REVIEW

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Assessment Tools and Performance Development in Sports Cardiology

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Abstract

Sports cardiology is a multidisciplinary field that has evolved to evaluate and optimize the cardiovascular health of athletes. The field focuses on improving exercise-related physical performance, reducing cardiovascular risks, and detecting potential diseases early. Sports cardiology monitors the heart health of athletes while also evaluating their cardiovascular responses during exercise. This process plays a critical role in increasing training intensity, managing fatigue, and preventing heart disease. In addition, one of the areas of interest of sports cardiology is performance medicine. A sports cardiologist and sports physician is a part of the athletic process from the athlete's first examination to the final step of athletic success. Sports cardiology and performance medicine provide athletic and economic value to the sports industry by preventing injuries, objectively assessing performance, rapidly and effectively improving performance, and enhancing athletic success. In this review, we aim to present the assessment tools, and study areas of sports cardiology.

Keywords: Sports cardiology, performance medicine, cardiorespiratory fitness

INTRODUCTION

Sports cardiology has emerged as a significant area of academic research in recent years. The vast majority of sports cardiology literature so far has focused on sudden cardiac death (SCD) and the relationship between sports and disease.[1] However, there are few cardiology articles related to performance medicine, an area of interest in sports cardiology. Athletic features related to muscles and joints have reached the upper limits of human performance in today's elite athletes. Along with external development, internal development is essential for elite athletes in order to remain competitive. Consequently, sports cardiology and performance medicine arise as a scientific discipline that has the potential to positively impact elite athletes. Evaluating performance medicine with a cardiologist's perspective may provide novel and beneficial support for sports and athletes. Moreover, sports cardiology and performance medicine present injury prevention, objective performance monitoring, accelerated and efficient performance enhancement, and economic savings and profitability for the sports industry in many situations. This review provides an overview of sports cardiology and performance.

Athlete in Sports Cardiology

The definition of an athlete can vary depending on the purpose and duration of training. In a proposed classification of athletes according to the minimum volume of exercise, "elite" athletes (i.e., national team members, olympians, and professional athletes) typically engage in over 10 hours per week, "competitive" athletes (i.e., high school, college, and older master club level athletes) participate in over 6 hours

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per week, and "recreational" athletes exercise for more than 4 hours per week.[2] The term "athlete's heart" refers to many alterations and adaptations, including structural, functional, physiological, and electro-physiological changes resulting from sport-specific cardiac remodeling.[3] Not only the duration of training but also the content of training in elite athletes reveals different variations of the athlete's heart.[4] In sports cardiology and performance medicine, the nature of the sport, age, and position of the athlete, and, if it is a team sport, the task expectations from the athlete on the field are elements that should be taken into consideration.

Athlete Examination and Sudden Cardiac Death

Despite ongoing debate on the funding and economic resources for systematic screening programs, there is a consensus that a cardiological examination should at least be performed. In the United States, only a medical history and directed physical examination are recommended; however, in Europe, a 12-lead electrocardiogram (ECG) is also included in the examination.[5]

Sports-related SCD is a phenomenon previously linked to both competitive and recreational sports activity. Screening strategies must be tailored to the target group and the specific diseases with the highest risks. The incidence of SCD in college-aged males is 1 in 35,000 person-years and 1 in 18,000 person-years for black males, with elevated risks associated with men's basketball, men's soccer, and American football. Inherited cardiomyopathies and electrical disorders comprise approximately two-thirds of sudden cardiac arrest/death cases and can be identified by an ECG.[6] SCD in young athletes results from many structural and electrical heart problems, such as cardiomyopathies, ion channel abnormalities, coronary anomalies, and acquired cardiac illnesses.[7,8] Atherosclerotic coronary artery disease is the predominant condition resulting in significant adverse cardiovascular events in adult and senior athletes.[9] Sports-related SCD has been observed to occur 5-33 times less frequently in women than in men, with this sex disparity being evident despite a swift rise in female engagement in sports.[10] ECG, echocardiography options, exercise test protocols, cardiopulmonary exercise tests (CPETs), tomography, and magnetic resonance imaging provide effective approaches in the examination of professional athletes. The presence of symptoms and family history should be taken into consideration prior to considering these options. In the examination of a team or the evaluation of an individual athlete, the presence of any cardiac symptoms or family history should be questioned first. Further examination can be planned according to these answers.

