

A study of the relationship between anxiety, cognitive emotion regulation and heart rate variability in athletes

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Abstract

Introduction: Heart rate variability (HRV) is a non-invasive psychophysiological biomarker, which accurately reflects external and internal environmental changes (Lane et al., 2009). Empirical findings show that HRV is a reliable physiological correlate of changes in the intensity of anxiety (Blázquez et al., 2009). The related previous findings revealed that HRV negatively correlated with healthy adults' emotion regulation deficits (Visted et al., 2017) and anxiety (Chalmers et al., 2014). At the same time, high HRV levels in elite athletes were associated with better athletic performance (Morales et al., 2015). **Purpose:** The present study tested the above associations of HRV with emotional states and emotion regulation strategies in Hungarian athletes. HRV was expected to show significant negative and positive associations respectively with self-report measures of emotional states such as anxiety and anger and with cognitive emotion regulation. **Methods:** The sample included athletes aged 18 to 30 years. The participants' HRV was measured with a NeXus10 MKII device. Sport anxiety was measured with the Sport Anxiety Scale-2 (SAS-2), state and trait emotions with the State-Trait Anxiety Inventory-Y (STPI-Y), and cognitive emotion regulation with the Cognitive Emotion Regulation Questionnaire (CERQ). **Results:** The results revealed significant positive associations between one HRV component (LrLog) and maladaptive emotion regulation strategies. Older participants showed more adaptive emotion regulation strategies than younger ones. This is in line with a finding reported by Nicholls et al., (2015), which suggests that emotional immaturity is accompanied by less effective emotion regulation strategies. **Discussions:** Accordingly, the obtained associations between sport anxiety and cognitive emotion regulation strategies showed that the cognitive component of sport anxiety, that is, worry, and the accompanying concentration deficit were likely to result in increased preference for maladaptive emotion regulation strategies. Coping with worry has key importance in adaptive emotion regulation. Furthermore, in line with previous findings, maladaptive (less effective) emotion regulation strategies have an unfavorable impact on autonomous self-regulation processes.

Keywords: heart rate variability, cognitive emotion regulation, sport anxiety, sports psychology

Introduction

Reaching peak athletic performance essentially requires adequate cognitive emotion regulation and anxiety management, besides physical preparation. Although the nature of human emotionality has to date been a widely debated issue, most experts in the field agree that emotions are complex processes involving coordinated functional changes in the peripheral and central nervous system (Thayer & Siegle, 2002), specific behaviors or behavioral tendencies, and cognitive processes (Appelhans & Luecken, 2006). The emotions people experience during social interactions vary in the intensity of the associated physiological arousal (Levenson, 2003). Changes in the level of physiological arousal are primarily induced by the autonomic nervous system (ANS). The ANS comprises the facilitative sympathetic nervous system (SNS) and the inhibitory parasympathetic nervous system (PNS), both of which act on the level of arousal, often antagonistically. A state of physical or psychological stress is characterized by predominant sympathetic activity, which supports adaptation to the stressor by increasing the arousal level, this latter resulting in increased heart rate, among others. By contrast, parasympathetic activity is primarily responsible for a reduced arousal level and heart rate under relatively secure and stable conditions. The extent to which one is able to adequately regulate one's arousal level depends on the ability of one's ANS to adapt to changing environmental conditions (Appelhans & Luecken, 2006). Autonomic rigidity results in a reduced ability to generate or adapt physiological and emotional responses in synchrony with changes in the environment.

Heart rate variability (HRV) is a result of continuous interaction between the SNS and the PNS, which provides information on autonomic flexibility and one's ability to regulate one's emotional responses (Appelhans & Luecken, 2006). The assessment of HRV may be based on various indices such as geometrical analysis, statistical interval analysis, and spectral analysis (Svendsen et al., 2016).

Irrespective of the pursued sport, reaching outstanding athletic performance requires athletes to keep balance between sympathetic and parasympathetic activity (Lo CT et al., 2008). To this end, many authors recommend HRV monitoring and analysis, since HRV sensitively indicates changes in athletes' mental state such as the effectiveness of rest after a stressful situation (Kiss et al., 2016; Nakamura et al., 2015; Plews et al., 2013).

