CHANGES OF THE HEART RATE VARIABILITY WITHIN THE ACTIVE STAND TEST DYNAMICS AMONG ATHLETES WITH REDUCED PHYSICAL PERFORMANCE

ZMENY VARIABILITY RYTMU SRDCA V RÁMCI DYNAMIKY TESTOVANIA AKTÍVNEHO STOJA U ATLÉTOV SO ZNÍŽENÝM FYZICKÝM VÝKONOM

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ABSTRACT
Background: Overtraining is regarded as a necessary stimulus to increase sports performance. On the other hand, adequate training with balanced recovery is also essential: performance may fall if there is no mutual balance.
Objectives: Physical exercise can be measured quantitatively via different methods. Heart rate variability measurements have remained relevant for the last decade. The heart rate variability provides vegetative blood circulation control. It describes the organism and cardiovascular ability to change heart rate for external and internal adaptation.
Sample and methods: We examined two groups of 71 track and field athletes. Within the main group of 30 people, the heart rate and blood pressure reactions to the Letunov test were unsatisfactory. For the comparison group of 41 individuals, the reactions were opposite.
Results: Practically, all indexes of the heart rate variability prevailed among athletes with a normal hemodynamic reaction to standard physical exercises. After the test, the heart rate recovery for a satisfactory hemodynamic reaction was complete (there were no changes in the heart rate variability: $p3 > 0.05$). However, caused by body position shifts, sympathetic activities affected the main test group. Most statistical data showed a significant variability decrease ($p2 > 0.05$).
Conclusion: Therefore, measurements of the heart rate variability for the pre- and post-postural exercises prove the insufficient and slow hemodynamic recovery of athletes with an unsatisfactory cardiovascular reaction to standard physical load. Besides, there is a rising vegetative dysfunction with the dominant sympathetic tone due to the parasympathetic decrease.

Key words: Heart rate variability. Overtraining. Orthostatic test. Physical performance. Athletes.

ABSTRAKT
Východiská: Pretrénovanie je považované za nevyhnutný stimul pre zvýšenie športového výkonu. Na druhej strane je nevyhnutný aj adekvátny tréning s vyváženou regeneráciou: výkonnosť môže klesať, ak neexistuje vzájomná rovnováha.
Ciele: Fyzické cvičenie sa dá kvantitatívne merať rôznymi metódami. Merania variability srdcovej frekvencie zostali relevantné aj v poslednom desaťročí. Variabilita srdcovej frekvencie poskytuje vegetatívnu kontrolu krvného obehu. Popisuje schopnosť organizmu a kardiovaskulárneho systému meniť srdcovú frekvenciu na vonkajšiu a vnútornú adaptáciu.
Súbor a metódy: Vyšetrili sme dve skupiny po 71 atlétov. V hlavnej skupine 30 osôb boli reakcie srdcovej frekvencie a krvného tlaku na Letunovov test neuspokojivé. Pre porovnávaciu skupinu 41 jedincov boli reakcie opačné.
Výsledky: Prakticky všetky indexy variability srdcovej frekvencie prevládali u športovcov s normálnou hemodynamickou reakciou na štandardné telesné cvičenia. Po teste bolo obnovenie srdcovej frekvencie pre uspokojivú hemodynamickú reakciu úplné (nedošlo k žiadnym zmenám vo variabilite srdcovej frekvencie: $p3 > 0,05$). Avšak, spôsobené posunmi polohy tela, sympatické aktivity ovplyvnili hlavnú testovaciu skupinu. Väčšina štatistických údajov vykazovala významný pokles variability ($p2 > 0,05$).
Záver: Preto merania variability srdcovej frekvencie pre pred- a posturálne cvičenia dokazujú nedostatočnú a pomalú hemodynamickú regeneráciu športovcov s neuspokojivou kardiovaskulárnou reakciou na štandardnú fyzickú záťaž. Okrem toho narastá vegetatívna dysfunkcia s dominantným sympatickým tonusom v dôsledku poklesu parasympatiku.

Kľúčové slová: Variabilita srdcovej frekvencie. Pretrénovanie. Ortostatický test. Fyzická výkonnosť. Atléti.

INTRODUCTION

The sports performance progress faces an unavoidable tiredness. Fatigue is a multifaceted phenomenon, which is manifested by a decrease in the ability to achieve maximum productivity and the inability to perform an achievable task (Russell et al., 2020). Meanwhile, post-training recovery is essential as well. It prevents chronic stress, overstrain, non-functional disorders and over-training. The adequate recovery issue has yet to be solved so far. Its registration statistics are also complicated. According to the research data (Lee et al., 2017), the overtraining prevalence is up to 30 %. It is especially typical for individual sports, particularly track and field. Subjective and common symptoms of chronic tiredness explain the diagnosing difficulty they reveal themselves as having vegetative dysfunction syndrome (Michael et al., 2017). However, there are objective symptoms to prove vegetative disorders and proper training and recovery (Sookan et al., 2012). A reliable indicator of recovery is a heart rate changes, which allows to directly assess the athlete's adaptation status and prevent a decrease in performance (Barrero et al., 2020).

