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REVIEW

The Influence of Physical Exercise, Stress and Body Composition on Autonomic Nervous System: A Narrative Review

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Abstract

The heart rate variability (HRV) changes under different situations such as physical exercise, stress and in obese/overweight subjects. It is considered a noninvasive marker of autonomic nervous system function. The aim of this narrative review was to discuss the relationship between HRV and physical exercise. Moreover, we will make an overview about HRV and stress, and HRV and body composition. There are a large number of studies dealing with HRV, however, few of them explain relationship between HRV and physical exercise, stress and body composition. HRV has proved to be a valuable tool to investigate the sympathetic and parasympathetic function of the ANS. Nonlinear parameters can be used to analyze the health of the subjects and is also used to investigate the stress and the physical exercise level. Despite the underlying mechanisms remain to be elucidated, these finding can be used as a starting point to determine a non-invasive index of cardiac wellness for clinical and nutritional application. Thus, physiological feedback via monitoring HRV would prove useful for addressing the individual's present capability, be it during selection processes or returning to duty following injury or illness but should not be used to diagnose any pathological conditions.

Keywords: *autonomic nervous system (ANS), herat rate variability (HRV), cardiovascular disease (CVD), physical activity, stress, overweight*

Introduction

The cardiovascular system, the heart and the circulation, are mostly controlled by higher brain centers and cardiovascular control areas in the brain stem through the activity of sympathetic and parasympathetic nerves (Aubert, Seps, & Beckers, 2003). Control is also affected by baroreceptors, chemoreceptors, muscle afferent, local tissue metabolism and circulating hormones (White & Raven, 2014). Study of cardiovascular variability allows mainly access to the activity of the nerves and the baroreceptors. Analysis of cardiovascular variability permitted insight into the neural control mechanism of the heart, leading to a new discipline: "Neurocardiology" (Aubert & Ramaekers, 1999). This area combines the disciplines of neurosciences and cardiovascular physiology on the research side and of neurology and cardiology on the clinical side. The normal heartbeat and blood pressure vary secondary to respiration, in response to physical, environmental, mental and multiple other factors and is characterized by a circadian variation.

Heart rate variability (HRV) is an easy and non-invasive

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tool for the assessment of variations in beat-to-beat intervals and autonomic nervous system activity with HRV obtained by linear methods within the domains of time and frequency analyses, and nonlinear methods (Task Force of the European Society of Cardiology and the North American Society of Pacing Electrophysiology, 1996). HRV has been studied extensively in regards to cardiovascular disease (Thayer, Yamamoto, & Brosschot, 2010; Frodl & O'Keane, 2013), exercise (Buchheit et al., 2010; Boullosa et al., 2012; Valenzano et al., 2016), stress, such as any type of change that causes physical, emotional, or psychological strain (von Borell et al., 2007; Kim et al., 2018), and body composition (Triggiani et al., 2015, 2019; Messina et al., 2017; Ciliberti et al., 2018). The way in which the cardiovascular system responds to different condition has captured the imagination of sport scientists over the past century (Vitale et al., 2019). For example, during physical activity, critical adjustments are continually made by the cardiovascular system to meet the diver's demands with respect to the musculature and the heart (Fagard, 1997). Rapid changes in heart rate (HR), and blood pressure, cause dynamic adjustments in cardiac and peripheral vascular control, including their regulation by the autonomic nervous system (ANS) (Monda et al., 2016; Messina et al., 2017). These variations also include circadian variations during the course of the day, which could have either a positive or negative effect on sport performance (Vitale & Weydahl, 2017). For this reason, understanding the interactions between cardiovascular function, activity of the ANS, chronobiology, biological rhythms, and chronotype allows to us understand the effects of exercise on human performance. The aim of this narrative review was to discuss the relationship between HRV and physical exercise. Moreover, considering that stress may be defined as a state of threatened homeostasis, which is counteracted by adaptive processes involving affective, physiological, biochemical, and cognitive–behavioral responses in an attempt to regain homeostasis, we will make an overview about HRV and stress, and the relationship between HRV and body composition.