Stress and anxiety accompany sports activities at all levels and largely influence sport performance (Ford, 2017). The existing empirical findings show that HRV and sport performance are closely associated (Nakamura et al., 2015; Proietti et al., 2017; Hasegawa et al., 2020). Flatt and colleagues (2017) found that sport performance was positively associated with both parasympathetic activity and HRV. It has to be noted, however, that precompetitive stress is accompanied by increased anxiety (Fortes et al., 2017), and, furthermore, individual athletes considerably vary in their responses to precompetitive anxiety (Raglin, 1992). Researchers of sport anxiety make an important distinction between cognitive and somatic anxiety. Cognitive anxiety is related to negative emotions such as worry and fear, while somatic anxiety is associated with physiological changes in athletes (increased perspiration, increased heart rate, cramp in stomach). Such an emotional state may equally emerge before, during and after competition (Ayuso-Moreno et al., 2020).

That is, competition itself is the most important stressor, which has an essential impact on both psychological and psychobiological processes (Arruda, 2017). Precompetitive stress is a mental state associated with intense anxiety, harmful somatic and cognitive effects, and reduced self-confidence, which clearly impair sport performance. Practitioners assess the psychological aspects of precompetitive stress with self-report measures such as the CSAI-2R, which provides measures of cognitive and somatic anxiety and self-confidence in a competitive context.

HRV is widely used to assess physical fitness and physiological adaptive capacity in both the normal population and competitive athletes (Bellenger et al., 2016). In the normal population, HRV frequencies in the low range are related to self-regulation deficits, while high frequencies provide an index of tonic parasympathetic activity (Szemenyei et al., 2018). As Mateo and colleagues (2011) point out, HRV analysis offers a comprehensive set of measures for assessing competitive pressure. Increased (predominantly parasympathetic) HRV frequencies indicate adequate regenerative capacity, which is associated with reduced risk of cardiovascular disease and death (Szabó, 2017).

The available physiological measures are often supplemented with psychological tests designed to assess anxiety, cognitive emotion regulation, metacognitive abilities, thought control, perceived resilience, and various personality traits. One such test is the CERQ, which is particularly useful because it enables the assessment of a variety of cognitive coping strategies with one single self-report instrument. The existing empirical findings demonstrate that the CERQ-Short provides both researchers and practitioners with a reliable picture of one's complete repertoire of cognitive strategies employed in coping with stressful life events (Garnefski & Kraaij, 2001). Similarly to the CSAI-2R designed for measuring competitive anxiety, the Sport Anxiety Scale 2 (SAS-2) is a multidimensional self-report instrument, which provides a reliable measure of athletes' state precompetitive anxiety (Smith et al., 2006).

The present study explored whether a single psychobiological assessment conducted under non-competitive conditions would provide adequate data on individual athletes' emotional states.

Hypotheses

The present study explored the associations between HRV and self-reported emotional states with a single assessment conducted under non-competitive conditions.

1. HRV was expected to show significant associations with self-report measures of emotional states such as anxiety and anger and with cognitive emotion regulation.
2. Those with HRV frequencies indicating lower levels of parasympathetic activity were expected to show significantly higher sport anxiety (due to lower levels of parasympathetic regulation). Furthermore, those with HRV frequencies indicating higher levels of sympathetic activity were also expected to show significantly higher sport anxiety (due to higher levels of sympathetic regulation).
3. Those with HRV frequencies indicating higher parasympathetic activity and lower sympathetic activity were expected to show significantly more adaptive cognitive emotion regulation, due to higher levels of emotion control. Those with higher parasympathetic activity and lower sympathetic activity were expected to significantly more frequently employ cognitive emotion regulation strategies in order to maintain optimal emotion control. Furthermore, these athletes were expected to show a significantly higher preference for adaptive (as opposed to maladaptive) cognitive emotion regulation strategies.
4. Athletes with higher qualifications were expected to show lower sport anxiety and more adaptive cognitive emotion regulation.

Material and Method

The sample comprised 20 athletes including 12 males (60%) and 8 females (40%), of whom 10 athletes (50%) pursued a team sport and an individual sport each, 10 of them (50%) at an international level and at an amateur level each. The participants' age varied between 18 and 30 years ($M = 21.95$, $SD = 3.57$). The sample

showed considerable heterogeneity in the number of active years in sports, which ranged from 3 to 20 years ($M = 11.95$). The number of training hours per week ranged from 1 to 12 ($M = 6.41$).

The athletes' cognitive emotion regulation strategies were measured by a short version of the Cognitive Emotion Regulation Questionnaire (CERQ; Garnefski & Kraaij, 2001; adapted to Hungarian by Miklósi et al., 2011). The 18-item CERQ provides measures of four maladaptive strategies (self-blame, rumination, catastrophizing, blaming others) and five adaptive strategies (refocus on planning, putting into perspective, positive refocusing, acceptance, positive reappraisal).

