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Commentary

The benefits of Heart Rate Variability (HRV) in the assessment of health and exercise performance

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Abstract

The purpose of this brief report is to stimulate further interest and to raise awareness in relation to the usefulness of assessing cardiac autonomic nerve function using heart rate variability (HRV). The paper outlines the mechanisms associated with HRV and the relationships between HRV, health, and athletic performance. The paper then summarizes the potential benefits of HRV in the assessment of health and exercise adaptations. The paper also provides suggestions about the practical implications of HRV measurement during data collection. We hope that the content provides useful information for the application of HRV for health evaluation and training adaptations. In addition, we hope the paper will provide a better understanding of how HRV measurements can be interpreted and used. Finally, the paper provides practical applications that are effective in the assessment of health and athletic training program outcomes.

Abbreviations

HRV: Heart Rate Variability; ANS: Autonomic Nervous System

Introduction

The cardiac autonomic nervous system (ANS) regulates the cardiovascular system. The ANS controls heart rate and associated blood pressure responses during daily activities. The ANS can also be used to observe the function of visceral organs, and therefore, is useful in determining the health status of humans [1]. Over the last decade, with the development of wearable device technology for heart rate variability (HRV) measurement, there has been an increase in the investigation of cardiac autonomic nerve function using HRV [2]. However, despite increased use, HRV assessment is still underutilized for the evaluation of cardiac health and as a method for investigating responses to exercise performance. HRV is a measure describing beat-to-beat variations of the time intervals between adjacent R-R intervals [3]. The information provided by HRV reflects the fluctuation in parasympathetic and sympathetic nerve activity and is an equilibrium measure between the two systems. There are three main methods used for HRV analysis. These can be described as time-domain, frequency-domain, and non-linear metrics [4]. HRV measurements have demonstrated decent reliability and test-retest measurement outcomes. A previous meta-analysis [5] suggested that the intraclass correlation coefficient (ICC) is a commonly used statistic to express test-

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retest reliability. Coefficients above 0.5 are generally considered to moderate test-retest reliability and coefficients above 0.8 as good reliability [6]. Also, a recent systematic review of short-term HRV test-retest reliability studies concluded that HRV assessed during rest had moderate test-retest reliability in healthy adults [7]. The highest ICCs ranged between 0.84 and 0.90 for time domain measures and between 0.67 and 0.96 for frequency domain measures [7].

Later studies also reported comparable findings [8-11]. Using structural equation modeling and latent state-trait theory. Bertsch et al. [8] quantified the relative proportions of variance in HRV explained by trait and non-trait factors in repeated HRV assessments. As little as 52% of the variance in a single HRV assessment was explained by trait, but this proportion increased to 66% and 75% when aggregating two and three HRV assessments, respectively [8].

In general, good cardiac autonomic control, which is accompanied by relatively high HRV, is advantageous for both physiological and psychological health. High HRV in populations is related to good health, low-stress levels, and low risk of sudden death and is a useful measure of a positive training outcome and adaptation for athletic performance improvement. Contrary to this, low HRV is associated with decreased physical fitness, high-stress levels, increased risk of cardiovascular disease, and poor training adaptations in athletes [2,12,13]. Table 1 outlines both patients' and athletes' HRV responses pre and post-intervention using different training loads. This table can be used as a reference point for researchers during the evaluation of the physical and mental health indicators described previously [14,15].

The application of HRV in health assessment

HRV has been used for various scenarios in the assessment of health. These include the assessment of population health, clinical assessment, cardiovascular research, and exercise performance. Regular physical exercise can improve cardiovascular fitness by beneficially elevating cardiac autonomic adjustment [16]. In relation to clinical assessments, HRV can be used to observe and evaluate autonomic nervous function in patients with various diseases. Cardiovascular diseases are always accompanied by impairments in cardiac autonomic control characterized by the reduced cardiac parasympathetic tone and low HRV. These measures are useful in the evaluation of cardiovascular health and can be predictors of sudden death, especially during and following strenuous exercise. As a result of this, more and more studies have focused on the changes in the HRV of patients with a variety of cardiovascular disease pathologies. These include increases in HRV when individuals with metabolic diseases increase their fitness levels using structured physical exercise [14,17]. This is especially true when individuals use aerobic exercise as the training modality. Aerobic exercise has positive effects on the cardiovascular system, and participation in aerobic activity causes an increase in HRV [18]. There may also be positive responses to anaerobic type activities, but this area is under-researched. HRV has also been used in the diagnosis of metabolic syndrome and diabetes. Type I and II diabetes are associated with an imbalance in autonomic modulation and low HRV [19].

