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Heart Rate Variability as an Indicator of Stress in Students' Athletes

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Abstract

Introduction: The wellbeing of student's athletes has a paramount importance, a prolonged period of cognitive and physical performance that characterizes the life of student's athletes often leads to fatigue, and a psychobiological state that increases the risk of injury and accidents. The use of Heart rate variability (HRV) has become increasingly popular as a non-invasive methodology that provides an indirect insight into the autonomic nervous system. HRV can be utilized as a diagnostic tool in detection of autonomic nervous system impairment and sympatho-vagal imbalance. HRV technology is employed to monitor the internal response of athletes to workload and identify athletes's psychophysical stress to predict and therefore prevent injuries. **Objective:** The objective of the investigation is to establish whether the use of Polar H10 sensor heart rate monitors worn by athletes in a sitting position (inclination 60 degrees) during periods characterized by stress can provide a valid and non-invasive method to assess the psychophysiological state during sports competition and school exams. **Method and Statistics**: In the study, the HRV of 12 basketball students athletes and 4 students non-athletes was analyzed as a control group. The autonomic nervous system activity was assessed based on heart variability parameters (HRV): SDNN, rMSSD, LF, HF, and LF/HF. The measurements were made after establishing the baseline at rest, during the training phase (CT), competition phase (CC) and during the acute phase of stressors due to school exams coinciding with the competitive season (CC + E). **Results**: Compared to the respective values prior to the stress of the competitions and exams, a significant decrease in HRV indices was found: SDNN ($P < 0.039$) and RMSSD ($P < 0.005$). A decrease in HF ($P < 0.006$) and an increase in LF ($P < 0.012$) were documented after the training phase and coinciding with the phases of sports competition and school exams. We observed during the training phase (CT) a significant increase in HRV values therefore consistent with a positive adaptive response to training stress alone. **Conclusions**: The analysis and examination of the data on the sample of the student population also showed a statistically significant correlation between decreased cardiac variability and injuries or indisposition to physical exertion.

Keywords

Heart Rate Variability, Level of Arousal, Stress in Students Athletes

1. Introduction

Scholastic wellbeing can be regarded as a central aim of all educational institutions; one of the primary objectives of coaches and educators is to create an environment suitable for motor learning and cognitive development for the achievement of positive results in academic and athletic performance [1].

The mental and physical state (psychophysiological balance) before and during both sports and school commitments are crucial to ensure that adolescents can adequately respond to cognitive needs for learning and sports performance [2].

Both athletic and academic performance can be hampered by exaggerated levels of both cognitive and somatic stress [3]. Performance anxiety for exams and in the case of student athletes also for sports competitions is well documented as an anxiety disorder in adolescence. This study takes place in a very specific context, a bilingual Chinese/English boarding school near Shanghai.

In this cultural context, the pressure for achieving academic results is a relevant factor [3]. Stress understood with a positive meaning is essential to stimulate a functional response of the organism allowing students and athletes to generate an adaptive response to external stimuli and thus facilitating a super compensation that can favor an improvement of the cognitive aspect. When it comes to learning new knowledge, acquiring new motor skills, and consequently obtaining positive results in exams and sports performance, an optimal level of arousal is an essential factor [4].

When the intensity and duration of the stressful stimulus is exaggerated (overarousal) there are decreases in sports and cognitive performance and a significant correlation with pathological states becomes evident [5].

The investigation analyzes and quantifies the effect of students' psychophysiological response to stress during three fundamental periods throughout the school year. Heart rate variability (HRV) was used to determine the extent to which athletes adapt to psychobiological stress and whether there is a correlation between cardiac variability and an increase in stressful load and an increase of frequency in injury/illness amongst the students' athletes. HRV is a reliable indicator of the many physiological factors that directly influence and modulate heart rhythm [6]. HRV analysis becomes a tool to observe the interaction between the sympathetic nervous system and the parasympathetic. The ability of the cardiac muscle to respond to the needs of adaptation to psychophysical stress, balancing the regulation of the autonomic nervous system is reflected in the degree of variability of the heart rate. HRV is a window to observe the activity of the autonomic nervous system responsible for managing a series of automatic, unconscious, and involuntary activities related to the maintenance of homeostasis, such as heart rate, blood pressure and digestion [7]. The investigation utilized heart rate variability to establish if this indicator (HRV) can be a reliable non-invasive mean of analysis to quantify the cardio-autonomous response of students' athletes during the exam period coinciding with the sport competitive period.