A modified version of the Sport Anxiety Scale (SAS-2) were used to obtain reliably predictive measures of athletes' state precompetitive anxiety (Smith et al., 2006). The SAS-2 comprises three 5-item subscales, which assess somatic anxiety, cognitive anxiety (worry), and concentration disruption associated with increased arousal. The scale has shown high internal consistency, high construct validity, and adequate test-retest reliability (Smith et al., 2006). A modified version of the State-Trait Personality Inventory (STPI-Y; Spielberger, 2005) was used to assess the participants' current emotional states and trait-like emotional characteristics. The STPI-Y comprises eight 10-item subscales, four of which assess current emotional states including anxiety, curiosity, anger, and depression, while the other four subscales assess the same four emotions at a trait level (Sipos & Spielberger, 2005).

A physiological assessment was conducted immediately after the administration of the psychological measures. Physiological data were obtained with a Nexus-10 MKII equipment (MindMedia CV, The Netherlands), while the participants' heart rate (HR) and interbeat interval (IBI) were recorded with a photoplethysmography probe. The obtained raw data were analyzed with the Biotrace software and the Kubios HRV Standard v. 3.4 software. Each participant was assessed for their physiological parameters in sitting position for five minutes. Each participant was instructed to sit at complete rest and quiet with open eyes during the procedure.

A statistical interval analysis was conducted to obtain data on participants' HRV including mean RR interval (MEANRR), heart rate (HR), standard deviation of normal R-R distances (SDNN), number of differences between successive R-R distances above 50 msec (NN50), percentage of differences between successive R-R distances above 50 msec (PNN50), and squared mean of differences between successive R-R distances (RMSSD). Furthermore, a spectral analysis was conducted to obtain low-frequency HRV (LF-HRV, 0.04 to 0.15 Hz), high-frequency HRV (HF-HRV, 0.15 to 0.40 Hz), and the LF/HF ratio. The Kubios HRV Standard v. 3.4 software was used to generate a parasympathetic index (PNS), a sympathetic index (SNS), and a stress index (SI).

The sample was divided into three groups by the PNS index including those with average parasympathetic activity (-1 to 1 SD , Group 1), those with high parasympathetic activity (1 to 2 SD , Group 2, 14% of the population), and those with extremely high parasympathetic activity (above 2 SD , Group 3, 2% of the population).

Similarly, the sample was divided into three groups by the SNS index including those with average sympathetic activity (-1 to 1 SD , Group 1), those with low sympathetic activity (below -1 SD , Group 2, 16% of the population), and those with high sympathetic activity (above 1 SD , Group 3, 16% of the population).

These two classifications were combined to further divide the sample into three groups including those showing average PNS combined with average SNS (Group 1), those showing high / extremely high PNS combined with average SNS or average PNS with low SNS (Group 2), and those showing average PNS combined with high SNS (Group 3).

The statistical data analysis was conducted with the IBM SPSS v. 22.0 software package (SPSS Inc., Chicago, USA). All variables were checked for normality of distribution with Kolmogorov-Smirnov tests. Pairwise associations between the variables were tested with Pearson's correlation coefficients. Mean differences between the groups were explored with ANOVA tests and paired-samples and independent-samples t tests at the $p < .05$ significance level. The data entered in the ANOVA model were tested for homogeneity of variances, while the significance values of the pairwise mean differences were obtained with Tukey's b post hoc tests. The expected predictive relationships were tested with multiple linear regression analyses.

Results

All three psychological self-report measures and their subscales showed adequate reliability (Cronbach's α s ranged from .71 to .89).

Descriptive statistics were obtained for all measures. Table 1 presents the means and standard deviations of the HRV indices relevant to the hypotheses of the study.

