed using the t-test in the software package G*Power with an alpha error of 0.05, power (1-ß error prob) = 0.9, and conservative effect size of 0.7 based on a related study investigating fatigue and stress in experienced FFT participants (Tibana *et al.,* 2016). The analysis revealed a total of 11 individuals needed to achieve an actual power of 0.90. The inclusion of the FFT participants followed the criteria: FFT experience of at least four years; at least one national/international competition before 2020 (due to the limitations of the number of competitions during the COVID-19 pandemic), and free use of any medication or performance-enhancing drugs based on a questionnaire. All the participants were in the tapering phase preceding a national competition. The participants were instructed to maintain their usual diet (not monitored) and not to train for 48h prior to the start of the study. All the participants volunteered their informed written consent to participate in the study, which the local ethic committee approved (CAEE: 13353719.4.0000.5659; November 2019), according to the Helsinki Protocol.

2.2 Experimental design

The experimental group gathered at the local gym at 06:30 am. The individual training plan was analyzed to understand how the athletes tapered. They performed the baseline assessments before the warm up (well-being questionnaire and HRV) in order to avoid interference from heart rate and fatigue. They warmed up for 10min as usual with and without an empty barbell, and performed the training workout. The benchmark FFT workout Fran was composed of 21 reps of thruster at 43kg, 21 reps of pull up, 15 reps of thruster, 15 reps of pull up, and finally 9 reps of thruster and 9 reps of pull up, for time. They performed the assessments after the experimental protocol (HRV and sRPE). HRV was assessed 5min after the FFT workout because of the excessive fatigue feeling right after the FFT workout (in the practice the subjects do not support be quiet and sitted to do the HRV assessment right after the FFT workout). Figure 1 shows the experimental protocol design and the timeline.

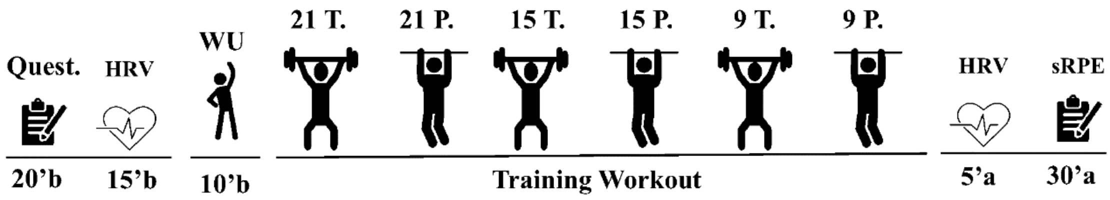

Figure 1. Time and assessments of the experimental protocol. Quest, questionnaire; HRV, heart rate variability; WU, warm-up; T, thruster; P, pull up; sRPE, session rating perceived exertion; b, before; a, after.

Table 1 The Well-being questionnaire.

	5	4	3	2	1	Result
Fatigue	Very fresh	Fresh	Normal	More tired than normal	Always tired	
Recovery	Very recovered	Recovered	Normal	Low recovery	Not recovered at all	
Stress Levels	Very relaxed	Relaxed	Normal	Feeling stressed	Highly stressed	
Mood	Very positive mood	A generally good mood	Less interested in others &/or activities than usual	Snappiness at teammates, Family and co-workers	Highly annoyed/irritable/down	
General Muscle Soreness	Feeling great	Feeling good	Normal	Increase in soreness/tightness	Very sore	
					Total score:	

Thruster

The thruster movement consisted of the barbell on the shoulder, performing the front squat, and finishing the movement with a full extension of the knees, hip and elbows in the overhead position.

Pull-up

The pull-up movement consisted of hanging the fixed bar, bending the elbows ending the movement with the chin up to the fixed bar.

2.3 Assessments

Well-being Questionnaire

The Well-being Questionnaire comprehends a custom-made psychological questionnaire based on the recommendations of (Hooper & Mackinnon, 1995) and (McLean *et al.,* 2010). This questionnaire assesses the individual perception of fatigue, recovery, stress levels, mood and general muscle soreness on a five-point scale (score 1 to 5, 1-point increments (Table 1). The sum of the scores varies from low well-being (5 to 10 points), average (11 to 15 points), high (16 to 19 points) to very high well-being (20 to 25 points), following the Dalda questionnaire (Rushall, 1990).