2. Method and Statistical Analysis

The evaluation of the psychophysiological status of 12 volunteer basketball players (male, mean age 16.3333 SD = 1.17851130) was obtained by comparing baseline values with values measured during the training period (TC = training condition), competitive period (CC = competitive condition), examination and competitive period (CCE = competitive condition and exams) and placed before a control group. Heart rate measurements were taken for all subjects in the morning as soon as they got up, fasting and without ingestion of stimulant beverages such as coffee, in a sitting position (tilt 60 degrees) and resting situation, using Polar H-10 heart rate monitors. Synchronized with Elite HRV software. The test was designed to collect data to provide information on changes in sympatho-vagal balance in the presence of pre-competitive and pre-exam stress [8].

3. Protocol

The short-term analysis (300 seconds) of the heart rate variability is proposed as a technique to complete the assessment of the precompetitive psychophysiological state of students' athletes during a period characterized by stressors, caused by the sport competitive season and the exams period. The measurement of the HRV is used as a method of evaluation of the balance of the autonomic nervous system. The assessment of the sympatho-vagal balance using HRV measurements provides a reference for the use and application of strategies that mitigates the negative effects caused by precompetitive anxiety on the performance of student-athletes. In addition, it was administered a test for self-assessment of cognitive, somatic precompetitive anxiety (competitive test anxiety inventory-2; CSAI-2R, Martens, Burton, Vealey, Bump y smith 1990) [9]. Measurements of heart rate variability were performed during the CT, CC and CCE phases/periods to assess whether there is a correlation between high levels of competition anxiety and a significant reduction in the time domain values (SDNN, RMSSD), and frequency domain (HF) and an increase in LF, the ratio from low frequencies to high frequencies (LF/HF %).

This study aims to verify whether it is feasible through the measurement of HRV to identify in a non-invasive and precise way the changes towards a predominance of the sympathetic branch of the nervous system as a result of the decrease of the parasympathetic branch (parasympathetic withdrawal).

4. Procedure

The sports director of the school and the coach of the basketball team were contacted to whom the objectives and general contents of the study were explained. The data taken into consideration are:

1) HRV time domain; the mean of the RR interval, the standard deviation of RR intervals (SDNN), RMSSD (TaskForce guidelines, 1996) [10].

2) Frequency domain methods, spectral analysis method using a self-regressive estimation model (Sztajzel, 2004) [11], to quantify the spectral power density of very low frequencies (VLF; 0.00 - 0.04 Hz), low frequencies (LF; 0.04 - 0.15 Hz) and high frequency bands (HF; 0.15 - 0.40 Hz).

Additional calculations include the ratio LF/HF expressed in normalized units (nu). The LF/HF ratio is generally used as an indicator of sympathetic-parasympathetic balance. An increase in the value in this parameter indicates a greater influence of sympathetic activity and a decrease in the activity of the parasympathetic system [11].

Presentation of data

The baseline values of the Time Domain parameters (SDNN - RMSSD) compared with the periods of CC (competitive period) and CCE (competitive period and exams) decreased significantly. The P-Value values confirmed the statistical difference between the baseline values and the values measured during the CCE period (competitive = exams).

SDNN reflecting sympathetic activity as a cardiovascular stress response factor increased during the CT training phase (functional adaptive response effect) and then decreased in the CC phase (competitive phase). It was observed a decrease of HRV values compared to CT (training condition) during the CCE period (competitive and exams). From the data it can be hypothesized that cardiac variability decreases due to inability to cope with stress [12] [13].