Table 1. Means and standard deviations of the relevant HRV indices

Variable	Total		Amateur athletes n=10		Elit athletes n=10	
	Mean	SD	Mean	SD	Mean	SD
PNS index (score)	0,715	1,34	0,766	1,46	0,654	1,27
SNS index (score)	-0,297	0,97	-0,272	0,99	-0,327	1,1
Stressz index (score)	7,696	3,15	6,843	2,35	8,745	3,8
LfLog (log)	7,322	1,08	7,638	0,94	6,937	1,16
HfLog (log)	7,226	1,1	7,544	1,01	6,837	1,06
Lf/Hf (rate)	2,752	4,4	2,91	4,48	6,559	4,59

The PNS index is based on three HRV indices, and it indicates the level of parasympathetic activity. The SNS index is also based on three HRV indices, and it indicates the level of sympathetic activity. The stress index (SI) is the geometrical value of the HRV, which reflects the level of cardiovascular stress. High SI values indicate decreased HRV and high sympathetic cardiac activity. The LfLog index indicates low HRV related to self-regulation deficits. The HfLog index indicates high HRV related to parasympathetic activity. The LF/HF index shows the ratio of low and high HRV frequencies.

In the cognitive emotion regulation strategies (CERQ) the most frequently employed strategy in the overall sample was *refocus on planning*, which is an adaptive strategy. The most frequently employed maladaptive strategy was *rumination*. The sum scores obtained for the five adaptive strategies and for the four maladaptive strategies indicate the quality of each participant's cognitive emotion regulation. The means obtained for the overall sample show that the participants generally preferred adaptive strategies to maladaptive strategies ($t = 9.51$, $df = 19$, $p < .001$). The total CERQ scores indicate the participants' relative preference for using any cognitive strategies (i.e., attentional or thinking processes) for emotion regulation purposes. Based on the results of SAS2, as compared to cognitive anxiety (i.e., worry), the participants showed significantly lower levels of both somatic anxiety ($t = 3.29$, $df = 19$, $p < .004$) and concentration disruption ($t = 4.51$, $df = 19$, $p < .001$).

Zero-order correlations were obtained for the employed measures including the nine cognitive emotion regulation strategies, the sum scores for the adaptive and maladaptive strategies, the total CERQ score, the three components of sport anxiety, and the six HRV measures.

The associations between sport anxiety and maladaptive cognitive emotion regulation revealed a characteristic pattern: both concentration disruption and cognitive anxiety (i.e., worry) showed moderate positive correlations with the sum score for maladaptive emotion regulation. Regarding the correlations obtained for the five specific maladaptive emotion regulation strategies, cognitive anxiety was moderately associated with self-blame and catastrophizing, while concentration disruption showed moderate associations with rumination and catastrophizing. Furthermore, interestingly, concentration disruption was also significantly associated with refocus on planning and the total CERQ score.

The results of Levene's test indicated that the data met the variance homogeneity assumption. The significance values of the pairwise mean differences were obtained with Tukey's *b* post hoc tests. The results revealed that the participants in Group 1 (average PNS and average SNS) showed a significantly higher preference for positive refocusing than those in Group 3 (average PNS and high SNS; $F(2,5.3) = 5.3$, $p < .041$; Regarding gender differences, women as opposed to men were found to show a significantly higher preference for refocus on planning ($t = -2.87$, $df = 18$, $p < .010$) and for maladaptive emotion regulation strategies in general ($t = -2.17$, $df = 18$, $p < .043$), while they were less likely to employ any cognitive emotion regulation strategies ($t = -2.18$, $df = 18$, $p < .042$). No gender difference was found either on the HRV indices or on sport anxiety.

Nor was any significant difference observed between those pursuing a sport at an international vs. amateur level.

Age-related differences were explored between two age groups defined by the median (Group 1 < 20.5 years; Group 2 > 20.5 years). Significant age-related differences were found in cognitive emotion regulation. Namely, Group 2 as compared to Group 1 was found to show a significantly higher preference for adaptive emotion regulation strategies in general ($t = -2.1$, $df = 18$, $p < .050$) and for putting into perspective specifically ($t = -2.17$, $df = 18$, $p < .043$). No age-related difference was found either on the HRV indices or on sport anxiety. Multiple linear regression analyses were conducted to test the predictive power of the cognitive emotion regulation strategies and the sport anxiety components for each HRV index.

The results revealed that the LfLog index was significantly predicted by two maladaptive emotion regulation strategies including catastrophizing and self-blame ($F = 6.331$, $p = .022$), which predicted 35.6% of the total variance in the LfLog index. (Table 2)

Table 2. Psychological correlates of the LfLog index

	Standardized beta	t (p)	The explanatory power of the model
	0,743	3,437 (0,003)	Adjusted R2=0,356
CERQ Self-blame	0,544	2,516 (0,022)	F=6,331 (p=0,0022)

Discussion

The PNS index in the normal adult population falls between ± 1 *SD* (68%). Negative and positive PNS values respectively indicate relatively low and high parasympathetic activity. The mean PNS obtained for the participants in the present study was 0.715 *SD*, that is, the PNS index was shifted towards the high range in the sample, which supports the expectation that athletes show relatively high parasympathetic activity when at rest. As demonstrated in previous studies, sport performance is positively associated with both parasympathetic activity and HRV (D'ascenzi et al., 2014; Mateo et al., 2012; Morales et al., 2013). In the present study, however, athletes competing at a higher level showed lower PNS values compared to those pursuing sports at a lower level.