Table 1: HRV Parameters Before and After Distinct Training Load.

Parameters	Appropriate training load		Excessive training load	
	Before exercise	After exercise	Before exercise	After exercise
SDNN (ms)	22 (12.5–33.25)	36 (30.75–40) *	75 ± 8	52 ± 4†
RMSSD (ms)	22.5 (11.65–37)	32.5 (24.4–40.9) *	67 ± 10	50 ± 4
pNN50 (%)	3.5 (0.15–16.25)	13 (3.62–22.5) *		
HF (ms^2)	57.5 (8.5–209.75)	175.5 (106.75–265.75) *	1150 ± 233	717 ± 106†
LF/HF (%)	0.97 (0.65–2.29)	0.63 (0.42–1.35) *	1.19 ± 0.19	1.02 ± 0.14†

Note: Values expressed in mean ± standard error of measurement. SDNN: Standard deviation of all RR intervals; RMSSD: The square root of the mean of the sum of the squares of differences between adjacent RR intervals; pNN50: Percentage of consecutive RR intervals that differ by more than 50 ms; LF: Power in LF range, 0.04-0.15Hz; HF: Power in HF range, 0.15-0.4 Hz; LF/HF: Ratio LF (ms^2)/ HF (ms^2).
†Significantly promoted after six months of suitable aerobic training ($p<0.05$).
†Significantly reduced after a period of field soccer competition, heavy training load ($p<0.05$).

HRV has also been used to evaluate the responses to training in both individual and team sports. This is particularly important for the identification of cardiovascular contraindications to health status and training adaptations in athletic populations and professional sportsmen and women. Furthermore, this information is crucial for both coaches and athletes as appropriate training loads should provide optimal improvements in fitness and performance [12]. This statement is supported by the findings of a previous study that investigated soccer players' HRV status over a training period. The results of the study indicated that the cardiac autonomic nervous system and HRV presented negative outcomes due to player fatigue [15]. In addition, HRV is useful for understanding and evaluating the cardiovascular responses to stress. Stress evaluation is crucial and is often related to the general health status of individuals and as a measure of overtraining in athletes. For athletes, HRV can be used to evaluate athletic cardiovascular changes during rest, and pre and post-exercise. This is an important consideration, as HRV is related to training load responses during rest and during recovery periods. D. Hernando et al. observed changes in HRV due to different training loads. They used frequency-domain parameters and found that the evaluation of HRV was useful as an indicator of over-training or overreaching during athletic performance [20]. In support of these findings, Naranjo et al. also revealed that HRV can also be useful in the detection of fatigue and over-training [21]. More suitable, precise, and objective training plans can be designed by monitoring HRV in comparison to individual pre and post-exercise measures that are used presently. Present methodologies for the evaluation and adaptation of athletes' cardiovascular responses to exercise are poorly monitored. HRV provides a valid and objective measure of cardiovascular health as well as providing information on exercise performance adaptations. D. F. D. A. Silva et al. designed a training plan based on pre-training HRV which was subsequently named HRV guided training. HRV has been demonstrated to be effective in monitoring training effects and can be optional as a beneficial supportive tool for coaches and athletes in the evaluation of traditional training assessments [22].

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The benefits of HRV in the assessment of health

The main advantage of assessing health status using HRV is that it is non-invasive which makes the application of HRV more practical and more accessible. Different from traditional blood index tests, HRV measures do not need sophisticated biochemical analysis. Additional patient analysis requiring biochemical investigation and associated comprehensive medical examination is only required following medical abnormalities or patient emergencies. Further positive considerations in the measurement of HRV are that there is no pain, discomfort, or related fear or trepidation for individuals when measurements are taken. This makes the measurement of HRV acceptable for all populations. Equally important, the HRV test is easy to administer, the analysis is non-complicated, and the equipment is portable, safe, and efficient. HRV equipment comprises a chest strap, electrode tabs, and a computer. The equipment can be operated comfortably at home, with no need to visit the laboratory or hospital which can cause anxiety and stress for patients. In addition, HRV results are easy to interpret and can be read using mobile technology such as mobile phones or other portable devices. Moreover, HRV results are immediate and don't rely on laboratory analysis techniques that can be very time-consuming. HRV tests can evaluate the health status of humans from the perspective of ANS, rather than using traditional kinetic systems. Besides, HRV testing provides immediate results, and changes in exercise plans can be performed efficiently and quickly without medical consultation [12]. Also, HRV is conducive to the timely detection of cardiac sports risks and the prevention of cardiovascular events and potential fatalities for athletes.

