Comprehensive mind-body interventions, such as exercise-based approaches (e.g., Tai Chi, Qigong or yoga), or self-regulation training, meditation and mindfulness programs, have become popular, and increasing numbers of scientific studies have been performed to evaluate their effects on autonomic system function or health, particularly by assessing vagal nerve activity. Most of such studies use heart rate variability (HRV), the variation in the time intervals of adjacent heartbeat, to quantify autonomic activities before, during or after an intervention of interest. Positive and negative findings in changes in HRV have been reported from a wide range of interventions; however, major limitations in some of the study designs, the HRV protocols or metrics used in the analyses, as well as confusion in the interpretation of the data often limit the conclusions that can be made from the studies.

One missing element for many new researchers using HRV is that they do not understand the importance of using an appropriate data collection protocol that adequately relates to the research question or how the context in which the recordings are taken affects the choice of measures and the interpretation of the results. Some of the measures used in HRV may require different interpretations when obtained in different contexts such as health risk assessment, or looking for changes in HRV pre and post intervention, or more immediate state specific changes during an intervention or during a stressor, or the differences between resting state and ambulatory recordings or recordings over different lengths of time.

Long-term (usually by 24-h ECG recording) and resting state short-term (usually 5, 10 or 15 min) are very different contexts and the interpretations of the same variables can be different. For short-term resting state HRV recordings, participants should be instructed to sit quietly (typically for 5-min but can be other times periods) without engaging in activities like talking, chewing gum, or reading, and to remain as still as possible without sacrificing comfort, and keep their eyes open to avoid falling asleep. Additional steps may be used or added to the assessment protocol, depending on the research question. For example, there may be a stress reactivity protocol, or a skill acquisition protocol where the participant is asked to mediate in a specific way, or to focus their attention in the center of the chest and feel a positive emotion, as if they were preparing themselves mentally and emotionally for an important upcoming event or activity. In some study designs, participants are asked to breathe as deeply as they comfortably can at a paced 6-breaths per minute (5 s in/5 s out) rhythm. HRV during deep breathing challenges the nervous system to determine the maximum vagally mediated (parasympathetic) HRV their nervous system can generate at that time. Different HRV metrics are often used in these various protocols.

The calculation of HRV involves many technical algorithms and parameters that can affect the results. Using linear algorithms, HRV are often analyzed in time and frequency domains. The time domain measures are statistical (e.g., SDNN, SDANN, RMSSD, pNN50, etc.) or geometrical (e.g., HRV triangular index, TINN, etc.) calculations of consecutive NN intervals, which are easier to calculate as compared to the frequency domain, but they tend to provide less detailed information. The frequency domain is usually identified as four main power bands in spectral analysis: ultra-low-frequency band (ULF, <0.0033 Hz), very low frequency (VLF, 0.0033–0.04 Hz), low frequency (LF, 0.04–0.15 Hz), and high frequency (HF, 0.15–0.4 Hz, or some use 0.15–0.5 Hz). Nonlinear approaches (e.g., detrended fluctuation analysis, entropy, complexity, etc.) and Poincaré plot indexes are newer techniques adopted in HRV.

Some HRV parameters and the interpretations of them in regards to physiological mechanisms are still controversial. For example, LF and HF components are often assumed to correspond to sympathetic and parasympathetic neural activity, respectively, and the ratio of LF/HF has been used as an index of the sympathetic and parasympathetic balance. However, this concept has been challenged,4 and growing evidence clearly demonstrates this assumption is naïve, context dependent and greatly over simplifies the complex nonlinear interactions between sympathetic and parasympathetic divisions of ANS.5 A common misunderstanding that occurs is when an intervention leads to an increase in LF power in resting conditions, and is interpreted as an increase in sympathetic activity and thus as a “bad” result. Many authors have suggested that in resting recordings that the LF does not reflect sympathetic activity in same way it does in long-term ambulatory recordings. When paced or controlled breathing is involved in the intervention, such as commonly in Yoga, Tai Chi, or meditation, when the dominant respiratory frequency is slow, e.g., less than 9 breaths per minute (<0.15 Hz), the slow breaths cause an immediate increase in the frequency distribution of RR spectra and peaks below 0.15 Hz, which is defined as the “low frequency” range.6 Other factors like increases in tidal or static lung volume increase the heart rate variability as well.

HRV has been shown to indicate psychological resiliency and behavioral flexibility, reflecting an individual’s capacity to self-regulate and effectively adapt to changing social or environmental

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demands. Therefore, interventions that increase HRV are of great interest.

In conclusion, one should fully understand HRV and consider key issues before designing a study. The physiological mechanisms that contribute to HRV and the outcomes that produced by various interventions are complex. A study using HRV may have negative outcomes for many reasons that may not have anything to do with the real intervention effects. Interpretation of the results is often ambiguous or controversial; especially when the intervention is a mind-body approach, because of its multiple components (e.g., relaxation, respiration, mental status, emotional self-regulation, etc.) can all be confounding mechanisms.

References


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