The SNS index in the normal adult population falls between ± 1 *SD* (68%). Negative and positive SNS values respectively indicate relatively low and high sympathetic activity. The mean SNS obtained for the participants in the present study was -0.297 *SD*, that is, the SNS index was shifted towards the low range in the sample. In the present study, athletes competing at a higher level showed lower SNS values compared to those pursuing sports at a lower level, that is, the former showed lower sympathetic activity.

The results on cognitive emotion regulation suggest that both the involved athletes' overall preference for using such strategies and their relative preference for adaptive and maladaptive strategies are similar to those observed in the normal population (Miklósi et al., 2011). These findings support the view that one's individual preference for certain emotion regulation strategies is acquired via social learning as part of one's family socialization, which essentially determines one's emotion regulation style (Miklósi, 2015).

The mean scores obtained for the three components of sport anxiety were similar to those found by the authors of the SAS-2 in an age-matched sample (Smith et al., 2006), including the significantly higher mean level of cognitive anxiety as compared to either somatic anxiety or concentration disruption. The explanation for these consistent differences is that athletes learn to regulate the somatic component at a relatively early sport age, while mature cognitive anxiety regulation only emerges in adulthood (Zhang et al., 2018). This observation is corroborated by the finding that the older athletes involved in the present study (i.e., those older than 20.5 years) generally showed more adaptive emotion regulation than their younger counterparts. Emotional immaturity is associated with less effective self-regulation, including emotion regulation (Nicholls et al., 2015). Accordingly, the obtained associations between sport anxiety and cognitive emotion regulation strategies corroborate that the cognitive component of sport anxiety (i.e., worry) and the accompanying concentration deficit are likely to result in increased preference for maladaptive emotion regulation strategies, which mediate between increased perceived stress and increased anxiety (Miklósi, 2015). In practical terms, improving athletes' adaptive coping capacity may help them effectively regulate competitive anxiety.

The athletes with more optimal levels of sympathetic and parasympathetic activity are more likely to engage in adaptive emotion regulation based on positive refocusing as compared to those with less optimal autonomic parameters. Positive refocusing appears to be an effective cognitive strategy in terms of maintaining optimal self-regulation. Cognitive strategies in general have been found to effectively help athletes cope with competitive stress (Hanton et al., 2008).

High LfLog values are related to self-regulation deficits in the normal population (Szemenyei et al., 2018). Accordingly, the LfLog index was positively associated with catastrophizing and self-blame in the present study. These findings suggest that a high relative preference for the two mentioned maladaptive emotion regulation strategies is responsible for the involved athletes' self-regulation deficits. Those athletes who reported to frequently employ these strategies showed relatively low levels of self-regulation.

Conclusions

The absolute and relative preferences for adaptive and maladaptive cognitive emotion regulation strategies shown by the athletes involved in the present study were similar to those observed in the normal population.

Emotion regulation becomes increasingly adaptive with age both among athletes and in the normal population. Different components of sport anxiety have distinctive effects on emotion regulation, in which the cognitive component has key importance. Maladaptive (less effective) emotion regulation strategies have an unfavorable impact on physiological self-regulation processes. The results revealed a positive association between the LfLog component of HRV and the athletes' emotion regulation capacity. The single-assessment design employed in the present study enabled no reliable conclusion on the relationship between HRV and sports anxiety in young athletes.

Limitations

The single-assessment measures obtained in a cross-sectional study design and the small sample size did not provide an optimal basis for testing the hypotheses of the study. Further related studies will be based on situation-specific assessments under submaximal and maximum load conditions.

Summary

The present study explored the associations of athletes' HRV indices with their state and trait emotions, sport anxiety, and cognitive emotion regulation strategies. The obtained findings demonstrate that the psychobiological parameters assessed at rest provide moderately accurate measures of athletes' emotional states and situation-specific self-regulation processes. Furthermore, the findings show that less optimal psychobiological characteristics are associated with less effective coping strategies, which may impair sport performance in competitive situations.

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