The RMSSD time domain value that reflects the activity of the parasympathetic system increased during the training period (CT) finding an inverse correlation with the decrease in resting heartbeats as an adaptive response to training. During the CC and CCE periods the intensification of stressors (competition and exams) influenced the activity of the parasympathetic system, which is reflected in HF, whose value decreases compared to the CT period.

HF (high frequency waves) are a measure of the activity of the parasympathetic system as they mirror the activity of the vagus nerve [11] (Claude Bernarde's (1865) [13]. While the LF reflect the activity of the sympathetic system. The influence of the parasympathetic system on heart rate is mediated by the release of acetylcholine by the vagus nerve. Muscarinic receptors and acetylcholine receptors respond by increasing the level of cell membrane conduction (increased membrane potential). Stressors stimulate the activity of the sympathetic nervous system (SNS) acting on the sinoatrial node by inducing an increase in heart rate due to the effect of adrenergic receptors, which generate a decrease in heart rate variability [14]. A decrease in HF corresponds to a decrease in the activity of the vagus nerve with a consequent decrease in the action of the parasympathetic system.

Statistical Analysis

SDNN

An analysis of variance (ANOVA) was performed for repeated measurements to determine if there was a significant difference within the protocol studied. In the SDNN tests, highly significant differences were found within the results (ANOVA for repeated measurements: F3.33 = 15.14; $P < 0.0001$; $\eta^2 = 0.58$; Power = 1.00) as evidence of observed adaptations.

Subsequent post-hoc tests, performed with Bonferroni significance level correction, showed statistically significant differences between Baseline1 and CCE1 ($P = 0.013$), TC1 and CC1 ($P = 0.008$) and TC1 and CCE1 ($P < 0.0001$).

RMSDD

An analysis of variance (ANOVA) was performed for repeated measurements to determine if there were significant differences within the protocol studied. In the RMSDD tests, highly significant differences were found within the tests (ANOVA for repeated measurements: F3.33 = 9.129; $P < 0.0001$; 2 = 0.45; Power = 0.99) as evidence of observed adaptations.

Subsequent post-hoc tests, performed with Bonferroni significance level correction, showed statistically significant differences between Baseline 2 and TC2 ($P = 0.015$), TC2 and CCE2 values ($P = 0.004$).

LF

An analysis of variance (ANOVA) was performed for repeated measurements to determine if there was a significant difference within the protocol studied. In the LF tests, significant differences were found within the tests (ANOVA for repeated measurements: F3.33 = 4.202; $P = 0.013$; $\eta^2 = 0.28$; Power = 0.81) as evidence of observed adaptations.

Subsequent post-hoc tests, performed with Bonferroni significance level correction, showed statistically significant differences between TC3 and CCE3 ($P = 0.018$), CC3 and CCE3 ($P = 0.005$).

HF

An analysis of variance (ANOVA) was performed for repeated measurements to determine if there was a significant difference within the protocol studied. In HF tests, no significant differences were found within the tests (ANOVA for repeated measurements: F3.33 = 2.765; $P = 0.057$; 2 = 0.20; Power = 0.61) as evidence of observed adaptations.

LF/HF

An analysis of variance (ANOVA) was performed for repeated measurements to determine if there was a significant difference within the protocol studied. In the LF/HF tests, there were no significant differences within the studies (ANOVA for repeated measurements: F3.33 = 0.087; P = 0.966; 2 = 0.01; Power = 0.06) as evidence of observed adaptations.

HR (Average heart rate)

An analysis of variance (ANOVA) was performed for repeated measurements to determine if there were significant differences within the protocol studied. In HR tests, no significant differences were found within the studies (ANOVA for repeated measurements: F3.33 = 2.128; P = 0.115; 2 = 0.162; Power = 0.494) as evidence of observed adaptations.

5. Conclusions

The primary purpose of this investigation was to hypothesize the susceptibility of the autonomic nervous system to stressful events and to use Heart rate variability (HRV) as a viable method to quantify stress in students' athletes.

