Oporavak srčane frekvencije – kratak pregled metodologije

Heart rate recovery – short review of methodology

Biljana Đurić[1], *Slavica Suzić*[1]

[1]Institute of Medical Phisiology "Rihard Burjan", Medical Faculty, University of Belgrade, Serbia

Contact: bilja.djuric@ymail.com

Abstract

Determination of the heart rate recovery (HRR) after the session of a physical activity, represents the valuable parameter for the investigation of autonomic balance and its dynamic in the general population, but also in the population of elite athletes. However, the methodology for its determination and analysis is still not entirely specified. It is necessary to define an adequate protocol of cardiopulmonary exercise test, by choosing an adequate ergometer (treadmill, ergo-bicycle or step bench). Organization of recovery period (active or passive), after the session of exercise is also very important, because its protocol interfered significantly with the value of HRR. Interpretation of obtained HRR values varies a lot, and researcher has freedom to choose the most adequate way, in accordance with the objectives of his study. Following paper represents a short review of determination, interpretation and analysis of HRR, followed by the latest recommendations.

Key words: heart rate recovery, cardiopulmonary exercise test, maximal oxygen uptake, autonomic balance

Sažetak

Praćenje oporavka srčane frekvencije nakon sesije fizičke aktivnosti (engl. *heart rate recovery*, *HRR*) predstavlja veoma značajan parametar koji možemo koristiti u cilju izučavanja balansa autonomnog nervnog sistema, kako u opštoj populaciji, tako i u populaciji vrhunskih sportista. Metodologija koja se koristi za određivanje i analizu *HRR*, međutim, još uvek nije adekvatno definisana. Prvenstveno je potrebno definisati adekvatan protokol testa opterećenja koji koristimo u svrhu određivanja *HRR*, a zatim i odabrati odgovarajući ergometar (tredmil, ergo – bicikl ili step – klupica). Potrebno je definisati i protokol perioda oporavka (da li će oporavak biti aktivan ili pasivan), budući da odabrani protokol značajno utiče na dobijene vrednosti *HRR*. Interpretacija dobijenih vrednosti *HRR* veoma varira od studije do studije, tako da istraživači imaju slobodu da izaberu način interpretacije koji najviše odgovara potrebama specifičnog istraživanja. Uzevši u obzir gore navedene činjenice, naš rad predstavlja jedan kratak pregled protokola koje možemo koristiti u određivanju, interpretaciji i analizi vrednosti *HRR*, prateći najnovije preporuke.

Ključne reči: oporavak srčane frekvencije, test fizičkog opterećenja, maksimalna potrošnja kiseonika, balans autonomnog nervnog sistema

Introduction

In recent years, determination of the heart rate recovery (HRR) after one session of the acute physical activity, represents a very powerful tool for the determination of the autonomic nervous system balance in the general population, but also in the population of elite athletes. The rapid recovery of the heart rate, interpreted through the high HRR value, indicates the high parasympathetic (PSY) tone, which represents a common finding in the population of elite athletes (1-3). Many studies have demonstrated that the drop in heart rate in the first minute of recovery (ΔHRR1) represents a good indicator of PSY reactivation (1, 4, 5). The delay in recovery of heart rate is associated with adverse cardiovascular outcomes and occurrence of insulin resistance (4, 6). On the other hand, faster recovery of heart rate suggests a positive adaptation to specific training load and also provides us information about athletes' training status (7). Despite the increasing popularity, the methodology for determination and analysis of HRR is not entirely uniformed, and there is often the problem of comparing the results of different studies (8).

Cardiopulmonary exercise test in HRR methodology - opportunities and challenges

Analysis of several studies, in which HRR was estimated, have indicated that the first problem for the researches is the choice of an adequate ergometer. The use of a treadmill is most preferred ergometer for cardiopulmonary exercise test, followed by the use of an ergo-bicycle and step-benches (1-3, 8). All of the subjects have reached higher values of maximal oxygen consumption (VO_2 max), when treadmill was used as ergometer in comparison to the use of ergo-bicycle, which also led to the significant difference in HRR values (9). Although the use of a treadmill, shows the mentioned advantages, ergo-bicycle will be adequate choice when it is necessary for the subjects to remain as stable as possible during the cardiopulmonary exercise test (for example when echocardiography is performed). Beside the choice of adequate ergometer, the position of the subject during the test is also affecting the values of HRR, knowing that supine position accelerates HRR compared with the seated positions (10-12).