HRV

Basal HRV was measured by the average of two consecutive weeks before the protocol, five times a week, at the same time, and similar environmental conditions to ensure the basal measurement. The participants were instructed to empty their bladders. The HR strap (Polar H10®, Finland) was placed in the chest position in the nipple line. The assessment was made with the participants sitting quietly in a comfortable chair for two minutes. The validate protocol is the Ultra-Short-Term HRV that includes only two minutes of assessment, discarding the first-minute measurement and using the second minute to measure the stabilization (Esco & Flatt, 2014; Nakamura *et al.,* 2018; Pereira *et al.,* 2016). The results obtained were analyzed by the software Kubius HRV (Finland) (Tarvainen *et al.,* 2014). The HRV components analyzed were:

- Log-transformed root mean square of successive R-R intervals, LnRMSSD (ms);
- High frequency, HF (ms).

sRPE

RPE consisted of a table exposing numbers from 0 to 10, where 0 means "rest", increasing the values corresponding with higher intensity to 10, which means "maximal intensity". The sRPE method comprises training intensity (RPE) multiplied by the training duration (minutes). The sRPE was proposed and validated by (Foster & *et al.,* 2001).

2.4 Statistical Analyzes

Data normality was checked using the Shapiro-Wilk test. Mauchly's test of sphericity was computed (p=0.014). Repeated measures of ANOVA performed HRV comparisons between basal, pre- and post-training workout. Partial Eta-squared effect size (ηp2) was also computed to verify the significance size between the HRV assessments multiple times (Cohen, 1988). ES: 0.0 to 0.01 = Small, ES: 0.02 to 0.06 = Medium, ES: 0.07 to 1.14 = Large, and ES > 1.15 = Very large effect size. Confidence intervals (95% CI) were computed, and correlations between variables were determined by Pearson correlation (rho) (Hopkins, 2000). Intraclass correlation coefficients (ICC) was used based on HRV and sRPE in an intermittent sport/training ranging from 0.69 (moderate) to 0.90 (near perfect), $p < 0.05$, following (Poietti *et al.,* 2017) study analyzing HRV in professional soccer players (N: 54, age: 21.8 ± 4.4 y, height: 179.7 ± 6.0 cm, body mass: 76.0 ± 5.5 kg), and (Wallace *et al.,* 2014) analyzing sRPE in male and female recreational participants performing intermittent training exercise (N: 10, age: 23.8 ± 8.4 y, VO_{2max}: 37.9 ± 4.3 ml·kg^{-1}.min^{-1}). The analyses were performed using IBM SPSS Statistics for Mac (Apple), version 23.0 (Armonk, NY: IBM Corporation®).

3. Results

From the 11 participants in the experimental group, two participants were excluded from the study because they related tiredness and did not complete the experimental protocol. All the participants were in the first week of the 14 days of tapering phase.