Athletic Performance Assessment and Development Tools in Sports Cardiology

Echocardiography

Echocardiography is a cost-effective method that facilitates the detection of the main causes of preventable sudden death, including cardiomyopathies, anomalies in coronary artery origin, and aortic disorders. In numerous competitive athletes, the left ventricular end-diastolic volume and diameter may above the established "normal" ranges for chamber quantification.[11] The left ventricular wall thickens symmetrically due to conditioning and can occur in isolation (concentric hypertrophy), in strength-focused activities or alongside an increase in chamber dilation (eccentric hypertrophy) in athletes engaged in sports necessitating both strength and endurance stimuli, such as swimming and rowing. Asymmetric hypertrophy and left ventricular wall thickness above 15 mm, should prompt concerns for pathological cardiomyopathy, especially in athletes participating in isometric exercises. Conditioned persons generally exhibit a normal left ventricular ejection fraction (LVEF) at rest; nevertheless, the regulation of stroke volume in a bigger ventricle occurs via the ejection of a diminished fraction of the end-diastolic volume. This may present as a low-normal or somewhat abnormal LVEF.[12] Despite the misleading decrease in LVEF, the systolic function remains intact or exceeds normal levels, as demonstrated by standard LV strain measurements.[13]

Another important aspect of echocardiography in performance medicine is analyzing the conditioned heart and elucidating the exercise methods that best form the athlete's heart. Our observation is that the rate of athletes' hearts is higher in endurance sports that require water mechanics, such as rowing, swimming, and canoeing. Fast and effective methods can be developed with the future specific training methodology studies.

Heart Rate Recovery Time and Vagal Tone

The heart exhibits physiological adaptations in response to prolonged and intense exercises, leading to distinct changes.[4] Vagal activity contributes to the differences observed in the athlete's heart.[14] While various cardiac arrhythmias and conduction abnormalities can be considered as pathology in untrained individuals, they are considered normal in athletes due to increased vagal tone.[15] Intensive level sports cause an increase in vagal tone in the heart. Vagal tone and heart rate recovery (HRR) are directly related to athletic success.[16] During postexercise recovery, heart rate initially falls rapidly, followed by a period of slower decrease, until resting values are reached.[17] HRR is an important parameter for the monitoring and evaluation of attack potential, the ability to maintain race pace, and the endurance.

For sports performance doctors, HRR and vagal tone should target the development of athletic success. The cranial electrical stimulator is a device that can enhance sports performance via vagal stimulation.[18] The parasympathetic system plays a crucial role in restructuring and recovery during rest periods, significantly alleviating athlete fatigue and enabling early recovery. Vagus nerve stimulation, the principal component of the parasympathetic system, can influence several cardiovascular, pulmonary, and metabolic parameters during both rest and exercise.[19] In addition, various breathing exercises are used to develop vagal tone and shorten the HRR time.[20] More scientific studies are needed to investigate vagal tone in the preservation and development of athletic capacity in performance medicine.

Cardiopulmonary Exercise Testing

CPET is a form of stress test that is primarily carried out on a treadmill or cycle ergometer. During this test, the O_2 (VO_2) in the air the patient breathes, CO_2 levels in the air given off, minute ventilation, minute respiratory rate, anaerobic threshold, heart rate, tidal volume, inspiratory capacity, oxygen saturation, 12-lead ECG rhythm, work done, exercise duration, and blood pressure are monitored. Sometimes more invasive measurements, such as blood lactate levels or arterial blood gases, are also taken.[21] CPET is the gold standard in determining the metabolic status of the organism and evaluating the functional capacities of the cardiac, pulmonary, and neuromuscular systems.[22] The purpose of CPET is to implement a certain amount of stress on the organs involved in the exercise. Therefore, during the test, large muscle exercises that use lower extremity muscles are preferred.[21,22] CPET can be used to optimize athletes' training programs or evaluate their cardiovascular health status. VO_2 max measured in this test indicates the individual's maximum oxygen consumption capacity and is an important parameter reflecting aerobic capacity. Resting VO_2 is 3.5 mL/kg/min. The highest values for women are 35 mL/kg/min and for men, 45 mL/kg/min. The average athlete can consume up to 60 mL/kg/min.[23] For this reason, athletes, runners, and individuals involved in other endurance sports often implement training programs aimed at increasing VO_2 max.[24,25] Many fitness watches offer VO_2 max measurement functionality, but this functionality needs improvement. Nowadays, it is possible to make measurements in the field and during exercise with portable CPETs. CPET provides information about the athlete's exercise capacity, peak performance indicators, and physiological responses to exercise through the professional team evaluation and analysis of special software.