HRV has an important role in evaluating the health of athletes and the general population. However, using HRV to assess health has certain limitations. Firstly, there are differences in ANS among individuals and populations. Therefore, making individual longitudinal comparisons are more meaningful than horizontal comparisons between different people. Secondly, attempting to control the test environment such as temperature, altitude, humidity, and physical activity, and trying to avoid the impact of emotional fluctuations on HRV is challenging. These potentially confounding variables need consideration in the interpretation of the results during measurement. There also appears to be a confounding diurnal effect in the measurement of HRV. Therefore, measurements not only need to be taken under standardized conditions, but they also need to be obtained at the same time of day. Thirdly, HRV should be measured at rest or during low-intensity exercise. HRV measurements during high-intensity exercise appear to be less reliable [12]. This indicates that pre and post-exercise measures when the subjects are in a resting state provide better results. It should also be noted that HRV decreases with age [23] but increases with improvements in health. This provides difficulty in the interpretation of results for physically active older populations. This potential paradox requires careful interpretation of the HRV index and careful analysis of the possible influencing factors contributing to the specificity and results of the measurements.

Conclusion

In summary, there is a positive relationship between HRV, health, and exercise performance. The main benefits of HRV are that it is non-invasive, easy to operate, and time-efficient. Hence, HRV can be used as an effective tool to evaluate the health status of individuals with public health concerns, for clinical patients or athletes. During HRV assessment, an identical environment is necessary, and measures should be performed at the same time of day if test re-test observations are required. Long-term structured longitudinal measurements are more helpful in the assessment of health status and athletic performance evaluation than occasional measurements. We hope that the information provided in this paper will promote increased use of HRV by clinicians, trainers, and coaches as a measure of cardiac health and as a measure of the cardiovascular response to exercise.

References

1. Buchheit M. Monitoring training status with HR measures: do all roads lead to Rome? Front Physiol. 2014 Feb 27;5:73. doi: 10.3389/fphys.2014.00073. PMID: 24578692; PMCID: PMC3936188.
2. Souza HCD, Philbois SV, Veiga AC, Aguilar BA. Heart Rate Variability and Cardiovascular Fitness: What We Know so Far. Vasc Health Risk Manag. 2021 Nov 13;17:701-711. doi: 10.2147/VHRM.S279322. PMID: 34803382; PMCID: PMC8598208.
3. Ernst G. Heart-Rate Variability-More than Heart Beats? Front Public Health. 2017 Sep 11;5:240. doi: 10.3389/fpubh.2017.00240. PMID: 28955705; PMCID: PMC5600971.
4. Grässler B, Thielmann B, Böckelmann I, Hökelmann A. Effects of different exercise interventions on heart rate variability and cardiovascular health factors in older adults: a systematic review. Eur Rev Aging Phys Act. 2021 Nov 17;18(1):24. doi: 10.1186/s11556-021-00278-6. PMID: 34789148; PMCID: PMC8597177.
5. Eikeseth FF, Sætren SS, Benjamin BR, Ulltveit-Moe Eikenæs I, Sütterlin S, Hummelen B. The Test-Retest Reliability of Heart Rate Variability and Its Association With Personality Functioning. Front Psychiatry. 2020 Nov 4;11:558145. doi: 10.3389/fpsyt.2020.558145. PMID: 33329098; PMCID: PMC7672153.
6. Koo TK, Li MY. A Guideline of Selecting and Reporting Intraclass Correlation Coefficients for Reliability Research. J Chiropr Med. 2016 Jun;15(2):155-63. doi: 10.1016/j.jcm.2016.02.012. Epub 2016 Mar 31. Erratum in: J Chiropr Med. 2017 Dec;16(4):346. PMID: 27330520; PMCID: PMC4913118.
7. Sandercock GR, Bromley PD, Brodie DA. The reliability of short-term measurements of heart rate variability. Int J Cardiol. 2005 Sep 1;103(3):238-47. doi: 10.1016/j.ijcard.2004.09.013. PMID: 16098384.
8. Bertsch K, Hagemann D, Naumann E, Schächinger H, Schulz A. Stability of heart rate variability indices reflecting parasympathetic activity. Psychophysiology. 2012 May;49(5):672-82. doi: 10.1111/j.1469-8986.2011.01341.x. Epub 2012 Feb 15. PMID: 22335779.
9. Pinna GD, Maestri R, Torunski A, Danilowicz-Szymanowicz L, Szwoch M, La Rovere MT, Raczak G. Heart rate variability measures: a fresh look at reliability. Clin Sci (Lond). 2007 Aug;113(3):131-40. doi: 10.1042/CS20070055. PMID: 17381425.
10. Cipryan L, Litschmannova M. Intra-day and inter-day reliability of heart rate variability measurement. J Sports Sci. 2013;31(2):150-8. doi: 10.1080/02640414.2012.721931. Epub 2012 Sep 11. PMID: 22963409.