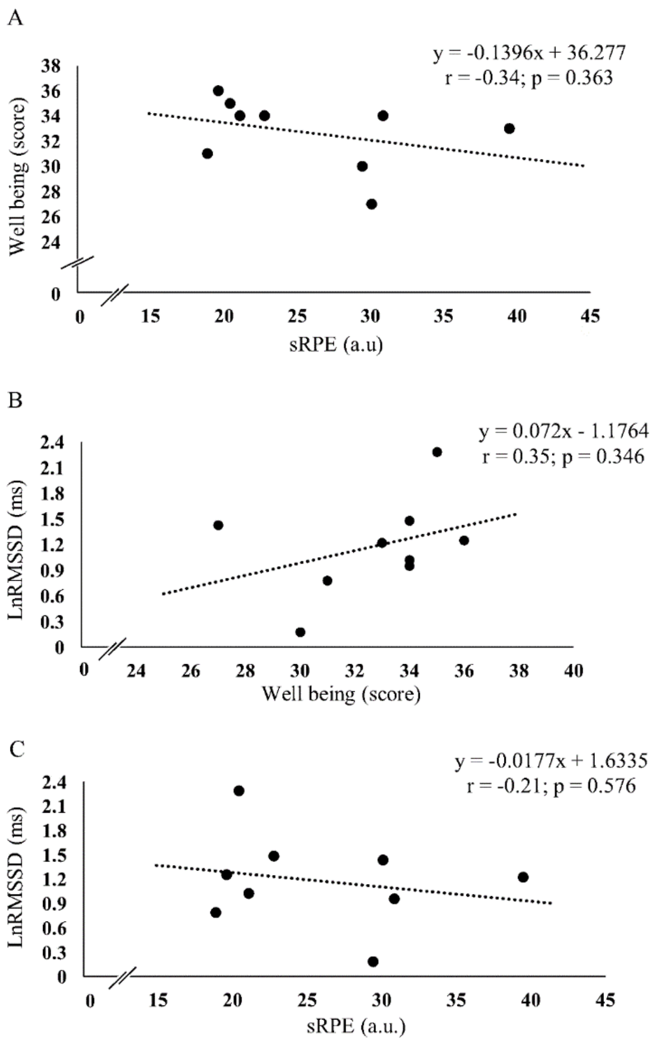

Figure 2. (A) correlation between well-being and sRPE; (B) correlation between LnRMSSD and well-being; (C) correlation between LnRMSSD and sRPE. Note: sRPE, session rating perceived exertion; LnRMSSD, log-transformed root mean square of successive R-R intervals; a.u., arbitrary units; ms, milliseconds.

Table 2 Heart rate variability levels at basal, pre- and post-training workout

INT (n = 9)						
Variables	**Basal assessments (mean ± SD)**	**Pre training workout (mean ± SD)**	**Post training workout (mean ± SD)**	**p (ηp2) basal and pre trainng workout**	**p (ηp2) basal and post trainng workout**	**p (ηp2) pre and post trainng workout**
LnRMSSD, ms	3.7 (0.5)	3.5 (0.6)	1.1 (0.5)	0.766 (1.0)	**<0.001 (14.0)**	**0.001 (11.5)**
HF, %	28.8 (15.1)	19.5 (15.8)	14.4 (14.5)	0.999 (1.7)	0.203 (2.9)	0.999 (1.0)

Note: ηp2, partial Eta-squared; LnRMSSD, log-transformed root mean square of suc-cessive R-Rintervals; HF, high frequency.

Seventy-five percent of the participants maintained the intensity as usual, and 20% lowered the intensity by 25%. Forty percent of the participants reduced the training volume by 30%, 40% lowered the training volume by 50%, and 20% of the athletes lowered the training volume by 40%.

Figure 2 shows the correlation between LnRMSSD, sRPE and well-being scores.

The values of LnRMSSD showed significant differences between basal, pre- and post- training workout in at least one comparison ($F [1.17, 9.39] = 78.143$; $p<0.001$). There was a statistically significant effect of time on variance in LnRMSSD comparing pre-training workout or post-training workout with baseline (ηp2=14.0, $p<0.001$; ηp2=11.5, $p=0.001$, respectively). There was 69% of increasing in LnRMSSD at post-training workout vs. baseline, and 67% of decreasing in pre- vs. post-training workout.

The was not statistically significance of effect of time on HF (n.s.) (see table 2).

The results of well-being were classified as "low". The average score was 6.5 ± 2.8 points. There was no relationship between well-being and sRPE, well-being and LnRMSSD (post-training workout), or LnRMSSD (post-training workout) and sRPE (r ranging from -0.34 to 0.35, $p>0.05$), (n.s.).

4. Discussion

In synthesis, we observed a lowered HRV function after the FFT workout comparing baseline and pre-FFT workout with post-FFT workout. Also, we did not find relationships between HRV function, sRPE and well-being (n.s.). Our hypothesis was not totally supported. Although the decreased HRV function after the FFT workout, the findings did not support for objective/subjective assessments to directly reflect acute training workout-relating stress and fatigue (HRV), internal training load (sRPE) with well-being.

The chosen FFT workout was intense enough to modulate the LnRMSSD negatively. (Chen *et al.,* 2011) investigated seven experienced weightlifters (19.3 ± 0.3 y; >6 y experience) performing a single bout of two hours of weightlifting training after 10 days of detraining. The HRV function recovery was completed only 72 hours after the training workout was done. Furthermore, the loss of acute HRV recovery in FFT workout is associated with overuse injury (Williams *et al.,* 2017). FFT programs use high intensity during all its application, and it is a potential contributor to decrease the HRV function.

Interestingly, the HF is another tool to analyze HRV function that did not change pre- or post-training workout. The HF is strongly associated with RR intervals, but it shows several limitations to analyzing the parasympathetic nervous system. Otherwise, the LnRMSSD is the most reliable and practically applicable daily monitoring athletes' stress and fatigue (Cottin *et al.,* 2004; Plews *et al.,* 2013). The reduction of LnRMSSD values reflects increased sympathetic activity related to higher levels of fatigue and stress, and it is common in athletes tapering before a competition (Stanley *et al.,* 2015). The high intensity and considerable volume right before the tapering may explain the taper's lower HRV function levels (accumulated training load). The objective of the taper is to adjust the fatigue and stress given before, but the stabilization of the HRV function might take more time to be concluded.

