International Journal of EXERCISE SCIENCE

Original Research

Effects of a Competitive Season on Autonomic Heart Rate Modulation in Field Soccer Athletes

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ABSTRACT

International Journal of Exercise Science 12(2): 1198-1205, 2019. The physical demands of soccer combined with the rigor of the competitive season may have a substantial impact on autonomic modulation in field soccer athletes. The number of sudden death cases associated with soccer may be related to the physical training required to maintain performance and fitness, minimal time for recovery, and recurrent game participation. It is possible to identify individuals at risk of cardiovascular events by measuring heart rate variability (HRV), which is an indirect method for assessing autonomic activity. Therefore, the objective of this study was to analyze HRV before and after a period of field soccer competition. We evaluated 17 healthy male professional field soccer athletes and 12 untrained controls. The HRV was analyzed during supine rest before and after a period of field soccer competition. The following parameters were evaluated: interval R wave variation (RR), standard deviation of normal–normal intervals (SDNN), Root-mean-square successive difference (RMSSD), low frequency component (LF), high-frequency component (HF) and sympathovagal balance (LF/HF). Results indicated that the RR ($p < .05$, ES: 2.77), SDNN ($p < .05$, ES: 1.70), LF ($p < .05$, ES: 1.86), HF ($p <.05$, ES: 0.89) and LF/HF ($p < .05$, ES: 0.89) all decreased after the competition in the professional athletes with no change observed in the control group. In conclusion, the data suggest that a soccer competition negatively influences the autonomic regulation of heart rate.

KEY WORDS: Heart rate variability, cardiovascular system, football athletes, competition

INTRODUCTION

Soccer is a professional sport known to require high levels of cardiovascular and musculoskeletal fitness. The development and honing of physical abilities, particularly strength, speed, and endurance, is required to make individual players competitive in this sport (17, 18). In this context, soccer athletes may be exposed to an increased risk of overtraining (1). This physiological stress is caused by excessive training loads leading up to and concurrent to periods of competition. Vilamitjana et al. (21) noted that extended periods of overreaching result in overtraining which in turn, compromises performance and is degenerative to health. Returning to play or to equivalent levels of performance after a bout of overtraining can take several weeks to months (8). Overtraining has been documented in division one soccer players simply by monitoring training load (16).

Overtraining may present as musculoskeletal weakness, acute illness, or as cardiovascular dysfunction (11). A simple, non-invasive measure of cardiovascular function is the analysis of heart rate variability (4, 13). Naranjo et al. (12) evaluated 22 soccer players over eleven months and determined the value of using HRV to control the weekly training load. Flatt et al. (7) also observed the interaction between HRV and training load during the pre-season in soccer players, thus establishing a relationship between HRV and fatigue. However, these investigations did not consider the added stress that accompanies competition. Thus, the present study sought to compare the behavior of cardiac variability (HRV) in professional soccer athletes before and after an important national tournament. This investigation compared the professional athletes' responses to a sample of non-soccer playing controls. It was hypothesized that cardiac autonomic modulation would differ between professionals and controls. It was also hypothesized that cardiac autonomic modulation would differ before and after a competitive period because of the levels of fatigue and stress observed at the end of the season.

METHODS

Participants

This investigation was approved by the Ethics Committee for Research of the São Judas Tadeu University. Apparently healthy, adult male professional soccer athletes (n = 17; 24 ± 3 yrs) and non-athlete controls (n = 12; 24 ± 3 yrs, sedentary healthy subjects with similar age as the athletic group) voluntarily participated in this study. Prior to data collection, participants signed an informed consent form. All subjects were asked to be present between 8 am and 10 am at the medical department of their club/university the day before and the day after a tournament. The group of untrained athletes followed the same methodological procedures for comparison. Participants were asked to remain seated and at rest for five minutes prior to data collection. The ambient room temperature was controlled at about 21°C. Volunteers were excluded from study participation if they presented with any of the following: smokers, systolic blood pressure > 140 mmHg, diastolic blood pressure > 90 mm, body mass index (BMI) > 30kg/m^2, cardiopulmonary, psychological and/or neurological related disorders, impairments that prevented the subject from performing the protocols, or currently undergoing a medical treatment that would influence cardiac autonomic regulation.

Protocol
For descriptive purposes, the investigators acquired the general training periodization scheme for which the athletes were exposed. The periodization established was modified according to guidelines established by Belozo et al. (2). Training consisted of three mesocycles (general, pre-competitive and competitive) over seven weeks, with a 48-hour recovery period between the weeks. The training microcycles consisted of eight sessions per week, from Monday to Saturday (Tuesday and Thursday had a morning and evening session). In this way all measurements were done before (one day prior to start) and after (one day at the end) of training periodization.

During the initial evaluation, systolic and diastolic blood pressures (BP) were monitored after 5 minutes of supine rest using an aneroid sphygmomanometer and stethoscope. The investigators collected other baseline information such as: age, sex, mass, height and body mass index (BMI).