Heart rate variability measures characterize the fluctuating changes in successive heart contractions, providing insight into the autonomic function of the heart and may be particularly useful for endurance athletes. The worst symptoms of dysautonomia and vegetative dysfunction are orthostatic disorders, physical performance falls for standard exercises, and decrease of heart rate variability (Lundstrom et al., 2023). Especially valuable data are obtained via the combination of heart rate variability measurements with orthostatic tests of postural modelling. The latter is prevalent in sports medicine. That defines negative hemodynamic changes and the general state of athletes within field conditions, which is reasonable for proper health control (Carrard et al., 2022). The joint use of these methods provides a complex study of functional disorders and conclusions about their interconnection (Fazackerley et al., 2019). Considering those mentioned above, we assessed the heart rate variability reactions for hyperergic and normoergic athletes in the case of standard physical exercises during orthostatic tests (Ni et al., 2022). It can also be assumed that adaptation of the parasympathetic nervous system and HRV decrease with age (Štursová et al., 2023).

Also, our results are very important and valuable for specialists in physical therapy practice, because athletes with early or late stages of overtraining syndrome need the attention of a physical therapist and should be involved in the rehabilitation process. Therefore, it is necessary to work in a team with such specialists in high-achieving sports.

AIMS

Studying heart rate changes for athletes with chronic tiredness during orthostatic tests.

MATERIALS AND METHODOLOGY

We examined two groups of 71 athletes. Within the main group (MG) of 30 persons, the heart rate and blood pressure reactions to the Letunov test were unsatisfactory (Koziy et al., 2018). The reactions were opposite for the comparison group (CG) of 41 individuals. Generally, there were 34 females (47.9 %): 15 in the MG (50 %), and 19 in the CG (46.3 %). For both groups, we detected $\chi 2 = 0.004$, $p = 0.76$. The average age was 22.49 (3.06) years: 22.93 (2.84) in the MG and 22.17 (3.20) in the CG. We saw no significant age differences between both groups ($p > 0.05$). The athletes gave their consent to examination and data registration. Bioethical and deontological principles were kept as well.

Standard physical exercises were conducted according to a classical pattern in three subsequent stages: 20 squattings for 30 seconds, the fastest running in place for 15 seconds, and jogging for 3 minutes. The time to rest and measure hemodynamic values was 3 (stage 1), 4 (stage 2) and 5 minutes (stage 3). As satisfactory, we regarded a normotonic reaction with the heart rate increasing by under 100 %, the moderate systolic blood pressure growing up to 15 – 30 % (about 20 – 30 mm Hg), the moderate diastolic blood pressure falling by 10 – 15 % (5 – 10 mm Hg), the significant pulse increases by 80 – 100 %, the pulse and blood pressure recovery till 3 minutes (Cadegiani et al., 2019). The active stand test was conducted via the classical methodology (Finucane et al., 2019). Electrocardiography was applied to define the heart rate variability before the active stand test and 5 minutes after its finish.

The analysis was conducted via the Social Science Statistics web service. We used conventional statistical methods to calculate M (mean) and SD (standard deviation). These data were compared among groups by the Mann-Whitney rule. Statistical significance was defined as $p < 0.05$.

RESULTS

According to the obtained research data (table 1), practically all heart rate variability indexes prevailed among athletes with normal hemodynamic reactions to standard physical exercises. Statistically significant were such indexes: SDNN (standard deviation of NN intervals), RMSSD (root mean square of successive RR interval differences), PNN50 (percentage of successive RR intervals that differ by more than 50 ms), SD1 (Poincaré plot

Table 1 The heart rate variability indexes among athletes of the examined groups (before the test)

Parameter	MG	CG	p
SDNN	59.50 (14.31)	67.5 (19.44)	0.039
RMSSD	37.40 (8.94)	43.7 (12.15)	0.009
PNN50	8.40 (2.27)	11.3 (3.30)	<0.001
SD1	27.30 (6.59)	32.0 (8.90)	0.009
LF	633.90 (151.88)	740.0 (206.83)	0.011
HF	353.33 (117.99)	557.9 (182.18)	<0.001
LF/HF	1.97 (0.49)	1.12 (0.33)	<0.001

Table 2 The heart rate variability indexes among athletes of the examined groups (5 minutes after the test)

Parameter	MG	CG	p1	p2	p3
SDNN	46.2 (15.18)	64.40 (19.22)	<0.001	<0.001	0.441
RMSSD	32.47 (9.12)	42.60 (12.25)	<0.001	0.032	0.555
PNN50	7.00 (2.09)	10.50 (3.14)	<0.001	0.010	0.174
SD1	23.20 (5.61)	28.70 (8.26)	0.002	0.013	0.077
LF	552.00 (140.17)	708.50 (193.63)	<0.001	0.030	0.390
HF	304.50 (102.35)	531.60 (158.55)	<0.001	0.038	0.352
LF/HF	1.93 (0.25)	1.15 (0.36)	<0.001	0.992	0.849

Legend: p1 – the significance of index differences in separate groups; p2 – index differences before and after the test MG; p3 – index differences before and after the test in the CG.