The well-being scores reported by the athletes confirmed fatigue and stress. The classification was considered "low" by the classification of the sum scores, indicating both high levels of psychological and physiological dysfunction. Investigations through sports recovery and well-being have shown that lower scores in well-being relating to fatigue and stress may return to baseline (better scores) through the first days of competition (McLean *et al.,* 2010). Taken together with physiological and psychological impairments, the participants may be in a non-functional overreacting state that is considered the "acute" phase of overtraining syndrome. In the past, some studies involving athletes have shown total mood disturbance (TMD) scores to be higher than those in functional overreacting (Hooper *et al.,* 1997; Morgan *et al.,* 1987).

Our results did not demonstrate significative association between sRPE and HRV function with well-being. In the opposite direction of our findings, in the literature, there is one research reporting a relationship between non-functional overreaching and well-being scores, also between non-functional overreaching and decreased HRV function (Coutts & Cormack, 2014). One study investigated the association between subjective/objective assessments and well-being in athletes through a systematic review (Saw *et al.,* 2016). There was moderate positive evidence for an association between stress and cortisol and a positive association between vigor and leukocytes. Also, they evidenced impairment in well-being when the training load was increased. While most of the studies related well-being questionnaires to subjective/objective assessments, there is no consistent association between them. Other well-being questionnaires such as Profile of Mood States (POMS), Recovery Stress Questionnaire for athletes (RESTQ-S) and Analyses of Life Demands of Athletes (DALDA), Questionnaire of the Societe Francaise de Medecine du Sport (SFMS), State-trait Anxiety Inventory (STAI), Perceived Stress Scale (PSS), Multi-Component Training Distress Scale (MTDS), Competitive State Anxiety Inventory-2 (CSAI-2), Derogatis Symptom Checklist (DSC), State-Trait Personality Inventory (STPI) and a Mood Questionnaire (Mood) were already validated. However, most of them are not very practical for daily analysis in FFT athletes because of the excessive time required to fill the multiple questions. The well-being questionnaire applied in this study is a short questionnaire that can be applied in less than a minute, and it was more acceptable by the athletes.

We tried to apply the DALDA questionnaire, and it can be easily applied for a single training session but is not very practical for daily analysis. Although this affirmation, further research is needed to determine under what circumstances mood state may be a reliable monitoring tool. This study is part of multiple projects (acute and chronic responses), so we decided to apply the well-being questionnaire. We hypothesized that if the assessments were conducted at the beginning of the competition phase, we could find significant associations between the subjective/objective assessments with the well-being (more stable data). This study does not support the association between subjective/objective assessments such as HRV and sRPE with well-being.

This study is not without limitation. We did not assess the time course of HRV function several times after the FFT workout. Future studies should investigate FFT and assess the HRV several times before and after the acute FFT workout session. We did not assess the individual sleep that is important for a better understanding of autonomic impairments. Although the recommendation of (Hooper *et al.,* 1997), the Well-being questionnaire is not yet validated in a Brazilian population. Finally, the sample size is limited, and it might be a potential bias to the observed results. Otherwise, the sample size was determined considering the difficulty of recruiting these participants' levels.

Despise these affirmations, this study strengthens the idea of impairment in HRV after an acute FFT workout.

5. Conclusion

Based on the results of this study, FFT athletes showed an impairment in HRV function after an FFT training session called Fran. We also found no relationship between subjective and objective assessments. We can conclude that sRPE, HRV and well-being should be used together, as the objective and subjective provide unique information about the athlete. The correlation observed in this study does not necessarily imply causation. Thus, the long-term relationship between subjective and objective assessments such as HRV function and sRPE with well-being in athletes performing FFT training needs to be proven in future studies.

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Author Contributions

Arthur Zecchin: Conceptualization, Supervision, writing original draft, review and editing; **Omero Benedicto Poli-Neto:** Methodology, Validation, Review and editing; **Marcel Frezza Pisa:** writing original draft, review and editing; **Rodrigo Aquino:** writing original draft, review and editing; **Enrico Fuini Puggina:** writing original draft, review and editing. All the authors read and approved the final version of the manuscript.

Informed Consent

Informed written consent was obtained from the participants.

Ethics Approval

The study was approved by Insititutional Review Board (CAEE: 13353719.4.0000.5659; November 2019).

Conflict of interest

None of the authors has reported conflict of interest.

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