Heart rate variability (HRV) was a composite score composing of several independent variables. The R-R intervals were recorded by the portable S810i heart rate (HR) monitor (with a sampling rate of 1000 Hz) and downloaded to the Polar Precision Performance program (v. 3.0, Polar Electro, Finland) according to previously publication of our group (3). This software allowed the visualization of heart rate and the extraction of a heart period (R-R interval). Following digital and manual filtering for the elimination of artifacts, 256 stable R–R intervals were used for the data analysis. Samples with incidence of sinus rhythm greater than 95% were included in the study. Linear indices were calculated using the HRV Analysis software (Kubios HRV v.1.1 for Windows, Biomedical Signal Analysis Group, Department of Applied Physics, University of Kuopio, Finland), which used the time domain (TD) and frequency domain (FD) as recorded through the RR interval (ms) (5). Subsequently, a time series was generated for each signal being studied using heart rate interval (tachogram). The oscillations of the RR interval series were evaluated in the TD and FD. The RR interval series were divided into segments of 509 beats (12). HRV analysis was performed the day before and the day after the tournament for soccer athletes and control group. The following parameters were evaluated: interval R wave variation (RR), standard deviation of normal–normal intervals (SDNN), Root-mean-square successive difference (RMSSD), low frequency component (LF), high-frequency component (HF) and sympathovagal balance (LF/HF).

Statistical analysis
Data were assessed using SPSS for Windows software (version 15.0, SPSS Inc., Chicago, IL, USA). All data are expressed as mean ± SD. D'Agostino-Pearson test was applied to Gaussian distribution analysis. The comparisons between time were assessed by Analysis of variance (ANOVA-two way) followed by Kruskal–Wallis or Bonferroni's post-hoc test or paired Student t-test. The alpha value was established at $p < .05$. The effect sizes (ES) were calculated and evaluated based on the following criteria: < 0.50 trivial, 0.50 to 1.25 small, 1.25 to 1.9 moderate and > 2 large.

RESULTS

Study participants were professional male soccer athletes (*n* = 17) with a mean age of 26 ± 5 yrs and non-athlete controls (*n* = 12; 24 ± 3 yrs). Table 1 describes the anthropometric parameters of all subjects.

Table 1. Anthropometric parameters.

Parameters	Untrained	Trained
Body mass (kg)	74 ± 5	71 ± 3
Height (cm)	177 ± 11	180 ± 12
BMI (kg/m²)	23 ± 6	23 ± 2

Note: Values expressed in mean ± standard error. BMI: body mass index.

As showed at Table 2, baseline HR and BP were not different between the two testing sessions in either group. A significant decrease was observed in the professional athlete group for RR and SDNN components after completion of the tournament. The RMSSD component was unaffected by competition. HRV data in the FD are presented in Table 2. A decrease in the low frequency (LF) component (ms²) was observed after completion of the tournament, but no significant difference was found for the other parameters.

Table 2. Hemodynamic and heart rate variability parameters after and before soccer championship.

Parameters	Untrained			Trained		
	Before	After	Cohen's d	Before	After	Cohen's d
Resting Hemodynamics						
HR (bpm)	75 ± 8	77 ± 5	0.25	57 ± 3	50 ± 2	1.00
SBP (mm/Hg)	118 ± 3	119 ± 4	0.33	112 ± 2	113 ± 3	0.50
DBP (mm/Hg)	78 ± 5	77 ± 6	0.20	71 ± 2	71 ± 3	0.00
Heart rate variability						
RR	5998 ± 1034	5978 ± 1009	0.02	6004 ± 1121	2895 ± 497*	2.77
SDNN	73 ± 7	75 ± 6	0.29	75 ± 8	52 ± 4*	1.70
RMSSD (ms)	68 ± 9	68 ± 7	0.00	67 ± 10	50 ± 4	2.75
LF (ms²)	1278 ± 147	1268 ± 124	0.07	1169 ± 169	705 ± 141*	1.86
HF (ms²)	1266 ± 185	1236 ± 185	0.16	1150 ± 233	717 ± 106*	0.89
LF/HF	1.17 ± 0.23	1.15 ± 0.23	0.09	1.19 ± 0.19	1.02 ± 0.14*	0.89

Note: Values expressed in mean ± standard error. HR: heart rate. SBP: systolic blood pressure. DBP: diastolic blood pressure. RR: Interval R wave variation. SDNN: standard deviation of normal–normal intervals. RMSSD: Root-mean-square successive difference LF: low frequency component. HF: high-frequency component. LF/HF: sympathovagal balance. *p < .05 vs. before competition.

DISCUSSION

In high performance sports, it is important to be able to manage the intensity of the training load in order to optimize training parameters and adaptations. This investigation adds to the literature by noting the importance of HRV as a valuable tool that provides information about physiological adaptions to training as well as possibly preventing cardiovascular events. The present study compared the HRV before and after an important national tournament. The results showed that the trained group lost autonomic control of HR immediately after the tournament.