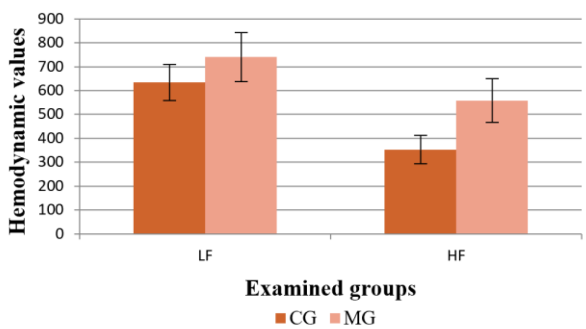

Figure 1 The LF-HF contrast in the examined groups

standard deviation perpendicular the line of identity), LF (low frequency for the autonomic nervous system), HF (high frequency for the parasympathetic tone). All these indexes did not exceed reference values for healthy people, even in the MG. However, the LF/HF ratio exceeded the MG normal values for young and older people (1.5 – 1.8), which shows their vegetative disorder. The difference in this index in both groups was one of the most considerable: for the CG, it decreased by over 40 %. However, contributions to such a vivid difference gap were various if we concern the numerator and denominator.

Figure 1 demonstrates the LF-HF contrast. In particular, the MG parasympathetic tone index was considerably lower (by 1.5 times) than the LF heart rate variability (17 %). Consequently, we can conclude that the low parasympathetic tone contributes more to the disorder's progress.

We studied the heart rate variability after the active stand test to assess the vegetative influence on orthostatic heart regulation. The results obtained are given in table 2.

The heart rate recovery after the test (for athletes with satisfactory hemodynamic reaction to standard physical exercises) was established to be complete. In other words, there were no changes in the heart rate variability within each index (p3 > 0.05). However, body position shifts and subsequent sympathetic features affected the MG athletes after the test: an apparent variability falls within most indexes (p2 > 0.05). Considering the LF and HF dynamics in the MG, there were generally no significant LF/HF ratio changes in the examined groups. For all compared indexes, p1 increased (after the test, it exceeded 0.001 only in one case). Therefore, research on the pre- and post-postural heart rate variability proves insufficient and slow hemodynamic recovery for athletes with unsatisfactory cardiovascular reactions to standard physical exercise. Among these people, we noted autonomic dysfunction with a rising sympathetic tone due to the falling parasympathetic one.

Thus, the study of heart rate variability is a reliable diagnostic method that allows to quickly and conveniently assess the influence of various parts of the autonomic nervous system on blood circulation. This study can be used as a method to monitor dynamic changes in athletes with evidence of non-functional changes (overreaching), particularly impaired orthostatic tolerance and overtraining. Using the study of heart rate variability, the influence of each component of autonomic regulation on the heart rate is assessed, and the relationship between the influence of the sympathetic and parasympathetic systems on the correctness of cardiac activity is determined. To obtain more accurate data, it was advisable to conduct long-term monitoring of the heart rhythm, during which tests should be performed with a change in body position. However, wearing a recording device will change the athletes' daily physical activity, so this issue needs further study.

DISCUSSION

The development of an athlete is associated with the process of adaptation to an increasing level of physical activity, which is stressful and allows for an increase in sports performance (Bellenger et al., 2016). It is known that an essential component of maintaining the health of athletes is adequate recovery; the difficulty is that due to several objective and subjective factors, it can occur superficially and not meet the situational challenges and the period of preparation. As noted, an essential task of the current medical and biological control remains the timely detection of the problem of non-functionality of training overloads, a comprehensive assessment of the athlete's condition, and feedback to them since most signs of a mismatch between the load and recovery are subjective, may be disguised problems of the psychological sphere or general, nonspecific manifestations (Koopmann et al., 2020). The statement of these symptoms at a single examination is insufficient; an essential condition for successful diagnosis is their persistence and dynamics. The emergence of underperformance syndrome (reduced physical performance) was pointed out by (Budgett, 1998) and later (Kreher, 2012; Carrard et al., 2022) as the primary manifestation of the overtraining syndrome (chronic fatigue of athletes, professional burnout of athletes), the author used these terms as synonyms. It is clear that if such changes are considered by the coach and the athlete as undertraining (rather than under-recovery), the intensity and duration of physical activity will only increase, leading to the progression of autonomic symptoms, an increased likelihood of infectious diseases, injuries, muscle problems, and hormonal status (Heidari et al., 2018). Because of this, an essential factor in establishing non-functional overload (overtraining) is the search for and interpretation of objective symptoms, of which assessing the circulatory system response is paramount.