Heart Rate Variability

Heart rate variability (HRV) reveals variations in the intervals between consecutive heartbeats, offering insights into cardiac autonomic function and overall physiological condition. High HRV indices typically reflect the presence of efficient autonomous systems, which are characteristic of an individual in a healthy state.[26] Endurance athletes generally exhibit better cardiac autonomic function than non-athletes, characterized by reduced resting heart rates and increased variability. The accessibility and use of HRV measures have expanded among the general population and may be especially beneficial for endurance athletes.[27] HRV monitoring enables the understanding of an athlete's internal dynamics. Daily measurement of autonomic nervous system activity by spectral analysis of HRV during training load appears to be a promising tool for improving performance.[28] In addition, HRV is a preferred parameter in the analysis of athletes' injury risk (Figure 1). HRV can provide a new approach to overuse injuries both in terms of athlete health and financial value in the sports industry. However, studies examining the use of HRV using consistent methodologies are limited, and more comprehensive studies are needed on this subject.

Performance Improvement

The limits of athletic performance have been a subject of speculation and discussion for a long time. Nonetheless, a noticeable plateau in sports performance has emerged in recent years, suggesting that the potential for further development of people's physical ability may be limited.[29] Consequently, doping substances have become increasingly seen as a controversial issue among professional athletes. Due to the wide variety of chemicals and the frequent introduction of new designer medications, the World Anti-Doping Agency (WADA) annually updates its list of prohibited substances and methods. Cardiac function is likely one of the most fundamental factors of athletic performance. This casts significant questions on the utilization of certain cardiac medications as performance-

Figure 1: As a result of strain and inadequate recovery, overuse injuries begin to occur in athletes. The low-grade inflammatory process that occurs before the pain symptom causes changes in the autonomic nervous system. The effect on the autonomic nervous system can be detected by heart rate variability analysis and may be useful as a predictive tool for overuse injuries

enhancing substances. The inclusion of trimetazidine in WADA's prohibited list as a doping agent in 2014 marks the commencement of this period. Other currently suspected drugs are ranolazine, sacubitril/valsartan and dapagliflozin. Therefore, a performance doctor should primarily be an ethical consultant to the athlete.[30,31]

In both aerobic and resistance exercise consultancy, the performance doctor should aim to increase training efficiency. Resistance exercise is rapidly gaining popularity in both cardiology patient groups and healthy individuals, and is one of the most important elements of athletic performance.[32] The exercise dose-response relationship differs among various populations. The optimal strength gains for untrained persons are achieved at an average training intensity of 60% of their one-repetition maximum (1RM), performed three times weekly, with an average training volume of four sets per muscle group. Recreationally trained non-athletes get optimal strength increases with an average training intensity of 80% of 1RM training twice weekly and performing an average of 4 sets. In athletic populations, optimal strength increases are achieved with training twice weekly at an average intensity of 85% 1RM and a volume of 8 sets per muscle group.

Heart rate-focused training approaches should be implemented for objectives such as injury rehabilitation, aerobic capacity enhancement, and anaerobic threshold improvement. Exercise intensity can be quantified as a percentage of an individual's heart rate reserve, calculated by taking a percentage of the difference between maximum heart rate max and resting heart rate, then adding this value to the resting heart rate, as per the Karvonen formula.[33] When calculating the athlete's target heart rate with the Karvonen formula, the type of sport and the player's task expectations should be taken into consideration. For example, if acceleration and sprint frequency are targeted for a football winger, it is necessary to work in zone 5. However, if the aim is simply to maintain performance, a training model in zone 3 is sufficient for the endurance athlete. In addition, the interval method will increase efficiency in aerobic training and make it easier to obtain long-term exercise responses.[34] Methods such as ischemic heart rate training, water mechanics training, and blood flow restriction will contribute to performance medicine in the future.

Additionally, artificial intelligence-based injury analysis methods and wearable technologies used in performance monitoring, are becoming widespread in both predicting training loads and providing objective performance data for athletes. Artificial intelligence applications that are integrated with tracking parameters such as HRV and catapult are the first examples of these technologies.