Neuronal networks are effective mechanisms in the control of physiological homeostasis [10]. HRV assessed by power spectral analysis is a great tool to obtain reliable indices of overall autonomic nervous system modulation and baroreceptor function. Naranjo et al. (12) reported that use of HRV in the early detection of fatigue or over-training might be based on physiological stress manifesting as a high sympathetic modulation. Thus, we speculate that poor administration of workloads (which lead to fatigue and/or over-training) are reflected in elevated sympathetic tone and/or depressed parasympathetic activity at rest. In the present study, after the tournament, both sympathetic and parasympathetic indicators were reduced when compared with pre-tournament values. Similar to our findings, Oliveira et al. (14) showed an improvement in the vagal-related HRV indices in futsal players after a pre-season period and remained stable during the competitive season. Naranjo et al. (12) observed the HRV behavior throughout a full season in Division 1 soccer athletes. The study sampled weekly for 11 months. The HRV parameters observed throughout the season, recorded lower values in the pre-season and the end of the season.

The present study observed a decrease in VAR RR and SDNN components. These findings conflict data reported by Oliveira et al (14), where no changes were observed in the RMSSD component after the pre-season. One possible explanation for the discrepancy is the stress of the season in which the HRV analysis was performed. Oliveira et al (14) performed assessments before and after the pre-season (six weeks) and our study evaluated the competitive period over a longer duration. It appears that athletes have a tendency to experience positive modifications of their autonomic regulation during the early phases of training programs, and with decreases in the indices afterwards. This undulation is likely due to the mere quantity of games and psychological stress. Thus, the results of these experiments indicated that the TD components (VAR, RR, and SDNN) lead to stimulation of the sympathetic nervous system and a decrease in parasympathetic activity.

No statistical difference was noted when we analyze the FD for the %HF, HF (ms^2), %LF, and LF/HF components. A significant decrease was observed in the raw values for the LF ms^2 component, but a difference was not observed when these were normalized. The FD analysis allowed for the quantitative and qualitative characterization of sympathetic and parasympathetic activity in absolute and relative terms (through the frequencies of the waves, and their respective physiological origins, which are divided into three stages). The first stage is mediated by the thermoregulatory and renin-angiotensin-aldosterone systems, with a very low frequency component (VLF, 0.015 to 0.04 Hz). The second stage is mediated by the baroreceptor reflex of the low frequency component (LF, 0.04 to 0.15 Hz), with mixed influences of the sympathetic and parasympathetic systems. The third stage, or high frequency component (HF, 0.15 to 0.40 Hz), is the indicator of vagal tone, which expresses the parasympathetic influence on the sinus node and respiratory rate (6). Different from our study, Vilamitjana et al. (21), sought to identify overreaching in a professional soccer player. These researchers observed a progressive decrease of the LF / HF component throughout a 5-month season, suggesting a sympathovagal imbalance. Thus, we can suggest that HRV follow-up be performed during the season, not just at the beginning and at the end.

In relation to the cardiovascular risk, the authors believe that the results observed are secondary to an increase in venous return and systolic volume consequent from physical training. These HR values were similar to the values found by Oliveira et al. (14) after six weeks of pre-season training in soccer players. The effect of chronic physical exercise results in decreased resting heart rate (11). According to Brum et al. (5) the lower the resting heart rate, the lower the likelihood of developing heart disease.

BP is a valued indicator of physiological responses. Changing BP can reflect chronic pathologic states, it is used for predicting risk for comorbidities, but also acutely impacted by stressors ranging from emotions to exercise (10). In our study, no difference was observed in BP after a bout of heightened emotional stress and exercise in the form of tournament competition. Silva et al. (19) investigated the behavior of BP in professional soccer athletes after 15 weeks of sport-specific physical training during the competitive season. Similar to our data, Silva et al (19) found no difference in BP due to the intervention. There is consensus in the literature that physical training induces reduction in resting BP values, however, this effect seems to be more pronounced in hypertensive patients (10). As such, we postulate that our sample was exposed to a floor effect, wherein BP values were already low due to chronic exposure to cardiovascular exercise training.

We suggest that a period of competition significantly diminished HR autonomic control. Through the TD index, the HRV, which is simple to perform and noninvasive, showed a decrease in HR fluctuation (caused by activation of the sympathetic nervous system). Therefore, the training of a high-level field soccer athlete should be applied in a consistent manner to maintain cardiovascular health. This process must be reinforced with methods that promote understanding.

ACKNOWLEDGEMENTS

The authors thank FAPES (Fundação de Amparo à Pesquisa e Inovação do Espírito Santo, Process 590/19 – n°84417625/2018) and CAPES (Coordenação de Aperfeiçoamento de Pessoal de Nível Superior) for fellowships awarded for research assistance. The fund providers had no role or decision in preparation or publication of this paper.

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