The practical significance of diagnostic methods that are advisable for athletes is determined by the possibility of their use dynamically following the changing conditions of the training schedule. Under such conditions, of all the methods of testing the reaction to physical activity in professional athletes, it is worthwhile to focus on simple and objective methods that allow them to assess their response to the load and hemodynamic parameters during and after physical activity of a different nature. During the combined test various physical activities are used to determine the recovery of cardiovascular system indicators – at the first stage, squats are considered as a warm-up (in persons not involved in sports, even this level of load is considered sufficient – the Martine test). During the second stage, the athlete runs on the spot for 15 seconds at the fastest possible pace, with high hip raising and vigorous arm work. This allows us to assess the circulatory response to speed and power challenges. At the final stage of the test, an endurance task is performed, which consists of jogging on the spot for three minutes. The break time for observation of hemodynamic parameters lasts 3 minutes after the first stage, 4 minutes after the second, and 5 minutes after the third. Before each exercise, baseline parameters are recorded: heart rate, systolic and diastolic blood pressure. The test is considered a universal test for assessing the hemodynamic response of athletes, both with the predominant use of exclusively physical qualities in training and those sports where tactical and technical data are essential; if we are talking about athletics, then first of all, it is jumping, all-around, throwing (pushing) (Winsley et al., 2011). In addition, the load during the test is considered standard, as it allows the evaluate the capabilities of the oxygen delivery system regardless of gender, age, and specifics of sports activity. An essential condition is regular sports activities, which determine a relatively serious level of physical fitness that a professional athlete must cope with without extreme (unnatural) reactions.

Throughout professional sports development, the need for recovery from exertion has never been in doubt. This is necessary to maintain the required physical shape, fully utilize the characteristics of athletes necessary to achieve high sports results and prevent the development of injuries and other occupational diseases. It is an integral part of the training process and includes several important aspects. First and foremost, it is the restoration of well-being and mental health after the challenges that arise during training and competitions. In particular, intense training can cause micro traumatization of muscles and other tissues and cause several unpleasant general and local symptoms, such as early and long-term muscle pain, general malaise, weakness, and a feeling of exhaustion. The recovery process allows the body to repair damaged tissues, ensure proper energy metabolism, and restore physiological balance. A crucial healing factor after exercise recovery is strengthening the immune system, as intense training can temporarily weaken the immune system. Accordingly, adequate recovery helps the body maintain normal immune system function. Full recovery helps to minimize the risk of acute injuries: chronic stress can lead to impaired complex coordination, reaction time, and impaired proprioception, which, especially in contact sports, can lead to several adverse effects in the form of injuries. Recovery helps to maintain psychological stability and is one of the most essential factors of psychohygiene in athletes. Proper rest helps maintain the necessary motivation and confidence. In other respects, this cannot affect the improvement of professional performance – the optimal functioning of the musculoskeletal system, energy supply, oxygen utilization system, regulatory and other body systems against the background of the appropriate level of integrative functions of the central nervous system are the key to sports success and the preservation of athletes' health. In this aspect, the importance of post-exercise recovery in preventing chronic overload and overtraining is that regular and adequate recovery contributes to the longevity of a sports career, as it reduces the risk of chronic injuries and fatigue. In any case, the selection of recovery methods should consider the sport, the psychological and biomedical status of athletes, individual characteristics of the body. The findings of the mentioned authors are in agreement with our results.

The study of heart rate variability allows timely detection of hyperactivation of the sympathetic division of the autonomic nervous system and, as our research has shown, can be an effective diagnostic tool for establishing non-functional overload and overtraining (Wittels et al., 2023). Particularly effective is the combination of simple, standardized tests with a short-term study of heart rate variability, which allows this technique to be used in field training in conditions close to the normal activities of athletes (Alfonso et al., 2022). At the same time, this method is promising in studying autonomic dysfunction in track and field athletes, as it provides objective functional data on such a condition as underperformance.

Also, the rational use of modern methods and physiotherapeutic means is important for the effectiveness of training programs, the prevention of overtraining, which will positively affect the improvement of the athlete's training to achieve a high result (Yudkina et al., 2021)., which is consistent with our results and experience.

CONCLUSIONS

The heart rate variability limits cause physical performance decrease, most vividly revealed after the active stand test. Investigation of heart rate variability and non-functional changes can be carried out simultaneously, especially in athletes with poor hemodynamic response to standard physical exercise. However, interconnections of chronic tiredness, orthostatic insufficiency and heart rate variability require further research.

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