HRV and physical exercise

During physical activity the vagal tone is withdrawn and HR is regulated principally by adrenergic system (Borresen & Lambert, 2008). The mechanism that physical activity induced increase in HR involves parasympathetic and sympathetic circuits. Thus, both the sympathetic and parasympathetic arms of the ANS play a crucial role during physical activity. Modification in HRV in response to physical exercise can vary in accordance to the degree, duration and load of physical activity and/or the kind of it (Plews, 2013; Chieffi et al., 2017). The HR increase during physical activity is due both a parasympathetic withdrawal and an increased sympathetic activity, and the role of the two drivers depends on exercise intensity. In particular, modifications in HRV, including variations in low frequencies (LF), high frequencies (HF), and total power (TP) (frequency domain), were observed in relation to different intensities of aerobic exercise. The HF peak is recognized in the power spectrum in the full range of relative intensity, being responsible for the most part of HRV at maximal load, while LF power does not change during low intensity exercise (below anaerobic threshold) and usually decreases to negligible values at medium–high intensity (above anaerobic threshold), where sympathetic activity is enhanced (Hottenrott, Hoos and Esperer, 2006). Accordingly, it has been showed that HR increase during physical activity is linked with the decrease in HRV in both HF and LF during a graded-work load exercise on a cycle ergometer (Lahiri, Kannankeril, & Goldberger, 2008), and the highest decrease in TP has been reported to occur during steady state exercises (Gronwald, Hoos, & Hottenrott, 2019). It seems that the modification in HF and LF showed during exercise do not reflect the decrease in vagal activity and the activation of sympathetic system occurring at increasing loads (Makivić, Nikić, & Willis, 2013). Moreover, during physical activity, technical problems arise from HR measurements because the steady state, which is mandatory for spectral analysis, is not always obtained (NASPE, 1996). The HRV measurement immediately after the end of physical activity reflects the subjects' responses to exercise, which primarily related to physical fitness. In fact, authors showed that the parasympathetic tone decrease after prolonged exercise and the recovery time was inversely correlated with subjects' maximal aerobic power (Hautala et al., 2001). Others authors have studied the effects of exercise intensity and duration on nocturnal heart rate variability and sleep quality (Myllymäki et al., 2012). In this study was showed that the increasing exercise intensity and/or duration caused a delayed recovery of nocturnal cardiac autonomic modulation (Myllymäki et al., 2012). Regarding the effects of supramaximal intermittent exercise, it was showed that there is relationship between exercise intensity and short- and long-term HRV recovery, because this kind of physical exercise improves post-exercise parasympathetic activity (Bonato et al., 2018). In general, it has been showed that athletes have lower HR values than sedentary controls (Fagard, 2003). Accordingly to this, authors showed that HR recovery after 30 and 120 seconds after exercise performed at different intensities was accelerated in well-trained athletes, highlighting a physiologic adaptation allowing for rapid HR recovery after intense exercise (Imai et al., 1994). According to this reasons, others authors showed that HRV has been widely researched in elite and well-trained athletes in order to understand the body's response via the ANS to intensified training loads (Vitale et al., 2019).

Others authors describe the link between Musculoskeletal overuse injuries and heart rate variability (Gisselman et al., 2016; Cotoia et al., 2018). Those authors hypothesized that athletes with accumulating somatic tissue damage would demonstrate changes in HRV at rest condition, reflecting decreased parasympathetic activity and increased autonomic nervous system (ANS) response. Relative to each athlete's baseline HRV measurements, imbalances in parasympathetic nervous system and sympathetic nervous system activity may indicate that an athlete is in a state of ongoing repair and recovery, as compared to an athlete who is adapting positively to training load (Gisselman et al., 2016; Valenzano et al., 2019).