The estimated value of HRR is also determined by the level of physical activity used in the study Criteria, for the completion of the test: a plateau in VO_2max despite the increased exercise intensity; respiratory exchange ratio value (RER max) ≥ 1.10; heart rate within 10 beats of the age predicted maximum (220 – age) or volitional fatigue (3). The use of submaximal cardiopulmonary exercise test (for example, the cardiopulmonary exercise test ends, when the 80% of predicted maximal heart rate is reached) requires a different set of standards for the value of HRR, since the value of the heart rate at which testing ends, depends on the age of subjects (4).

There are different ramp protocols on treadmill used in studies, but the Bruce protocol remains the most popular. However, if the maximal cardiopulmonary test is performed, the protocol itself, does not influence the value of the HRR (13). On the other hand, the recovery protocol after the session of physical exercise, influences significantly the value of HRR. In some studies, the active recovery protocol is used, in which the subject, after the completion of the test, continues with low grade physical activity (walking on the treadmill with the speed of 4km/h). Subjects that preformed active recovery protocol have demonstrated lower HRR values in comparison to the subjects that had the immediate rest state after the maximal cardiopulmonary exercise test. A position that subjects occupy during the recovery period also affects the value of the HRR, with the faster recovery in the supine position (3, 8, 12).

Interpretation of HRR values

There is still no universal agreement about the most suitable method of interpretation of the heart rate recovery for the comparison of results obtained in different studies. The most commune is the interpretation of the HRR as the difference between maximal heart rate reached during maximal cardiopulmonary exercise test and the heart rate determined during the first, second or third minute of recovery (HRR1, HRR2, HRR3, respectively). HRR1 and HRR2 are widely used and validated through numerous studies as the adequate method for the interpretation of the autonomic balance (3, 14 - 16). Other method of heart rate recovery analysis includes the construction of HRR curve, using mathematical functions, such as exponential disintegration. The first order exponential curve represents an adequate parameter for displaying the dynamic changes in heart rate during recovery, but the complexity and time required for its development and interpretation, as well as the lack of validation through epidemiological studies, gives the priority to the HRR1 and HRR2 in the everyday clinical use (8, 17).

In the literature, there are different ways to interpret the value of HRR. In some studies, the HRR is presented as a continuous variable, while in others, subjects are allocated within the tertiles and quartiles based on the value of HRR (1,3,18). Within the epidemiological and clinical aspect, it is most important to define the value of HRR, that will indicate whether a subject is in a life-threatening condition or not. For HRR1, it is defined, that values lower than 12 min^{-1} and even lower than 17 min^{-1} represent the pathological finding, pointing to an imbalance of the autonomic nervous system. The degree of deviation of HRR1 value from the predefined cut off, is directly related to the frequency of adverse outcomes (8, 17).

Significantly higher values of heart rate recovery are observed in the population of elite athletes, compared to the general population (19, 20). The recovery of the heart rate is initially (during the first minute of the recovery) predominately conditioned by the activation of the parasympathetic part of the autonomic nervous system. Population of elite athletes is characterized with higher parasympathetic tone, so it is expected to find faster heart rate recovery in this population in comparison to the general population (1 - 3). However, in the population of elite athletes, we can observe significant differences in the heart rate recovery, caused by the type of physical activity performed by subjects. Elite athletes engaged with physical activity characterized by high dynamic component (cross-country skiing, marathon, basketball, cycling, etc.) express an increased parasympathetic tone and significantly higher values of HRR1 compared to the athletes engaged with physical activity, characterized by low dynamic component (gymnastics, martial arts, golf,

etc.). The most supportive hypothesis is that increased parasympathetic tone expresses a protective effect on the cardiovascular system, causing higher survival rate in the population of elite athletes (21). However, further investigation of this hypothesis is quite necessary.

Conclusion

Evaluation of HRR1 and HRR2 is a routine part of the cardiopulmonary exercise test. These parameters could be easily measured and they provide valuable information about the balance and dynamic of the autonomic nervous system. Depending on the needs of the study, researchers can present these values as continuous variables or within adequate percentile groups. It is necessary to deal with the standardization of the methodology (protocol of the cardiopulmonary exercise test and recovery protocol after the session of the physical activity), so the results obtained in different studies could be compared with each other.