CONCLUSION

Sports cardiology and performance medicine focus on performance development in addition to athlete health. It can be beneficial in preventing injury, analyzing performance, and enhancing it to an optimal level, especially in industrial sports branches. More studies are needed in performance medicine, both in the prevention of performance issues and in the development of performance.

Footnotes

Authorship Contributions

Surgical and Medical Practices: A.T., Ş.K., Ö.I., Concept: A.T., Ş.K., Ö.I., Design: A.T., Ş.K., Ö.I., Data Collection or Processing: A.T., Ş.K., Ö.I., Analysis or Interpretation: A.T., Ş.K., Ö.I., Literature Search: A.T., Ş.K., Ö.I., Writing: A.T., Ş.K., Ö.I.

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REFERENCES

1. Pelliccia A, Sharma S, Gati S, Bäck M, Börjesson M, Caselli S, *et al*. 2020 ESC guidelines on sports cardiology and exercise in patients with cardiovascular disease. Eur Heart J. 2021;42:17-96.
2. McKinney J, Velghe J, Fee J, Isserow S, Drezner JA. Defining Athletes and Exercisers. Am J Cardiol. 2019;123:532-5.
3. Liu PY, Tsai KZ, Lima JAC, Lavie CJ, Lin GM. Athlete's heart in Asian military males: the CHIEF heart study. Front Cardiovasc Med. 2021;8:725852.
4. Torun A, Erdem A, Doğan S, Orhan AL, Acar B, Simsek U, *et al*. Comparison of the effects of resistance, aerobic and mixed exercise on athlete's heart. J Sports Med Phys Fitness. 2024;64:88-93
5. Boraita A. Muerte súbita y deporte. 'Hay alguna manera de prevenirla en los deportistas? [Sudden death and sport. Is there a feasible way to prevent it in athletes?]. Rev Esp Cardiol. 2002;55:333-6.
6. Harmon KG. Incidence and Causes of Sudden Cardiac Death in Athletes. Clin Sports Med. 2022;41:369-88.
7. Harmon KG, Asif IM, Maleszewski JJ, Owens DS, Prutkin JM, Salerno JC, *et al*. Incidence, cause, and comparative frequency of sudden cardiac death in national collegiate athletic association athletes: a decade in review. Circulation. 2015;132:10-9.
8. Peterson DF, Siebert DM, Kucera KL, Thomas LC, Maleszewski JJ, Lopez-Anderson M, *et al.* Etiology of sudden cardiac srrest and death in US Competitive athletes: a 2-year prospective surveillance study. Clin J Sport Med. 2020;30:305-14.
9. Finocchiaro G, Papadakis M, Robertus JL, Dhutia H, Steriotis AK, Tome M, et al. Etiology of sudden death in sports: insights from a United Kingdom regional registry. J Am Coll Cardiol. 2016;67:2108-15.
10. Rajan D, Garcia R, Svane J, Tfelt-Hansen J. Risk of sports-related sudden cardiac death in women. Eur Heart J. 2022;43:1198-206.
11. Parry-Williams G, Sharma S. The effects of endurance exercise on the heart: panacea or poison? Nature reviews. Cardiology. 2020;17:402-12.