HRV and stress

The Stress was defined as a maladaptive state in which the sympathetic nervous system is over activated, causing acute or chronic physical, psychological, and behavioral impairment (Kim et al., 2018). The search for stress biomarkers remains a challenging task for researchers and clinicians as there are several obstacles. One obstacle is a lack of consensus on the definition of stress. Furthermore, we lack a comprehensive framework for studying how organisms function in and adapt to constantly changing environments (Thayer et al., 2012;

Buonocore et al., 2020). At present, there is no universally recognized standard for stress evaluation. Different studies using existing stress measurement methods and examining biological markers have been conducted, and recently, studies on HRV and stress are increasing in frequency. An important study showed that increases in stress were associated with decreases in the RR interval (Sloan et al., 1994; Moscatelli et al., 2020). Moreover, psychological stress was significantly associated with an increase in the LF/HF ratio, suggesting increased SNS activity during stressful periods (Sloan et al., 1994; Valenzano et al., 2018). In another study authors investigated the relationship between the number of job stressors, self-reported sleep quality, and daytime autonomic activities (Kageyama et al., 1998; Messina et al., 2018). Those authors found no correlation between the HRV parameters and five job stressor scores Messina et al., 2015a; 2015b). However, subsequent studies have showed that some HRV indicators reflect psychological stress.

HRV is sensitive to changes in ANS activity related to stress. In different studies (Kim et al., 2018; Viggiano et al. ,2008; 2010; 2016), HRV variables changed in response to stress. The most frequently reported factor associated with changes in HRV variables was low parasympathetic activity, which is characterized by a decrease in the HF and an increase in the LF. HRV may be correlated to the activity of a flexible network of neural structures, which are dynamically organized in response to environmental modifications. In fact, neuroimaging investigations show that HRV may be linked to reduced threat perception, mediated by cortical regions involved in the appraisal of stressful situations. In clinical situations, HRV can be considered a tool that reflects heart activity and overall autonomic health, rather than specific mental illnesses or disease states (Kim et al., 2018). Thus, when evaluating the relationship between stress and HRV, it is crucial to consider the overall autonomic context as well as the patient's medical and psychological history.

HRV and body composition

The correlation between the overweight/obese and modifications in the activity of the ANS is widely accepted (Triggiani et al., 2015, 2019). In particular, it is known that the ANS influences physiological time variation between heartbeats. Hence, the HRV is considered an appropriate measure of the cardiac autonomic function (Shaffer & Ginsberg, 2017).

In the last two decades, different authors investigated the relationship between HRV, body mass index (BMI) and other indices of body composition (Skrapari et al., 2007). In particular, a decrease in HRV has been proposed to be related to body fat content (Berthoud, 2008). Moreover, in another important investigation conducted with healthy women, was found a statistically significant inverted U-shaped curve fitting the distribution of some HRV parameters along with the percentage of body fat extent (Triggiani et al., 2015). In particular, this data showed a reduction in HRV either in overweight or underweight subjects compared with normal weight subjects, and this appeared to be a result of the abnormal control of homeostatic mechanisms related to an altered distribution of body fat. One of the emergent explanations for those controversies might arise from the enhancing conviction that visceral adipose tissue (VAT), more than the general body fat mass, might be responsible, or, at least, related to the impairment of ANS activity (Hillebrand et al., 2014). In another important study was investigated visceral fat and HRV (Triggiani et al., 2019). The results of this investigation suggest a general decreased of HRV variables associated with increased body fat content although only HF resulted statistically significant. Moreover, the authors found a significant association between HRV indices and VAT (Messina et al., 2018). This authors conclude that in young adult healthy normotensive women, the association between ANS control and body fat is mostly due to VAT. Despite the underlying mechanisms remain to be elucidated, these finding can be used as a starting point to determine a non-invasive index of cardiac wellness for clinical and nutritional application (Triggiani et al., 2019).

Conclusion

Heart rate variability analysis has become an important tool in cardiology, because its measurements are noninvasive and easy to perform, have relatively good reproducibility and provide prognostic information on patients with heart disease. HRV has proved to be a valuable tool to investigate the sympathetic and parasympathetic function of the ANS. Spectral analysis of HR has clarified the nature of diabetic autonomic neuropathy and of other neurologic disorders that encounter the ANS. Nonlinear parameters can be used to analyze the health of the subjects and is also used to investigate the stress and the physical exercise level. The feasibility and possibilities of HRV within this particular field of application are well documented within the existing literature. Future studies, focusing on translational approaches that transfer current evidence in general practice (i.e. training of athletes) are needed. Thus, physiological feedback via monitoring HRV would prove useful for addressing the individual's present capability, be it during selection processes or returning to duty following injury or illness but should not be used to diagnose any pathological conditions.

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Conflict of Interest
The author declares that there is no conflict of interest.

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