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11. Guijt AM, Sluiter JK, Frings-Dresen MH. Test-retest reliability of heart rate variability and respiration rate at rest and during light physical activity in normal subjects. Arch Med Res. 2007 Jan;38(1):113-20. doi: 10.1016/j.arcmed.2006.07.009. PMID: 17174734.

12. Buchheit M. Monitoring training status with HR measures: do all roads lead to Rome? Front Physiol. 2014 Feb 27;5:73. doi: 10.3389/fphys.2014.00073. PMID: 24578692; PMCID: PMC3936188.

13. Hinde K, White G, Armstrong N. Wearable Devices Suitable for Monitoring Twenty Four Hour Heart Rate Variability in Military Populations. Sensors (Basel). 2021 Feb 4;21(4):1061. doi: 10.3390/s21041061. PMID: 33557190; PMCID: PMC7913967.

14. Goit RK, Pant BN, Shrewastwa MK. Moderate intensity exercise improves heart rate variability in obese adults with type 2 diabetes. Indian Heart J. 2018 Jul-Aug;70(4):486-491. doi: 10.1016/j.ihj.2017.10.003. Epub 2017 Oct 4. PMID: 30170641; PMCID: PMC6116720.

15. JMDQ MIRANDA. Effects of a Competitive Season on Autonomic Heart Rate Modulation in Field Soccer Athletes. Int J Exerc Sci. 2019; 12:2;1198,.

16. Lee DC, Sui X, Ortega FB, Kim YS, Church TS, Winett RA, Ekelund U, Katzmarzyk PT, Blair SN. Comparisons of leisure-time physical activity and cardiorespiratory fitness as predictors of all-cause mortality in men and women. Br J Sports Med. 2011 May;45(6):504-10. doi: 10.1136/bjsm.2009.066209. Epub 2010 Apr 23. PMID: 20418526.

17. Picard M, Tauveron I, Magdasy S, Benichou T, Bagheri R, Ugbolue UC, Navel V, Dutheil F. Effect of exercise training on heart rate variability in type 2 diabetes mellitus patients: A systematic review and meta-analysis. PLoS One. 2021 May 17;16(5):e0251863. doi: 10.1371/journal.pone.0251863. PMID: 33999947; PMCID: PMC8128270.

18. Pearson MJ, Smart NA. Effect of exercise training on endothelial function in heart failure patients: A systematic review meta-analysis. Int J Cardiol. 2017 Mar 15;231:234-243. doi: 10.1016/j.ijcard.2016.12.145. Epub 2016 Dec 28. PMID: 28089145.

19. Jabbour G, Iancu HD. Supramaximal-Exercise Training Improves Heart Rate Variability in Association With Reduced Catecholamine in Obese Adults. Front Physiol. 2021 Mar 30;12:654695. doi: 10.3389/fphys.2021.654695. PMID: 33859574; PMCID: PMC8042138.

20. Hernando D, Hernando A, Casajús JA, Laguna P, Garatachea N, Bailón R. Methodological framework for heart rate variability analysis during exercise: application to running and cycling stress testing. Med Biol Eng Comput. 2018 May;56(5):781-794. doi: 10.1007/s11517-017-1724-9. Epub 2017 Sep 26. PMID: 28948522.

21. Naranjo J, De la Cruz B, Sarabia E, De Hoyo M, Domínguez-Cobo S. Heart Rate Variability: a Follow-up in Elite Soccer Players Throughout the Season. Int J Sports Med. 2015 Nov;36(11):881-6. doi: 10.1055/s-0035-1550047. Epub 2015 Jul 3. PMID: 26140687.

22. da Silva DF, Ferraro ZM, Adamo KB, Machado FA. Endurance Running Training Individually Guided by HRV in Untrained Women. J Strength Cond Res. 2019 Mar;33(3):736-746. doi: 10.1519/JSC.0000000000002001. PMID: 28570494.

23. Voss A, Schroeder R, Heitmann A, Peters A, Perz S. Short-term heart rate variability--influence of gender and age in healthy subjects. PLoS One. 2015 Mar 30;10(3):e0118308. doi: 10.1371/journal.pone.0118308. PMID: 25822720; PMCID: PMC4378923.

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