12. Baggish AL, Battle RW, Beaver TA, Border WL, Douglas PS, Kramer CM, *et al*. Recommendations on the use of multimodality cardiovascular imaging in young adult competitive athletes: a report from the American society of echocardiography in collaboration with the society of cardiovascular computed tomography and the society for cardiovascular magnetic resonance. J Am Soc Echocardiogr. 2020;33:523-49.
13. Addis DR, Townsley MM. Imaging Considerations for the athletically conditioned heart: an echocardiography-focused overview of the 2020 American society of echocardiography recommendations on the use of multimodality cardiovascular imaging in young adult competitive athletes. J Cardiothorac Vasc Anesth. 2020;34:2867-70.
14. Coote JH, White MJ. CrossTalk proposal: bradycardia in the trained athlete is attributable to high vagal tone. J Physiol. 2015;593:1745-7.
15. Zorzi A, Vio R, Bettella N, Corrado D. Criteria for interpretation of the athlete's ECG: A critical appraisal. Pacing Clin Electrophysiol. 2020;43:882-90.
16. Peinado AB, Benito PJ, Barriopedro M, Lorenzo I, Maffulli N, Calderón FJ. Heart rate recovery in elite Spanish male athletes. J Sports Med Phys Fitness. 2014;54:264-70.
17. Torun A, Kilic S, Uzun M, Simsek U, Aslan GY, Kahraman G. Evaluation of high altitude training camps with heart rate recovery and heart rate variability analysis: beneficial effect in elite swimmers. J Sports Med Phys Fitness. 2024;64:1026-30.
18. Güçlüer EÖ, Ural İH, Özden AV, Alptekin HK, Hatık SH. Effects of auricular vagus nerve stimulation on cardio-respiratory functions after aerobic exercise. International Journal of Disabilities Sports &Health Sciences. 2024;7:494-501.
19. Hatik SH, Asrlan M, Demirbilek Ö, Özden AV. The effect of transcutaneous auricular vagus nerve stimulation on cycling ergometry and recovery in healthy young individuals. Brain Behav. 2023;13:e3332.
20. Balban MY, Neri E, Kogon MM, Weed L, Nouriani B, Jo B, et al. Brief structured respiration practices enhance mood and reduce physiological arousal. Cell Rep Med. 2023;4:100895.
21. Albouaini K, Egred M, Alahmar A, Wright DJ. Cardiopulmonary exercise testing and its application. Postgrad Med J. 2007;83:675-82.
22. Ceylan E. Kardiyopulmoner egzersiz testleri. Journal of Clinical and Experimental Investigations. 2014;5:504-9.
23. Shin K, Minamitani H, Onishi S, Yamazaki H, Lee M. Assessment of training-induced autonomic adaptations in athletes with spectral analysis of cardiovascular variability signals. Jpn J Physiol. 1995;45:1053-69.
24. Štursová P, Budinská X, Nováková Z, Dobšák P, Babula P. Sports activities and cardiovascular system change. Physiol Res. 2023;72:S429-44.
25. Chtara M, Chamari K, Chaouachi M, Chaouachi A, Koubaa D, Feki Y, *et al*. Effects of intra-session concurrent endurance and strength training sequence on aerobic performance and capacity. Br J Sports Med. 2005;39:555-60.
26. Mendes RG, Simões RP, De Souza Melo Costa F, Pantoni CB, Di Thommazo L, *et al*. Short-term supervised inpatient physiotherapy exercise protocol improves cardiac autonomic function after coronary artery bypass graft surgery--a randomised controlled trial. Disabil Rehabil. 2010;32:1320-7.
27. Lundstrom CJ, Foreman NA, Biltz G. Practices and applications of heart rate variability monitoring in endurance athletes. Int J Sports Med. 2023;44:9-19.
28. Botek M, McKune AJ, Krejci J, Stejskal P, Gaba A. Change in performance in response to training load adjustment based on autonomic activity. Int J Sports Med. 2014;35:482-8.
29. Berthelot G, Sedeaud A, Marck A, Antero-Jacquemin J, Schipman J, Saulière G, *et al*. Has Athletic Performance Reached its Peak? Sports Med. 2015;45:1263-71.
30. Jarek A, Wójtowicz M, Kwiatkowska D, Kita M, Turek-Lepa E, Chajewska K, *et al*. The prevalence of trimetazidine use in athletes in Poland: excretion study after oral drug administration. Drug Test Anal. 2014;6:1191-6.
31. Li YJ, Wang PH, Chen C, Zou MH, Wang DW. Improvement of mechanical heart function by trimetazidine in db/db mice. Acta Pharmacol Sin. 2010;31:560-9.
32. Torun A. Role of Resistance exercise in cardiology. Anatol J Cardiol. 2024;28:217–21.
33. Myers J, Hadley D, Oswald U, Bruner K, Kottman W, Hsu L, *et al*. Effects of exercise training on heart rate recovery in patients with chronic heart failure. Am Heart J. 2007;153:1056-63.
34. Mueller S, Winzer EB, Duvinage A, Gevaert AB, Edelmann F, Haller B, *et al*. Effect of high-intensity interval training, moderate continuous training, or guideline-based physical activity advice on peak oxygen consumption in patients with heart failure with preserved ejection fraction: a randomized clinical trial. JAMA. 2021;325:542-51.