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Significance of Respiratory Sinus Arrhythmia in Human Health and Disease

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ABSTRACT

By definition respiratory sinus arrhythmia (RSA) is the alternate increase in heart rate during inspiration and decrease in heart rate during expiration so that heartbeat is synchronized with respiratory rhythm [1-3]. The autonomic nervous system has been indicated to play a major role in the interaction of respiration and circulation to coordinate the events happening during RSA [2]. Respiratory sinus arrhythmia has also been linked to serve as an index of cardiac vagal tone [4] and good health [3]. This phenomenon that is RSA is observed in many species including human beings where RSA is found to be strongest (i.e. a larger difference between inspiration heart rate and expiration heart rate) in the young and fit meaning that professional athletes would generally be found to have a much greater RSA compared to the general population [3,5]. Conversely, lower RSA is linked to several human diseases and conditions shyness or reticence in toddlers [6], substance use disorder [7], stress [8], and autism spectrum disorder [9]. Therefore, this review seeks to discuss the significance of RSA in human health and disease.

Introduction

It is well documented that RSA is widely observed among vertebrates throughout their evolution which suggests that it may have an intrinsic physiological role [1,2,4,10]. Early studies have shown that the physiological role of RSA is to coordinate ventilation of the lungs with blood perfusion of the lungs so as to maximize the exchange of gases between alveoli and blood [2,10]. Thus during inspiration when alveoli oxygen content is highest, heart rate is fastest to ensure that the most blood is pumped to the lungs for maximum efficiency in gas exchange. The reverse is true for expiration when alveoli carbon dioxide content is relatively higher with lower oxygen content where heart rate is slowest resulting in less blood being pumped to the lungs. Respiratory sinus arrhythmia has even been used as an index of toddler parasympathetic arousal in a study investigating fathering and how it influences toddler emotion regulation [11]. Without question, RSA has an immense physiological role to play in the human body. The entire organism depends upon a constant supply of oxygen and nutrients and a constant removal of metabolic waste and carbon dioxide to and from all cells for the organism to function properly. Thus the cardiovascular system plays a pivotal role in organisms. It is therefore critical for the heart to function optimally for the wellbeing of an organism [12] and is exactly the reason why HR is precisely controlled by several mechanism in the body [13]. Respiratory sinus arrhythmia is front and center as part of these mechanisms that modulate or influence HR. It goes without saying and comes as no surprise that RSA itself involves a system that furnishes the body with oxygen and removes carbon dioxide, namely the respiratory system, which is an attempt by the organism to ensure strict regulation of these gases. Indeed, RSA has been linked to the efficiency by which pulmonary gas exchange occurs in healthy individuals where ventilation is synchronized with perfusion in each respiratory cycle [14]. Consequently, it is therefore important to understand why RSA happens and the various mechanism involved in RSA.

Not only is RSA associated with and is used to explain phenomena in healthy human beings including superior physical ability, RSA has been associated with various human conditions and is used to diagnose disease in humans. Shyness is a human behavioral trait or disposition that is marked by fear of or guardedness within new social settings [15]. Respiratory sinus arrhythmia measured at rest (basal RSA) is thought to signify a temperamental capacity for self-regulation of emotional arousal through control of vagal activity and the effects of the parasympathetic nervous system [16]. Based on this observation, Grady and Callan, in a study of shy toddlers

and their exhibition of reticence in social contexts, reported that high basal RSA was positively correlated with bold approach with an unfamiliar female examiner by shy toddlers [6]. This means that low basal RSA is associated with being reserved in shy toddlers indicating that toddlers with low basal RSA will not thrive in new social settings such as daycare, kindergarten later in life, and so forth eventually affecting their effectiveness in social settings as adults or their intellect for that matter. The research on shyness in toddlers [6] is related to substance use disorder in that emotional and self-regulatory processes are disrupted in people with this disorder as a result of the dysfunction of physiological regulation systems [7]. Price and Crowell investigated whether RSA could be used as a psychophysiological index of emotional regulation which could furnish information useful in the treatment of substance use disorder as well as in its recovery process. They indeed found that RSA may be used as an index of self-regulatory capacity in the 4 mindfulness-based intervention studies they reviewed. In 2 of the studies that had substance using samples, Price and Crowell [7] showed that pre-post RSA was elevated and was related to improved substance use outcomes. Three of the 4 studies were randomized control trials of which 2 studies reported significant increases in RSA in the experimental condition compared to the comparison condition. The diversity of situations and conditions in which RSA may be applied yielding relevant and useful data is astounding.

Since RSA is used as a peripheral marker of cardiac-linked parasympathetic regulation as well as an index for emotion regulation, it follows that the parasympathetic modulation of the heart as signified by RSA is linked to a complex system in which the nervous system regulates emotional and cognitive processing [8]. It is with this understanding that Tonhajzerova and coworkers [8] concluded that high resting or basal RSA may lead to greater withdrawal during stressors and subsequently better recovery which may represent a flexible and adaptive physiological response system to a challenge. On the other hand, low resting RSA together with poor reactivity to stress may be indicative of maladaptive regulatory mechanisms; Tonhajzerova and coworkers [8] further extrapolated. The increases in RSA were different depending on the stressor which suggests that this may have important implications for several mental disorders such as depression and anxiety [8]. Another study [9] also utilized basal RSA and RSA reactivity to predict restricted repetitive behaviors in children with autism spectrum disorder and found a positive correlation between severity of these restricted repetitive behaviors and RSA. There seems to be no end to the applications for which RSA is useful. There is a multitude of studies describing what RSA is and how it is applied in studies with healthy individuals, athletes, and also how RSA is applied in studies of various conditions and disease states yet it seems we are just barely scratching the surface when considering the potential wealth of information we can attain from studies of RSA. The various applications for RSA in and of themselves are testament to the importance of RSA. More studies looking at other physiological factors that may affect RSA in healthy subjects will continue to further our understanding of this phenomenon.

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