In the study it was possible to document with the collected data changes of the heart rate variability in response to periods in the student's school life characterized by stressful events such as training, sports competition, and exams. These changes in HRV are associated with periods of sports competition and school exams. Therefore, from the data observed in this study it emerged that heart rate variability (HRV) can be a reliable indicator to assess the level of adaptability of students' athletes to psychophysiological stress. These results suggest that the use of this technology to monitor HRV is a valid diagnostic tool that deserves attention and further investigation. The study was limited by a small population sample. A larger sample size would provide more accurate average values, alloeingto obtain even more significant statistical results.

As **Table 1** shows a measure of the relative reliability of the measurements obtained during the tests, the ICC and the Alfa Cronbach were calculated. The degree of consistency between the measurements for each component of the heart variability of the subjects [8].

As **Table 2** shows, descriptive statistics for the variables under consideration, comparing heart rate variability baseline values with measurements obtained during 3 distinct phases of stress. Stress during training phase (TC training condition

Table 1. Relative reliability of HRV parameters.

Test	ICC (Mean Measure)	Confidence Interval (95%)	P	Cronbach's Alpha
SDNN	0.395	−0.461 - 0.805	0.130	0.395
RMSDD	0.445	−0.339 - 0.821	0.094	0.445
LF	0.835	0.601 - 0.947	<0.001	0.835
HF	0.850	0.638 - 0.952	<0.001	0.850
LF/HF	0.866	0.677 - 0.957	<0.001	0.866
HR	−0.614	−2.892 - 0.479	0.799	−0.614

Table 2. Descriptive statistics of HRV parameters.

	SDNN (ms)			CI 95%
	Mean	SD	CV %	Lower Bound
Baseline 1	85.17	22.29	26.2%	71.00
TC 1	102.54	21.97	21.4%	88.58
CC 1	68.90	15.60	22.6%	58.99
CCE 1	56.30	16.13	28.6%	46.06
	RMSDD (ms)			CI 95%
	Mean	SD	CV %	Lower Bound
Baseline 2	59.26	16.03	27.1%	49.075
TC 2	73.15	17.49	23.9%	62.041
CC 2	54.67	13.27	24.3%	46.238
CCE 2	45.28	10.55	23.3%	38.581
	LF (Hz)			CI 95%
	Mean	SD	CV %	Lower Bound
Baseline 3	2559.90	1244.25	48.6%	1769.342
TC 3	2703.72	919.68	34.0%	2119.384
CC 3	2819.86	1118.91	39.7%	2108.938
CCE 3	3596.47	1172.77	32.6%	2851.324
	HF (Hz)			CI 95%
	Mean	SD	CV %	Lower Bound
Baseline 4	1430.13	866.75	60.6%	879.422
TC 4	1704.66	685.04	40.2%	1269.400
CC 4	1200.33	826.52	68.9%	675.183
CCE 4	1198.73	716.74	59.8%	743.333
	LF/HF (a. u.)			CI 95%
	Mean	SD	CV %	Lower Bound
Baseline 5	2.80	1.91	68.5%	1.580
TC 5	2.95	2.10	71.2%	1.616
CC 5	3.03	2.08	68.5%	1.713
CCE 5	2.96	1.29	43.7%	2.134
	HR (bpm)			CI 95%
	Mean	SD	CV %	Lower Bound
Baseline 6	80.49	5.31	6.6%	77.112
TC 6	74.86	6.73	9.0%	70.577
CC 6	78.81	2.48	3.1%	77.236
CCE 6	79.97	7.28	9.1%	75.351

SD = Standard Deviation; CV% = Coefficient of Variation%; CI95% = Confidence Interval 95%. ms = millisecond; Hz = Hertz; a. u. = arbitrary unit; bpm = beat per minute. SDNN; RMSSD; LF; HF; LF/HF; HR; BASELINE; TC =Training Condition ; CC = Competition Condition; CCE = Competition and Exams Condition.

phase), CC (competition condition phase), CCE (competition and exams condition pahese). Descriptive statistics (M, SD, CV%, C. I 95%) of the values recorded during the tests are provided [14].

Conflicts of Interest

The author declares no conflicts of interest regarding the publication of this paper.

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