References

1. Lahiri MK, Kannankeril PJ, Goldberger JJ. Assessment of autonomic function in cardiovascular disease: physiological basis and prognostic implications. J Am Coll Cardiol. 2008 May 6; 51(18):1725-33.
2. Lamberts RP, Swart J, Capostagno B, Noakes TD, Lambert MI. Heart rate recovery as a guide to monitor fatigue and predict changes in performance parameters. Scand J Med Sci Sports. 2010 Jun; 20(3):449-57.
3. Suzic Lazic J, Dekleva M, Soldatovic I, Leischik R, Suzic S, Radovanovic D, et al. Heart rate recovery in elite athletes: the impact of age and exercise capacity. Clin Physiol Funct Imaging. 2015 Jul 4. doi: 10.1111/cpf.12271. [Epub ahead of print]
4. Cole CR, Foody JM, Blackstone EH, Lauer MS. Heart rate recovery after submaximal exercise testing as a predictor of mortality in a cardiovascularly healthy cohort. Ann Intern Med. 2000; 132:552–5.
5. Goldberger JJ, Le FK, Lahiri M, Kannankeril PJ, Ng J, Kadish AH. Assessment of parasympathetic reactivation after exercise. Am J Physiol Heart Circ Physiol. 2006 Jun;290(6):H2446-52.
6. Jouven X, Empana JP, Schwartz PJ, Desnos M, Courbon D, Ducimetiere P. Heart rate profile during exercise as a predictor of sudden death. New Engl J Med. 2005; 352: 1951–1958.
7. Bosquet L, Gamelin FX, Berthoin S. Reliability of postexercise heart rate recovery. Int J Sports Med. 2008 Mar;29(3):238-43.
8. Adabag S, Pierpont GL. Exercise heart rate recovery: analysis of methods and call for standards. Heart. 2013; 99(23):1711-2.
9. Maeder MT, Ammann P, Rickli H, Brunner-La Rocca HP. Impact of the exercise mode on heart rate recovery after maximal exercise. Eur J Appl Physiol. 2009; 105: 247–55.
10. Ranadive SM, Fahs CA, Yan H, Rossow LM, Agiovlasitis S, Fernhall B. Heart rate recovery following maximal arm and leg-ergometry. Clin Auton Res. 2011; 21:117–20.
11. Shizukuda Y, Tripodi DJ, Smith KP, Arena R, Waclawiw MA, Rosing DR. Can we use heart rate recovery information generated by supine ergometry exercise? Am J Cardiol. 2006; 98:1297–8.
12. Barak OF, Ovcin ZB, Jakovljevic DjJ, Lozanov-Crvenkovic Z, Brodie DA, Grujic NG. Heart Rate Recovery after Submaximal Exercise in Four Different Recovery Protocols in Male Athletes and Non-Athletes. J Sports Sci Med. 2011 Jun; 10(2): 369–375.
13. Pierpont GL. Effect of exercise protocol ('warm-up') on post exercise heart rate recovery. J Exerc Physiol Online/Am Soc Exerc Physiologist. 2008; 11:38–44.
14. Lipinski MJ, Vetrovec GW, Froelicher VF. Importance of the first two minutes of heart rate recovery after exercise treadmill testing in predicting mortality and the presence of coronary artery disease in men. Am J Cardiol. 2004; 93:445–9.
15. Gorelik DD, Hadley D, Myers J, Froelicher V. Is there a better way to predict death using heart raterecovery? Clin Cardiol. 2006; 29:399–404.
16. Tulumen E, Khalilayeva I, Aytemir K, Erqun Baris Kaya FE, Sinan Dveci O, Aksoy H, et al. The reproducibility of heart rate recovery after treadmill exercise test. Ann Noninvasive Electrocardiol. 2011; 16:365–72.
17. Pierpont GL, Stolpman DR, Gornick CC. Heart rate recovery post-exercise as an index of parasympathetic activity. J Auton Nerv Syst. 2000; 80:169–74.
18. Vicente-Campos D, Martín López A, Nuñez MJ, López Chicharro J. Heart rate recovery normality data recorded in response to a maximal exercise test in physically active men. Eur J Appl Physiol. 2014 Jun; 114(6):1123-8.
19. Imai K, Sato H, Hori M, Kusuoka H, Ozaki H, Yokoyama H, et al. Vagally mediated heart rate recovery after exercise is accelerated in athletes but blunted in patients with chronic heart failure. J Am Coll Cardiol. 1994; 24:1529–1535.
20. Otsuki T, Maeda S, Iemitsu M, Saito Y, Tanimura Y, Sugawara J, et al. Postexercise heart rate recovery accelerates in strength-trained athletes. Med Sci Sports Exerc. 2007; 39(2):365-70.
21. Nagashima J, Matsumoto N, Takagi A, Musha H, Chikaraishi K, Sagehashi M, et al. Dynamic component of sports is an important determinant factor of heart rate recovery. J Cardiol. 2011 Sep; 58(2):191-6.